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Petronumbers:
Oil statistics and changing power relations

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ABSTRACT

Il petrolio è stato il motore dello straordinario sviluppo industriale ed economico del XX secolo, ma descriverlo semplicemente come una risorsa energetica è senza alcun dubbio riduttivo. Nel tempo, la proprietà e il controllo delle risorse petrolifere hanno coinvolto interessi economici, strategici e politici, comportando al tempo stesso un'evoluzione nel ruolo dell' “oro nero”, prima principale mezzo nel mantenimento della supremazia economica e dello stile di vita Occidentale, e successivamente simbolo della sovranità e dell'indipendenza dall'Occidente stesso dei paesi precedentemente oggetto della dominazione coloniale.

Di conseguenza, i dati e le statistiche che descrivono alcune dei principali tratti del petrolio, vale a dire riserve, produzione e prezzi, acquisiscono un'importanza cruciale, in quanto possono diventare una misura del peso, attuale e potenziale, di un attore sulla scena internazionale; inoltre, un'analisi avente ad oggetto la loro evoluzione nel corso della storia può costituire un prisma interessante attraverso cui osservare il mutamento delle relazioni di potere dettate dal controllo di tale minerale nel tempo. Tuttavia, tale resoconto risulterebbe incompleto se non venissero considerati i concetti su cui tali dati quantitativi sono fondati e, di conseguenza, il contesto istituzionale in cui questi stessi concetti sono stati elaborati.

Pertanto, il presente studio si propone di investigare come i dati e i concetti chiave riguardanti le stime delle riserve di petrolio, i livelli di produzione e i prezzi, non solo siano stati plasmati dall'evoluzione dei rapporti di forza e dall'emergere di particolari interessi istituzionali all'interno dell'industria petrolifera nel corso della sua esistenza, ma inoltre si siano tramutati in mezzi utili a perseguire quegli stessi interessi.

Le riserve petrolifere appartengono al campo dell'incertezza fisica ed economica: non è infatti possibile sapere con esattezza quanto petrolio giaccia ancora nel sottosuolo, così come non è detto che eventuali depositi si rivelino sfruttabili da un punto di vista commerciale. Manca inoltre un sistema generale per la definizione e classificazione delle quantità stimate, anche se è possibile estrapolare degli elementi comuni dai vari *frameworks* esistenti, come ad esempio una generale suddivisione in riserve provate, probabili e possibili. Le stime vengono calcolate e riportate da attori differenti per ragioni differenti: compagnie petrolifere nazionali e private possono averne bisogno per esigenze di *accounting* interno, per ottemperare ad obblighi fiscali, o per ottenere dei prestiti; oltre a ciò, le riserve costituiscono la base sulla quale un governo può improntare le proprie politiche energetiche. Dati riguardanti le riserve petrolifere sono in aggiunta diffusi da annuari statistici, riviste specializzate e agenzie di consulenza operanti a stretto contatto con l'industria. Nel tempo, l'accuratezza delle stime delle riserve petrolifere e la precisione nell'attività di prospezione, volta a localizzare eventuali depositi di idrocarburi, sono cresciute esponenzialmente, grazie a

maggiori conoscenze geologiche, all'enorme progresso tecnologico, e all'impiego di metodologie di calcolo sempre più meticolose. Un breve excursus dei più recenti dati statistici, rivela come il petrolio sia caratterizzato da una distribuzione geografica estremamente iniqua: l'80% delle riserve provate mondiali è concentrato nei dodici paesi che costituiscono l'Organizzazione dei Paesi Esportatori di Petrolio (OPEC). Non bisogna però dimenticare nell'osservare tali dati che essi risultano inevitabilmente caratterizzati da incertezze ed ambiguità intrinseche, le quali si vanno ad aggiungere all'oggettiva impossibilità di conoscere l'esatto ammontare delle riserve: spesso i concetti sono poco definiti, manca uno schema universale di classificazione, e i dati possono risultare sovra o sottostimati, o addirittura non essere riportati. Nonostante ciò, è proprio il carattere quantitativo delle riserve che le porta ad essere facilmente accettate come valide e che pertanto conferisce loro potere. Inoltre, non bisogna scordare che le stime sono degli artefatti, il prodotto di un processo che si svolge all'interno di una realtà sociale: la scelta delle metodologie da applicare per il calcolo, la decisione di attribuire validità ad un particolare set di informazioni, e la preferenza per un determinato output riflettono inevitabilmente il contesto istituzionale in cui la stima è creata. Tale contesto è plasmato dagli interessi istituzionali prevalenti, a loro volta influenzati da cambiamenti significativi nel più ampio contesto storico esistente in un dato momento.

Lo sfruttamento commerciale del petrolio comincia solo a partire dal IXX secolo: la culla dell'industria petrolifera sono gli Stati Uniti d'America, ma ben presto il cuore della produzione mondiale di petrolio si sposta nel Medio Oriente, dove le *majors* occidentali costruiscono un impero basato sui *concession agreements*. Il petrolio che fluisce dalle concessioni è abbondante e a buon mercato, il connubio perfetto per trainare la crescita economica ed industriale dell'Occidente. Ben presto diventa chiaro che tale risorsa non ha un valore strettamente economico: il petrolio diventa un minerale controverso, su cui si concentrano considerazioni strategiche e politiche. Gli anni Sessanta e Settanta assistono alla disintegrazione del sistema delle concessioni, e all'emergere d un nuovo importante attore sulla scena petrolifera internazionale, l'OPEC. Il petrolio assume un nuovo significato: la sua proprietà, e soprattutto il controllo della sua produzione, due elementi che non coincidevano nel caso delle concessioni, diventano la chiave per affermare il proprio status di Stato sovrano e la propria liberazione dalla dominazione economica Occidentale. In tal senso, gli anni Settanta, marcati da due shock petroliferi, rappresentano l'era del dominio dell'OPEC; gli Stati Uniti, messi di fronte al picco della propria produzione di petrolio e a nefaste previsioni per il futuro, si ritrovano ad essere dipendenti dal petrolio mediorientale, e la sicurezza degli approvvigionamenti diventa l'obiettivo principale da perseguire. La crisi del 1973 ha però una conseguenza importante: i prezzi esorbitanti portano all'introduzione nel mercato di nuovi importanti produttori, collocati principalmente nel Mare del Nord, Alaska e Messico. L'influenza dell'OPEC risulta pertanto parzialmente ridimensionata, e verrà ulteriormente intaccata dal collasso dei prezzi del 1986. Dagli anni 90 ai giorni nostri, sebbene il Medio Oriente rappresenti tuttora il principale produttore mondiale di petrolio, l'industria ha cercato di sviluppare nuove aree e frontiere produttive: si tratta in particolare della regione del Caspio e delle aree offshore, il cui crescente sfruttamento è reso possibile da tecnologie sempre più sofisticate. L'evoluzione della produzione di petrolio è stata accompagnata dal parallelo emergere di differenti forme contrattuali nel corso del tempo, che hanno costantemente rispecchiato gli interessi degli attori dominanti e l'evoluzione dei rapporti di forza all'interno del panorama petrolifero internazionale. Nello specifico, le vaste concessioni, indubbiamente di stampo coloniale, hanno lasciato il posto nel corso degli anni Sessanta e Settanta, i più flessibili ed "equi" *Production-Sharing Agreements*, i quali prevedono la partecipazione diretta del paese esportatore all'attività produttiva, da un punto di vista sia pratico che finanziario. Inoltre, le grandi *majors* ricoprono sempre più spesso il ruolo di *service providers*, coordinando una moltitudine di operatori, i quali offrono alle compagnie nazionali e private i propri servizi altamente specializzati nel campo del *field development*.

Allo stesso modo, i concetti e i regimi che hanno determinato i prezzi del petrolio nel corso delle decadi hanno costantemente rispecchiato le caratteristiche del sistema istituzionale circostante, e la transizione da un sistema di prezzi al successivo è sempre avvenuta in corrispondenza di importanti cambiamenti nel contesto economico e politico del tempo. Pertanto, i regimi di prezzo diventano l'immagine degli squilibri esistenti in un determinato momento storico, e degli interessi perseguiti dall'attore dominante. Quattro fasi possono essere identificate: nella prima, caratterizzata dal controllo delle *majors* occidentali, il regime di prezzo era costruito in modo tale da proteggere il petrolio americano dalla concorrenza del più economico petrolio mediorientale. A seguito del cambiamento nello status degli U.S.A da esportatori ad importatori di petrolio, la struttura dei prezzi si trasforma: l'obiettivo è assicurare una fornitura di petrolio abbondante e a basso costo, e viene raggiunto tramite il consolidamento degli accordi di concessione e l'imposizione di livelli di prezzo ufficiali (i cosiddetti *posted prices*); al tempo stesso, i costi fiscali derivanti dalla produzione di petrolio nei paesi ospitanti vengono incapsulati e bloccati attraverso apposite clausole. Negli anni Settanta, tale situazione viene completamente rovesciata: il nuovo amministratore dei prezzi del petrolio è l'OPEC, la quale esclude le compagnie occidentali da ogni decisione e adotta come obiettivo principale, almeno in prima istanza, l'incremento delle proprie *oil revenues*. Infine, a seguito del tracollo dei prezzi del 1986, l'OPEC viene spodestata dall'attuale "amministratore", vale a dire il libero mercato, la cui espansione dagli anni Ottanta è esponenziale e caratterizzata da una crescente finanzializzazione. Sebbene non vi sia un'istituzione capace, nel contesto attuale, di determinare in modo diretto il prezzo del petrolio, in quanto tale prezzo si forma sul mercato, è comunque possibile individuare delle "intereferenze", esercitate sia dalle Agenzie adibite alla scoperta del prezzo, sia dall'OPEC tramite le decisioni prese in merito ai propri livelli di output.

Concludendo, è possibile derivare dal presente studio tre considerazioni. La prima sottolinea come le stime delle riserve di petrolio possano diventare dei mezzi per la trasmissione di un preciso messaggio, capace di riflettere gli interessi particolari dell'attore istituzionale che ha prodotto tali dati. La seconda riflessione sottolinea come tale messaggio possa essere pienamente compreso solo se vengono presi in considerazione i concetti e i regimi che regolano il funzionamento dell'industria petrolifera in un determinato momento storico. Infine, si intende smentire l'idea che l'evoluzione delle principali dinamiche riguardanti le riserve, la produzione e i prezzi del petrolio siano state esclusivamente il risultato di deliberati processi decisionali da parte degli attori coinvolti: al contrario, la ricerca ha evidenziato come questi abbiano costantemente subito degli importanti *feedbacks* dalle strutture che essi stessi hanno contribuito a creare, e come questi *feedbacks* si siano rivelati a volte controproducenti.

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INTRODUCTION

Oil literally fuelled the 20th century staggering economic growth; however, to describe it as simply a commodity or an energy source like any other is reductive. The ownership and the disposal of hydrocarbon resources constantly entailed a host of vested interests, arising not only from economic concerns, but also from political and strategic considerations: notably, oil shifted from being a crucial means in the maintenance of Western economic supremacy and way of life, to being a symbol of sovereignty and independence from the West itself, thus reflecting the changing nature of the relationship between the main international actors through time.

In 1909, President Theodore Roosvelt's call for the conservation of natural resources[1] set the stage for the first national oil survey in the United States, cradle of the hydrocarbon industry. As the relevance of this mineral grew more and more, also statistics and data reporting the main features of its commercial exploitation, namely oil reserves, production levels and prices, multiplied: soon, each major institution, from the government to specialized trade journals and business associations, started publishing its own oil data and forecasts. Such trend was undoubtedly an expression of the particular relevance that still is attributed by the modern society to quantification: virtually any phenomenon can be translated into quantitative terms, and oil makes no exception.

In the particular case of hydrocarbon resources, two issues arise. First of all, relevant data concerning oil are often imbued with inherent ambiguities. In particular, as observed by Madureira, “the history of oil reserves is a history of long lasting misunderstandings”[2]. Available public data is often characterized by an ambivalence not only arising from the existence of different standards for the classification and reporting of figures, but also embedded in the very concept of proven reserves and reserves estimation. In addition, since quantitative information is after all an human artifact, it is possible to assume that the existing historical, social, and institutional context exerts some kind of influence not only on the selection of the methodologies adopted to produce such information, but also on the the

1 "If we of this generation destroy the resources from which our children would otherwise derive their livelihood, we reduce the capacity of our land to support a population, and so either degrade the standard of living or deprive the coming generations of their right to life on this continent (…) then conservation is the great fundamental basis for national efficiency". Roosvelt, T., Special message from the president of the United States transmitting a report of the National Conservation commission, 1909, United States, 60th Congress, 2nd session, 1908-1909, Document n. 676, http://memory.loc.gov/cgi-bin/query/r?ammem/consrvbib:@field%28NUMBER+@band%28amrvg+vg38%29%29, accessed March 11, 2013.

2 N.L. Madureira, “Estimating oil reserves: History and methods”, in Khan S. (edited by), *Fossil fuel and the environment*, InTech, 2012, pp. 162.

perception of this data and on the desired output of the quantification process.

Secondly, data concerning oil production and prices unquestionably provide a clear-cut snapshot of the current state of affairs in the industry, but at the same time do not offer any insight on the operative pricing concepts and production frameworks on which they are grounded in the first place. The evolution of these regimes had supposedly mirrored the emergence of different institutional interests through time, and, as a consequence, major shifts in the balance of power between the key players on the international oil scene.

Under these assumptions, data and statistics describing oil reserves, production, and prices, acquire a crucial importance: they can become a measure of both the actual and potential relevance of an actor on the international scene; in addition, the analysis of historical series for such data provides an interesting prism through which it is possible to observe the evolution of power relations related to the ownership and disposal of oil through time. However, such account results inevitably incomplete without addressing the very concepts on which numbers are grounded and, subsequently, the institutional context in which such concepts were conceived.

Therefore, the aim of the present study is to investigate how data and key concepts concerning crude oil reserves estimates, production levels, and prices, not only have been shaped by the evolution of power relations and by the emergence of particular institutional interests throughout the history of the hydrocarbon industry, from the 1850s to the present day, but also have in turn become useful means to pursue those specific interests. The analysis will allow further insights, focused respectively on the implications deriving from the quantitative nature of oil statistics, and on the inevitable feedback effects experienced by the key players as a consequence of the same frameworks and structures they had contributed to create.

The research takes into account the evolution of relevant statistical data for each of the three phenomena considered (proven reserves, production rates, prices), along with a detailed evaluation of how the related frameworks, concepts, and regimes unfolded through time, eventually trying to link this process to broader shifts both in the relationships connecting the various actors in the industry, and in the particular objectives pursued by each player.

Specifically, the first chapter will deal with the topic of oil reserves. After a brief overview of the existing standards for reserves classification, and of the reasons for the reporting and publication of reserves data, an overview of past and present estimation methodologies is provided. Subsequently, some considerations are dedicated to the latest figures concerning oil proven reserves, and to their geographical distribution, marked by a tremendous disparity. Finally, the main sources of ambiguity concerning the definition, estimation, and reporting of reserves figures are outlined, and an extensive attention is dedicated to the institutional interferences impacting not only on the process of estimation, but also on the attribution of validity to a particular piece of quantitative information and on the choice of the figure that will eventually be reported: vested interests can favor one outcome instead of another and, at the same time, consensus over data arises according to the existing political reality and to the predominant organizational interests, which in turn are influenced by the external economic and historical context.

The second chapter will focus on oil production: following an overview of the historical development of the oil industry, of its main characters, and of the different areas that have emerged through time as core producers, the main data depicting the current state of oil production are briefly examined, also providing some basics concerning the characteristics of crudes and the development of an oil prospect. Conclusively, following the assumption that the development of hydrocarbon resources in modern times is carried out within a contract framework, which is not only negotiated (or imposed) by the actors involved, but also shaped by the surrounding historical, economic and social environment, a comprehensive review of the governance structures that have marked oil production is carried out, with a final remark concerning the dynamics defining the present situation.

The third chapter will confront the subject of prices: the history of the oil industry has been marked by a succession of pricing regimes, each one anchored to a peculiar set of price concepts conceived to rule different transactions between different parties. Such concepts did not always have a clear (or existing) economic meaning; additionally, they were constantly observed from different standpoints by the several actors involved, and, most importantly, were a direct consequence of the leading actors' interests and goals. At first, the historical evolution of pricing regimes, and the alternation of different institutional administrators for oil prices will be considered, followed by a short account of the evolution of the crude spot market. Consequently, the main features of the current oil pricing system will be delineated. Finally, a few remarks concerning the evolution of a public discourse addressing the issue of oil pricing, and the reporting practices for historical series of data, will be succeeded by some reflections on the past and present institutional interferences on oil prices, and on the new role performed by the OPEC within the current system.

The final section concludes, and tries to identify possible patterns for future research.

1
OIL RESERVES

1.1. Defining oil reserves

How much oil is there in the ground? Since the beginning of the oil era in the 18th Century, and even more after the end of World War II, a major issue in the hydrocarbon industry has been attempting to produce reliable figures depicting the actual endowment of the natural resource that has become the lifeblood and main driver of economic growth in the contemporary world, the one able to fuel industries, countries, cars and new ways of life.

Oil reserves belong to the field of physical and economic uncertainty. They are estimated, not measured, since it is impossible to know the exact amount of oil below the Earth's surface. Furthermore, oil is not always an economic asset: a reservoir[3] can be economically irrelevant or not exploitable depending on its geological characteristics, on its geographical location, on the characteristics of the crude[4] it contains, or on the current oil prices[5].

Governments, institutions and companies usually provide a classification framework for the estimated quantities of oil and gas, covering discovered and undiscovered volumes of conventional and unconventional petroleum resources[6]. Such standards can vary widely from region to region[7] and from actor to actor; in addition, they are often designed to fit the needs of the issuing institution[8], leading to potentially misleading results, and making comparison difficult. In 2007, the Society of Petroleum Engineers (SPE) and the World Petroleum Council (WPC), jointly adopted standardized petroleum classifications, highlighting the need for an universal language for reserves. The framework is currently quite widespread at the international level, and most countries have adopted the SPE/WPC guidelines. Nonetheless, some remarkable exceptions can be mentioned, such as the classification of the Russian Federation, and the Norwegian Petroleum Directorate classification[9].

3 A reservoir can be defined as a subsurface accumulation of hydrocarbons contained within a porous or fractured solid rock matrix.

4 Crude oil refers to the mixture of naturally occurring hydrocarbons that must be processed in a refinery to separate out indivual finished products, such as gasoline, diesel, etc.

5 L. Maugeri, *Petrolio*, Milano, Sperling & Kupfer, 2001, p. 84.

6 Generally, oil is considered conventional when it can be processed by using normal production practice, without necessity to alter its viscous state; on the other hand, unconventional oils must be treated before entering the refining process.Unconventional oils are tar sands, shale oil, and coal-based syncrude.

7 C.J. Campbell, J.H. Laherrère, “The end of cheap oil”, *Scientific American*, 278(3), 1998, p. 80.

8 G.M. Haider, “World oil reserves: Problems in definition and estimation”, *OPEC Review*, 24(4), 2000, p. 324.

9 Society of Petroleum Engineers, Comparison of selected reserves and resource classifications and associated definitions, http://www.spe.org/industry/docs/OGR_Mapping.pdf, accessed March 11, 2013.

Despite the lack of an universally accepted classification of oil reserves, it is possible to extrapolate a general framework, loosely overlapping the SPE/WPC classification. In 1969, geologist Lewis Week provided a good suggestion for distinguishing among the different categories of reserves: "A potential resource estimate is aimed, first and foremost, at efficiency in spending the exploration dollar; that is, it is an indicator of the area or areas in which that dollar may be best spent"[10]. Thus, a first clear distinction is necessary between resources, recoverable resources and reserves. The term "oil resources" refers to the total endowment of oil, identified and unknown, from a strictly physical and quantitative point of view, excluding all economic and development considerations[11] (also referred to as Original Oil in Place, OOIP[12]). "Recoverable resources" identify the part of the mineral stock which can be potentially exploited from an economic and technical perspective[13]; they differ from Ultimate Recoverable Resources (URR), which are the total amount of discovered and undiscovered oil produced in the past and estimated to be technically feasible to recover in the future[14]. Conversely, "reserves" are that portion of identified resources estimated to be actually producible in the future, from both an economic and a technical perspective[15].

Reserves are commonly classified by their degree of certainty, and we can outline two sets of definitions depending on the adopted method of evaluation[16]. The first one is the classical deterministic approach, which aims at providing a single specific discrete scenario for reserves, reflecting realistic combinations of estimates of geological, economic and engineering parameters[17]. Following this approach, the industry has traditionally recognized three categories of reserves, namely Proven, Probable and Possible Reserves (also referred to as Low, Best and High Scenarios). Generally, Proven Reserves are described as "the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions"[18]. Probable Reserves are those which are estimated to have a better than 50% chance[19] of being technically and economically producible, while Possible Reserves include

10 L.G Weeks, "Offshore development and resources", *Journal of Petroleum Technology*, 21(4), 1969.
11 L. Maugeri, *L'era del petrolio: Mitologia, storia e futuro della più controversa risorsa del mondo*, Milano, Feltrinelli, 2006, pp. 235.
12 M. Downey, *Oil 101*, New York, Wooden Table Press LLC, 2009, p. 292.
13 Maugeri, *L'era del petrolio*, cit. p. 235.
14 Downey, *Oil 101*, cit., p. 292.
15 *Ibidem.*
16 See paragraph 1.4.
17 Society of Petroleum Engineers (SPE), Guidelines for the application of the Petroleum Resource Management System, http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, accessed March 11, 2013.
18 BP, *Statistical Review of World Energy*, 2012.
19 "Chance" must not be confused with a quantitatively defined probability and can be interpreted as a broadly inferred confidence level.

those resources which, at present, cannot be regarded as "probable", but which are estimated to have a significant, although less than 50%, chance of being technically and economically producible in the future[20]. Estimated values can also be cumulatively described as 1P (corresponding to Proven Reserves), 2P (corresponding to Proven plus Probable) and 3P (corresponding to Proven plus Probable plus Possible).

Alternatively, since "uncertainty in resource estimates is best communicated by reporting a range of potential results"[21], the most recent[22] probabilistic or stochastic approaches allow the estimator, through the definition of a distribution function[23] representing the full range of possible values for all the relevant parameters, to obtain a frequency distribution describing the full range of potential results for the estimates of recoverable quantities. Particular estimates can be selected as representative outcomes: hence, the method defines P_{90} as the representative value for reserves with a 90% subjective probability of being greater than the stated value; P_{50} as the representative value for reserves with a 50% subjective probability of being either grater or smaller than the stated value, and P_{10} as the representative outcome for reserves with a 10% subjective probability of being greater than the stated value[24]. Such probability levels can also be associated to the deterministic 1P, 2P and 3P categories of reserves.[25]

Finally, some classification frameworks, such as the SPE/WPC's, also make a distinction between Contingent Resources and Prospective Resources. Contingent resources lie within the discovered recoverable resource category, and are defined as "those quantities of petroleum which are estimated, as of a given date, to be potentially recoverable from known accumulations (…) but which are not currently considered to be commercially recoverable due to one or more contingencies"[26]. On the other hand, prospective resources are defined as "those quantities of petroleum that are estimated, as of a given date, to be potentially recoverable from undiscovered accumulation"[27] and, therefore, are highly speculative.

20 British Petroleum, Oil reserves definitions, http://www.bp.com/sectiongenericarticle800.do?categoryId=9037318&contentId=7068756, accessed March 11, 2013.
21 SPE, *Guidelines*, cit. pp.12.
22 The probabilistic approach started gaining wider and wider application in the 1980s, as a consequence of the increased use of numerical and statistical techniques and of computing power.
23 A distribution curve, or function, describes how the distribution of a particular parameter in relation to an observed population evolves depending on the real value potentially expected for the examined parameter.
24 K. Aleklett, C.J. Campbell, "The peak and decline of world oil and gas production", *Minerals and Energy*, 18(1), 2003, p. 6.
25 Campbell, Laherrère, *The end of cheap oil*, cit., p. 80; and J.H. Laherrère, Forecasting future production from past discovery, http://www.watercrisis.org/laherrere/opec2001.pdf, accessed March 11, 2013.
26 SPE, *Guidelines*, cit., p.195. An example of contingent resources are the billion of barrels of bitumen contained in carbonate rocks under the Athabasca tar sands in Alberta, Canada.
27 *Ivi*, p. 211.

1.2. Reporting and publication of reserves estimates

Estimates of reserves are produced and reported by national and private oil companies and governments on a regular basis and for manifold reasons, both internal and external to the concerned institution. Figures are also published by trade journals and periodicals, or can be collected and made available for consultation in specialized industry databases or by consultants. The most part of the reported figures refer to proven reserves, even if information about 2P reserves has recently become more frequently available in the public domain.

Usually, private and national oil companies estimate reserves mainly for internal reporting reasons, deriving the information from exploration activity, and from feasibility and design studies for resource development and commercial evaluation[28]. Figures of proven reserves are needed for management, budgetary and planning purposes, or for reporting to stockholders[29]: they are a "working inventory" suggesting companies' market value, their future production potential, and therefore future income.

What is more, data on reserves may be needed to satisfy specific external objectives and reporting requirements: some countries require companies to report figures in compliance to fiscal regulations[30], as illustrated by the case of the U.S. Security Exchange Commission (SEC). Equity oil holdings[31] can be used by financial and trade journals to rank companies, paving the way for new investors, or reserves can be used as a collateral security in order to obtain a loan[32]: for instance, in 2010, Petróleos Mexicanos (Pemex), the Mexican national oil company, was granted a 600 million US$ loan by The Japan Bank for International Cooperation, aiming at financing the Chicontepec oil and gas field development project, after a massive increase in reserves took place in 2009[33].

Likewise, governments and government organizations produce their own figures using information produced by companies, independent geological studies or studies by government agencies and consultants. These data play a significant role in informing national energy policies related to imports, subsidies, and the research and development of alternative sources of energy, constituting also valuable information for those countries fueled by large oil

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28 J. Mitchell, Petroleum reserves in question, http://www.chathamhouse.org/sites/default/files/public/General/mitchell_sdp.pdf, accessed March 11, 2013.
29 Haider, *World oil reserves*, cit., p. 311.
30 *Ibidem.*
31 The term refers to reserves developed by a company in the framework of a production-sharing agreement or of a concession.
32 *Ibidem.*
33 In 2009, original reserves amounting to 139 billion barrels of crude oil equivalent were reported. However, difficulties encountered in trying to increase oil production despite massive investment lead to a downward revision of original reserves to 81 billion barrels of crude oil equivalent in 2012.

revenues.

Estimates of world proven reserves are regularly reported in various trade journals, such as the Oil and Gas Journal (OGJ), and in annual statistical reports, such as the OPEC Annual Statistical Bulletin (ASB), the BP Statistical Review of World Energy and the ENI World Oil and Gas Review (WOGR). The OGJ collects data through a questionnaire distributed to the different countries at the end of each year, whereas BP reproduces official data and information derived from other sources, such as the OGJ itself[34]. Figures reported in the WOGR and ASB are based on various other sources of information, such as trade press (OGJ, Arab Oil and Gas Directory, etc.), independent consultants and industry databases (such as De Goyler-Naughton, IHS Global Insight, Platt's), government agencies and ministerial bureaus (such as the U.S. Energy Information Administration, EIA), and other statistical reviews[35]. In addition, the ASB reports information received through direct communication from the countries to the OPEC Secretariat. All publications deal with a massive amount of energy data, focusing not only on reserves, but also on oil production, prices, imports and exports, stocks, and demand, usually including whole sets of data regarding natural gas and unconventional oil.

Additionally, several industry consultants and organizations provide independent estimates of reserves figures. As an example, Information Handling Services (IHS) holds a world database including proven reserves figures as well as 2P (proven plus probable) estimates for both individual fields and countries, also providing detailed analysis. The database is used, among others institutions, by the U.S. Geological Survey (USGS), which, since the 1970s, has conducted various assessments and studies of world oil reserves, presenting its first findings at the 11th World Petroleum Congress in 1983[36]. Due to the difficulty of assembling and assessing 2P field information in order to provide credible national, regional and world totals, access to this kind of data sets is very expensive and often prohibitive for scholars[37]. However, public-domain 2P data are increasingly available from companies in the form of publicity material, from governments[38], from USGS assessments, and from other organizations, like the Association for the Study of Peak Oil (ASPO)[39].

34 Haider, *World oil reserves*, cit., p. 307.
35 OPEC, *Annual Statistical Bulletin,* 2012; ENI, *World Oil and Gas Review,* 2012.
36 Haider, *World oil reserves*, cit., p.310.
37 For example, the IHS Energy's global set of oil and gas 2P discovery and production data by country can be purchased for about $ 5000.
38 For instance, the United Kingdom and Mexico provide 2P data publicly via the web.
39 R.W. Bentley, S.A. Mannan, S.J. Wheeler, "Assessing the date of the global oil peak: The need to use 2P reserves", *Energy Policy*, 35, 2007, pp. 6369-6370. The monthly ASPO newsletter by C.J. Campbell frequently reports 2P and other relevant reserves and resources data.

1.3. A brief history of oil exploration and estimation

During the last century, early and almost magical approaches in estimating the existing quantities of hydrocarbons gradually gave way to massive technological breakouts and increasingly analytic techniques, which greatly enhanced our understanding and knowledge of oil reservoirs, above all in the field of geological prospecting, leading to more and more informed estimates. Some examples from the American oil industry can be helpful in trying to outline the path followed by exploration and estimation activities during the past century.

Hirsch describes reserves estimation as a blindfolded person trying to judge what the whole elephant looks like from touching it in just a few places[40]. It is possible to claim that, at the very beginning of the oil industry in the 1850s, the "elephant" was almost completely out of reach. American wildcatters, with no geological or geophysical background, would count on nearly magical approaches in order to strike oil, even hiring mediums and dowsers; more frequently, they would simply hope to find it by chance.[41] Oil was commonly thought to lie in huge underground lakes and caves; doubtlessly, at that time, the overall amount of resource was a non existent concern.

At the dawn of the 20th Century, fears of imminent depletion started spreading in front of unregulated drilling and breathtaking pace of extraction set by the "rule of capture", according to which the owners of a land above an oil pool could take as much resource as they wanted, inconsiderate of reservoir conditions and nearby wells. In 1909, President Theodore Roosvelt's call for the conservation of natural resources[42] set the stage for the first national oil survey in the United States. Commissioned by the USGS and carried out under the supervision of geologist David T. Day, the first attempt to undertake an extensive and accurate estimate of national crude oil resources resorted to the newest geological achievements of the time, namely the study of reservoirs as traps[43] and the volumetric

[40] R.L. Hirsch, "The inevitable peaking of world oil production", *Bulletin of the Atlantic Council of the United States*, 16(3), 2005, p. 2.

[41] Maugeri, *L'era del petrolio*, cit., p. 233.

[42] "If we of this generation destroy the resources from which our children would otherwise derive their livelihood, we reduce the capacity of our land to support a population, and so either degrade the standard of living or deprive the coming generations of their right to life on this continent...then conservation is the great fundamental basis for national efficiency". Roosvelt, T., Special message from the president of the United States transmitting a report of the National Conservation commission, 1909, United States, 60th Congress, 2nd session, 1908-1909, Document n. 676, http://memory.loc.gov/cgi-bin/query/r?ammem/consrvbib:@field%28NUMBER+@band%28amrvg+vg38%29%29, accessed March 11, 2013.

[43] Petroleum needs a particular trap configuration to exist, made up of a source rock, a layer of porous and permeable rock allowing for oil accumulations in the pore spaces, an impermeable cap rock preventing oil from leaking upwards, and some kind of geological unconformity sealing the reservoir and allowing gravitational factor to operate. At that time, however, experts did not completely agree on petroleum origins or on the theory of accumulation.

approach. Conceiving the reservoir as a measurable space from which a commercially relevant amount of oil could be drawn, the volumetric method allowed to infer in-place oil reserves through the analysis of parameters such as the average porosity of source rocks and the amount of crude obtained per cubic foot of oil sands. The assumption was that geologically similar basins would contain comparable amounts of oil per unit of volume; as a result, it was possible to calculate the expected quantity of resource in the unexplored basin, multiplying the volume of unexplored rock sediment by the estimate of oil per unit of volume derived form the known basin[44]. Accordingly, Day was able to create a forecast for whole oil pools, subsequently obtaining an estimate for the oil that could actually be extracted from the ground at current technical conditions, given a recovery factor and the total amount of oil already found in the ground. If production statistics per well were also available, the future recovery factor could be derived from past experience, therefore depicting a "per cent decline curve" which expressed each year production as a percentage of the first year of output. Similar curves were estimated for neighboring wells, allowing estimates for entire oil fields[45].

The USGS report estimated that oil endowment ranged between 10 and 24.5 billion barrels, of which only about 15 billion were considered recoverable, and predicted the exhaustion of U.S. oil resources by about 1935, assuming the stability of the 1909 consumption level[46].

However, such early figures presented several fallacies: resource definitions were imprecise and estimates soon proved to be highly conservative[47]. Estimation methods relied upon ex-post measurements on existing wells; they excluded both the application of enhanced oil recovery practices, which would be increasingly taken into account starting from the 1920s[48], and prospective or untapped reserves[49].

Interestingly, the following 1915 USGS report depicted an even bleaker prospect for U.S reserves, estimating an original resource base only amounting to 9 billion barrels[50]. In addition, the 1910s were a decade of "dry wells" and no major discovery replaced U.S oil withdrawals: the 1923 survey predicted that only 6 years remained before complete

44 G. Bowden, "The social construction of validity in estimates of U.S. crude oil reserves", *Social studies of science*, 15(2), 1985, p. 212.
45 Madureira, *Estimating oil reserves*, cit., pp. 144-145.
46 E.D. Porter, Are we running out of oil?, American Petroleum Institute Policy Analysis And Strategic Planning Department Discussion Paper #081, p. 8 http://gisceu.net/PDF/U30.pdf, accessed March 11, 2013.
47 The report was actually limited to developed fields: the so called "proved territory" principally consisted of Pennsylvania, Ohio, and West Virginia, therefore conservative report results were reasonable. *Ivi*, p. 9.
48 In the 1920s, new recovery techniques such as gas injection and water flooding were introduced. See: Madureira, *Estimating oil reserves*, cit. p. 150.
49 *Ibidem.*
50 Porter, *Are we running out of oil?*, cit., p. 8.

exhaustion[51]. This apparent rush towards depletion started the still ongoing debate between those claiming an imminent oil famine, and those suggesting the evidence of oil abundance.

In 1922, the USGS and the American Association of Petroleum Geologists jointly produced an accurate and comprehensive study, for the first time distinguishing between known fields and undiscovered resources, and introducing a probabilistic categorization of reserves: 5 billion barrels of oil "in sight" were identified, along with 4 billion of "prospective" and "possible" barrels, respectively described as "reasonably reliable" and "speculative and hazardous"[52].

From that moment on, undiscovered resources[53] became the crucial point of contention between competing reports, and the main source of uncertainty: in the 1920s, there was still limited knowledge of the factors leading to the existence of oil accumulations, and an insufficient geological understanding of the physics of a reservoir. Geology could only forecast where oil was or was not supposed to be found, giving advice about which areas to drill first. In order to get a clue about the location of a potential reservoir, geological observation relied on surface indicators: on clear-cut ones, like seepages, bituminous lakes, and gas natural springs; or, in their absence, on landscape configuration, according to the anticlinal theory of oil accumulation[54]. Following the theory first exposed by I.C. White in 1885, oil, gas, and water were separated along convex upward underground folds (anticlines), according to their specific gravities; such formations could reach the surface, resulting in hills, or folds, which became the main target of geological exploration[55]. The popularity of the anticline theory, and the new topographical relationship between landscape and oil reservoirs, greatly increased the value of geological prospecting, to both the public and companies. The first half of the 20th Century can be considered the "era of geologically-inspired invasions", as the largest oil companies started moving abroad looking for untapped reserves in order to face increasing competition in the market. As a result, in the 1920s, every oil firm ended up hiring 10, 15, 20 geologists, since working with surface indicators required a huge, labor-intensive organization[56].

51 Madureira, *Estimating oil reserves*, cit., p. 150.
52 *Ivi*, p.151.
53 *Ivi*, pp.155-157. However, after 1925, U.S institutions headed towards the opposite direction, removing uncertainty from the activity of estimating resources. In 1938, the API required oil companies to assess and report "only the amount of oil which may be extracted by present known methods from fields completely developed or drilled or sufficiently drilled and explored to permit of reasonably accurate calculations". It was a narrow definition of proven reserves, which clearly informed current reporting practices established by SPE for the US oil industry.
54 *Ibidem.*
55 M.A. Dennis, "Drilling for dollars: the making of US petroleum reserves estimates, 1921-25”, *Social studies of science*, 15(2), 1985, p. 244.
56 Madureira, *Estimating oil reserves*, cit., p.153. Notably, the multinational holding company was the only organizational structure able to finance a multiform presence in oil fields around the world.

Nevertheless, finding an untapped reservoir was still a hit or miss affair: there were not specific location criteria, traps could have an unexpected stratigraphic configuration, and oil could be actually found in a variety of rock structures. Therefore, geological prospects could lead either to huge findings or to huge blunders. In 1923, BP chairman Arnold Wilson, evaluating the possibility of major oil findings in the Arab kingdom of ibn-Saud[57], claimed: "I personally cannot believe that oil will be found in his reign. As far as I know, there are no superficial oil-shows, and the geological formation does not appear to be particularly favorable from what little we know of it"[58]. At least until the 1960s, in order to ascertain the existence of oil, a hole in the ground seemed to be the only sure test [59].

Between 1919 and 1929, several new geophysical technologies were experimented for the first time, thanks to increasing pay-offs to investments in oil exploration and production. Gravity, magnetic and seismic refraction surveys all were based on the idea that it was possible to track and map interruptions and variations in rock density (the so-called "bright spots") by measuring the way they conveyed a signal[60]; the resulting data were correlated with underground structures, which in turn could imply the presence of an exploitable accumulation of hydrocarbons. Successful discoveries in Texas, Mexico, and Venezuela sealed the validity of the new techniques that still today are at the core of oil prospecting activities, although in more technologically-advanced forms[61].

Geophysical surveys changed the meaning of geological observation and mapping technologies: gravitational, magnetic and refraction methods became increasingly associated with efforts to produce qualified assessments of sediment thickness and of the amount of untested probable resources[62]. Furthermore, in 1933, Texaco carried out the first mobile offshore drilling on Lake Petro, Louisiana; in 1947, the first bottom-supported platform out of sight of land was constructed in the Gulf of Mexico. The new frontier of offshore reserves exploration and estimation was mainly based on marine seismic surveys, and gained momentum in the 1960s and 1970s with the development of production areas such as the North Sea and offshore West Africa, especially in Angola and Nigeria[63].

Since the 1950s, many of the newly-born computer companies began to provide pioneer technologies to the oil industry, which soon became one of the largest users of

57 As later discovered, the territory coincided with the region of Saudi Arabia most rich in oil.
58 Maugeri, *L'era del petrolio*, cit., p. 58.
59 Madureira, *Estimating oil reserves*, cit., p. 151.
60 *Ivi*, p. 154. Such as electrical current generated by a magnetometer or cuncussive sound produced on the surface and directed downwards.
61 *Ivi*, p. 155.
62 *Ibidem.*
63 Downey, *Oil 101*, cit., p. 115.

computing power in the world. Remarkably, oil exploration was toppled by the introduction of 3-D seismic surveys, which were tested for the first time in the 1970s, but became commercially widespread starting from the 1980s and 1990s. 3-D modeling made it easier not only to locate the optimal drilling point, but also to find and measure the size of a prospect, by providing a virtual image of the reservoir[64]. Later on, also 4-D seismic analysis (a time lapse of the 3-D analysis) was introduced, allowing the evaluation of how production flows would impact oil accumulations. Equally important, the geochemical breakthrough in the 1980s made possible to associate the oil produced from a well with the rock in which it was generated, leading to a deeper understanding of the extraordinary conditions required for oil formation[65].

1.4. Current approaches and methods in estimating oil reserves

Producing consistent estimates of oil reserves is a complex process, that requires not only geological expertise: it also implies a joint effort between engineering, mathematics, statistics and economics, in an ongoing dialogue and consultation[66]. Despite the staggering technological improvements of the last decades, it is actually still impossible to know the exact amount of oil under the Earth surface: the estimation of reserves is an imprecise science due to many unknown parameters and to the limited amounts of data available, coupled with different estimation methods and approaches. Obviously, uncertainty swells when global URR and undiscovered resources are concerned. However, thanks to the acquisition of new information through drilling and production activity, accuracy of the estimations and knowledge of the reservoir increase with time, often leading to an upward revision of the initially estimated reserves, which are usually conservative figures. The impact of relevant non geological factors on reserves trends has also to be taken into account.

In order for a prospect[67] to qualify for size estimation and subsequent development, it has to meet specific criteria. Location, geology, environmental conditions and crude quality can even make an oil accumulation irrelevant from an economic perspective. The exploration process looks for indicators of economically and technically producible oil; therefore, after a geological structure of potential interest has been located, it is crucial to verify that at least

[64] *Ivi*, p. 100.
[65] Aleklett,Campbell, *The peak and decline of world oil and gas production*, cit.
[66] Maugeri, *L'era del petrolio*, cit., p. 250.
[67] Downey*, Oil 101,* cit., p. 88. A prospect can be defined as an area thought to contain hydrocarbon accumulations, once surface and mineral righs have been established, and the area itself has been evaluated and is ready for drilling.

three conditions are met. First, the geological target ought to be in communication with a source rock[68]; second, a reservoir rock, communicating with the source rock and characterized by sufficient porosity and permeability, should have allowed oil to flow upwards, occupying pore spaces; and, last but not least, the structure must be capped by an effective impermeable seal, usually in the form of clay or salt, preventing oil to leak on the surface[69]. Undoubtedly, geophysical imaging technologies, such as 3-D modeling, enable to locate and characterize the resource base far more precisely than in the past; however, the actual drilling of an exploratory well (or wildcat well)[70] remains the only and ultimate way to prove oil existence in relation to a prospect[71]. Thereafter, appraisal wells and seismic analysis[72] provide crucial information in order to determine if a known accumulation is commercial, an essential feature to allow the formulation of a field development plan.

In particular, 2-D seismic surveys are useful in mapping structures, whereas 3-D seismic defines trap geometry along with rock and pore-fluid properties. In addition, time-lapse seismic, or 4-D seismic, monitors changes in pore-space composition, pressure, and temperature as production causes fluids to move within the reservoir[73].

Depending on the available data, on the characteristics of the reservoir and on the stage of development, different estimation techniques can be utilized. Methods employed before oil is actually produced from a reservoir are labeled as indirect, since they try to infer estimated recoverable resources from geological and engineering survey data, requiring previous and independent estimates of recovery efficiency[74]. Instead, methods employed after production has begun are based on production performance data and are referred to as direct methods[75].

Nominal and Volumetric methods are the most commonly used indirect estimation techniques. According to the Nominal method, a new field is compared to another known field, if an exploratory well suggests the existence of a continuous productive rock formation. It is a method which lacks accuracy, being based on rule-of-thumb analogies. Conversely, the Volumetric method takes into account geological and engineering data such as average

68 *Ibidem.* A source rock is a rock laden with kerogen, a solid dark waxy rock formed by organic and inorganic sedimentary material; also referred to as "mother rock", it allows oil formation, due to thermal degradation and pressure.

69 Aleklett, Campbell, *The peak and decline of oil and gas world production*, cit.

70 Downey, *Oil 101*, cit., p. 101. Globally, the ratio of dry to successful wildcat wells tends to be about 4:1.

71 Porter, *Are we running out of oil?*, cit., p. 28.

72 Specifically, 3-D analysis is incresingly used instead of appraisal wells since it helps lowering production costs.

73 SPE, *Guidelines*, cit., pp. 23-28.

74 Recovery efficiency (or recovery factor) identifies the maximum percentage of oil in olace in a reservoir whihc is technically recoverable. The average worldwide recovery factor is around 30%.

75 *Ivi*, p. 38.

porosity, pore volume, average water saturation, average hydrocarbon saturation, and areal extent in order to estimate the amount of oil potentially recoverable from the reservoir. Often, in the history of the oil industry, the two methods have been used jointly, allowing to calculate the expected quantity of resource in a new basin: the volume of unexplored rock sediment is multiplied by the estimate of oil per unit of volume derived from a known and similar nearby basin[76]. When evaluating volumetric estimates accuracy, the dearth of flow testing or data on actual production flow must be considered[77]. Table 1.1 shows an example of volumetric assessment of reserves, undertaken in an appraisal stage of development, therefore with limited information available; input parameters are listed, and a deterministic scenario approach is employed.

		Bases and Reserves Categories		
Estimated Parameters	Units	**Low Estimate**	**Best Estimate**	**High Estimate**
Bulk Reservoir Pay Volume	M ac-ft	821.0	1,370.8	1,917.9
Average Porosity	%	18.9%	18.7%	18.5%
Pore Volume (PV)	M ac-ft	**155.2**	**256.3**	**354.8**
Average Initial Water Saturation	%	14.8%	15.0%	15.3%
Hydrocarbon Pore Volume (HCPV)	M ac-ft	**132.2**	**217.9**	**300.5**
Average FVF (B_{oi})	RB/STB	1.330	1.330	1.330
Oil Initially In-Place (OIIP)	MMSTB[1]	**771.2**	**1,271.0**	**1,753.0**
Recovery Factor[2]	% OIIP	35%	40%	45%
Recoverable Oil(EUR)*	MMSTB	**269.9**	**508.4**	**788.8**
Initial Solution Gas-Oil Ratio (R_{si})	scf/STB	550	550	550
Gross-Heating Value of Raw Solution Gas	Btu/scf	1,200	1,200	1,200
Original Gas In-Place (GIIP)	Bscf	**424.1**	**699.0**	**964.1**
Recoverable Raw Gas (EUR)*	Bscf	**148.4**	**279.6**	**433.9**
	MMBOE[3]	30.7	57.9	89.8

Calculated by using the conversion factor of 7,758 bbl/acre-ft.
Under Peripheral Water Injection, already well-established in several nearby analog reservoirs and projects.
Calculated using an average conversion factor of 5.8 MMBtu per BOE.
* Estimated Oil and Gas Reserves categories of **1P**, **2P** and **3P**, respectively.

Table1.1. Example of volumetric assessment of reserves (appraisal stage)
Source: SPE, 2011

Material balance, Decline curve analysis (DCA), and Reservoir simulation are direct techniques of estimation, based on data on production performance[78]. Material balance relies on the periodic measurement of reservoir pressure[79], and it is particularly fit to the earliest stage of production. On the contrary, DCA is used to plot production rates and pressure drops in order to produce an estimate of remaining oil volumes once production rates are already declining. Finally, Reservoir simulation can be employed to develop a detailed computer

76 See paragraph 1.3.
77 Downey, *Oil 101*, cit., pp. 296-297.
78 *Ibidem*.
79 It is the differential between the average pressure inside the reservoir and the pressure at the bottom of the well bore that propels the oil out of the reservoir; as more and more oil is extracted, pressure within the reservoir decreases, causing production rates to decline. Therefore, pressure measurements allow to estimate the remaining amount of oil in the reservoir.

model of the basin, by coupling geological models, well logs[80], and data on production performance data such as production rates, pressures, etc[81].

Nowadays, two different approaches define how figures on reserves are formulated and reported, namely the deterministic approach and the probabilistic approach. Since comparable results are required irrespectively of the adopted method, the underlying philosophy is actually the same. Both methodologies provide at least three outcomes for estimated recoverable quantities, specifically a low, best, and a high estimate, reflecting the inherent uncertainty of such figures. The best estimate is considered the most realistic assessment of recoverable quantities, generally supposed to represent 2P (Proven plus Probable reserves) estimates, in the case of the deterministic approach, or P_{50} estimates, in the case of the probabilistic approach.

With reference to the deterministic approach, either an incremental or a scenario perspective can be embraced. In the deterministic incremental approach, a single value is adopted for all the relevant geological and engineering parameters in order to obtain discrete estimates for each reserves category. Similarly, in the deterministic scenario approach, which adopts some elements of the probabilistic method, three separate analysis are prepared using three plausible sets of relevant input parameters[82]. Estimates obtained are classified as Proven, Possible and Probable reserves in the incremental approach, or as 1P, 2P, and 3P in the scenario approach[83]. Unquestionably, the deterministic approach reveals several advantages: it describes a specific case, it is direct and easy to explain, and it has a long history of application. Notwithstanding, it does not provide a quantification for the plausibility of low, best, and high estimates.

"The probabilistic method uses the full range of values that could reasonably occur for each relevant parameter in order to generate a full range of possible outcomes for the resource volume"[84]. A probability function based on available geological and engineering data is created for each individual parameter reflecting uncertainty; thereupon, a stochastic procedure is used, such as the Monte Carlo simulation, which generates a frequency distribution curve describing the full range of potential results for recoverable quantities estimates, by randomly drawing a value for each parameter to calculate the likely outcome, and repeating the process

80 Well logging is a test performed while drilling: it helps determining the rock formation type, the rock porosity, and the deviation from true horizontal of the rock formation.
81 SPE, *Guidelines*, cit., p. 58.
82 *Ivi*, p. 35.
83 See paragraph 1.1.
84 *Ivi,* p. 82.

for a sufficient number of times[85]. Results are afterward classified as P_{90}, P_{50}, and P_{10}[86] estimates (Fig 1.2). The probabilistic approach allows to apprehend the range of possible outcomes, linking it with an uncertainty range; additionally, it can be used throughout the whole production cycle, and, from a numeric and statistic perspective, provides easily treatable data. On the other hand, this approach can require an excessive, and sometimes ineffective, amount of calculation work, categories may not be related to specific physical areas or volumes, especially if geological and simulation models are not used concurrently, and dependencies between relevant parameters can be difficult to evaluate, since it is not possible to trace back input parameters associated with a certain result.[87].

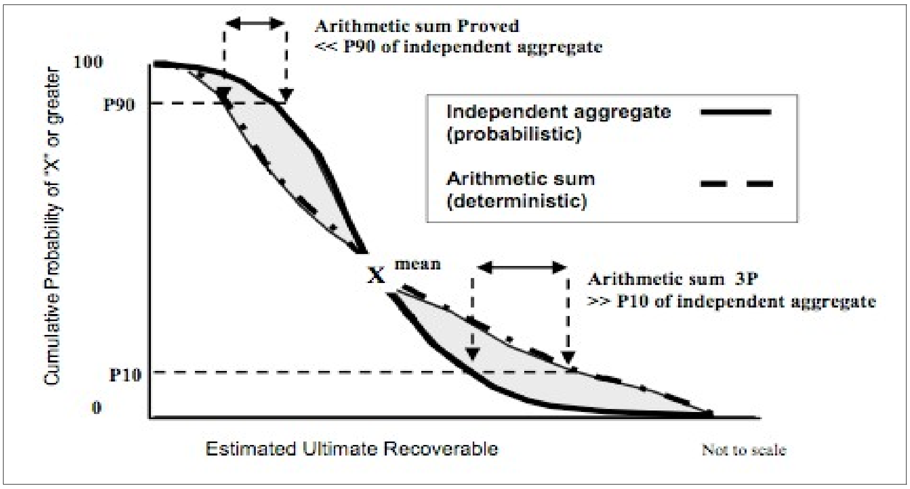

Figure 1.1. Example of distribution curve for estimated ultimate recoverable reserves, and comparison between Probabilistic and Deterministic Aggregation.
Source: Laherrère, 2007

The deterministic and the probabilistic approach can be, and often are, used concurrently: if obtained values agree, then consistency in the reserve calculation is increased, whereas, if results differ prominently, underlying assumptions need to be reconsidered.

Figure 1.2 enables to a further consideration: when producing aggregate reserve figures, an arithmetic sum of deterministic values for proven reserves will result in under-estimation, while for Possible reserves it will result in over-estimation. Proven reserves are usually very conservative numbers, reporting only the amount of oil just about to enter the market. Therefore, if a 90% probability is assigned to such values, it is misleading to add them and apply the same probability to the aggregate, which can refer to a region, a country, or the entire planet. A probabilistic assessment is needed to add values according to the underlying probability distribution, avoiding extremely conservative figures. Alternatively,

[85] *Ibidem*.
[86] See paragraph 1.1.
[87] *Ivi,* p. 87-88.

Campbell and Laherrère suggest to add the mean, or average, estimate of oil in each field[88]. For instance, Laherrère evaluates data reported for eight regions in the USGS 2000 geological survey: by applying a Monte Carlo procedure, a Low Case and a High Case of 339 giga barrels(Gb)[89] and 1107 Gb respectively are given, compared to 179 Gb and 1289 Gb resulting from simple arithmetic addition. By contrast, the mean value of 649 Gb (identified with 2P reserves) is the same under both methods of calculation[90].

The intrinsic conservative nature of proven reserves and the subsequent revision of reserve calculations are among the causes of the growth of reported reserves in time. The growth of reserves is a phenomenon common to all fields. For instance, USGS reports that estimates of ultimate recovery for the Midway-Sunset field more than doubled over a period of 28 years, increasing from 1.2 billion barrels in 1968 to 1.65 billion barrels by 1976, and further to 2.8 billion barrels by 1996[91]. In addition to initially conservative figures, the trends of reserves estimates are affected by improvements in recovery percentage[92], mainly due to technological innovation, and by the delineation of additional oil-in-place accumulations, due to a better knowledge of already developed reservoirs. For instance, by 1986, the Kern River field in California had 970 million barrels of estimated remaining reserves: during the previous forty-four years it had produced 736 million barrels, despite an estimate of 54 million remaining barrels in 1942. The only thing that had changed was knowledge[93].

Difficulties in producing aggregate figures for reserves stand out prominently when facing the challenging task of estimating global or national reserves. Different and sometimes contrasting approaches can be adopted: for example, the macro-approach contemplates an overall picture of the planet, combining satellite imagery and physical geological data. Contrariwise, the field-by-field method is used to originate global data sets by assessing independently individual field estimates around the world, also evaluating the methodologies of estimation employed. Usually, consultants such as IHS venture in such assessments, which require a massive deployment of manpower and a careful appraisal of collected information. The result is the creation of industry data sets tremendously expensive to enter upon. A third approach, the analysis of the decline curve, exploits DCA methods on a worldwide scale, finding its rationale in the central limit theorem: when adding the log-normal probability

88 Campbell, Laherrère, *The end of cheap oil*, cit., p. 80.
89 1 Gb = 1 000 000 000 barrels (1 barrel = 158.987295 liters or 42 gallons).
90 J.H. Laherrère, Is USGS 2000 assessment reliable? http://www.oilcrisis.com/laherrere/usgs2000, accessed March 11, 2013.
91 USGS, Reserve growth effects on estimates of oil and natural gas resources, http://pubs.usgs.gov/fs/fs119-00/fs119-00.pdf, accessed March 11, 2013.
92 Laherrère harshly critics the assumption of the recovery factor, for example by the USGS, as a function of the technology level, claiming that it is mainly determined by the geological qualities of the reservoir.
93 Maugeri, *L'era del petrolio*, cit., p. 234.

distribution of production rates from a large numbers of reservoirs, the resulting sum will tend to form a normal distribution, in the form of a bell-shaped curve; the curve represents production over time for a considered region, while the area underneath it defines URR. DCA provided the basis for the renowned model developed in 1956 by Marion King Hubbert, who described the peaking and declining of U.S. crude oil production. A final method, which Downey calls the "trust but do not verify approach"[94], is employed by trade journals and statistical publications, and simply requires contacting oil producers and asking for figures of proven reserves, which will be subsequently aggregated and reported to the public.

Attempting to produce a consistent set of estimates for oil resources at a global level implies also dealing with undiscovered petroleum resources, which can be defined as the difference between URR and discovered resources: they are a forecast of the oil that is thought will be discovered and produced in the future[95]. Ahlbrandt and Klett[96], provide a comparison of the methods used to estimate conventional undiscovered amounts of petroleum, reporting examples on a worldwide scale. Compared approaches include the Discovery Process model, based on past drilling activity and field-discovery history; Fractal models, linear or parabolic, based on assumptions about resource distribution among field size classes; the PETRIMES model, which estimates the remaining potential starting from a ranked size distribution of known fields and assuming undiscovered field sizes; Material Balance, based on reservoir engineering properties; and the method adopted in the USGS World Petroleum Assessment 2000, based on both geology, which allows to estimate the number and sizes of undiscovered fields in *unexplored plays*, and discovery history, which allows to estimate the number and size of undiscovered fields in *existing plays*. Interestingly, all methods were applied on a given set of data[97], obtaining different results. By way of illustration, undiscovered petroleum potential estimates for the Neuquen Basin Province in Argentina range from 0.69 billion barrels of oil equivalent (BBOE) in the case of the linear fractal method, to 17 BBOE in the case of the PETRIMES method. The authors highlight how the linear fractal method conceives the basin as extremely mature, with only 6% of remaining ultimate potential, whereas the PETRIMES approach considers the basin as immature, and endowed with undiscovered resources twice the size of already discovered quantities[98].

94 Downey, *Oil 101*, cit., p. 301.

95 C.J. Campbell, The Twenty-First Century, the world's endowment of conventional oil and its depletion, http://www.oilcrisis.com/campbell/cen21.htm, accessed March 11, 2013.

96 T.S. Ahlbrandt, T.R. Klett , "Comparison of methods used to estimate conventional undiscovered petroleum resources: World examples", *Natural resources research*, 14(3), 2005, pp. 187-210.

97 Data refers to a sample of discovered petroleum fields, including cumulative production, field discovery date, field area, number of exploratory and wildcat wells drilled per year in the play, remaining reserves.

98 *Ivi*, pp. 194-195.

A final observation is pledged to two non geological factors impacting reserves estimation: expectations about oil prices, and the existing political framework[99]. Optimistic expectations about an increase in oil prices usually trigger investment in technology and exploration, potentially leading to higher recovery factors, new basins, and therefore growing reserves estimates, as illustrated by the North Sea oil boom in the 1970s and 1980s, grounded on the skyrocketing prices of the 1973 oil shock. At the same time, investment decisions are informed by political considerations, for example concerning concessionary systems and fiscal regimes implemented by the producing countries. Furthermore, producers, who are legitimate and sovereign owners of their resources, can restrict exploration, as well as close their boundaries to investment from foreign oil companies. Maugeri reports that, between 2002 and 2005, only a mere 3% of total exploratory wells was drilled in the Middle East, owner of 70% of world petroleum resources[100].

1.5. Proven reserves: latest figures and geographical distribution

According to published figures, oil proven reserves have experienced a striking increase since the beginning of the oil industry, thanks to better geological knowledge, improved estimation techniques, technological progress in oil recovery, and increasing oil prices: these factors allowed exploration in areas previously out of reach and the development of new prospects. For instance, the Energy Information Administration (EIA) reports that, in 1899, U.S. crude oil reserves amounted to 2,500 million barrels (mb); in 2010, they summed up to 23,367 mb, after reaching a peak of 39,001 mb in 1970.

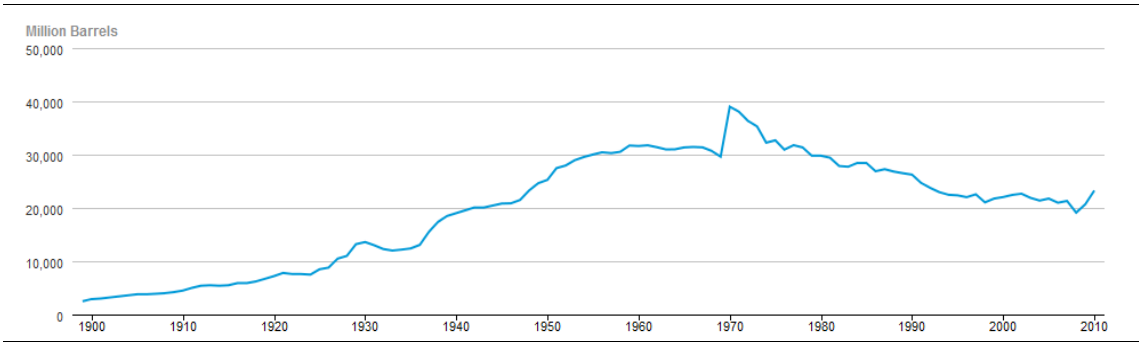

Figure 1.2. U.S. Proven oil reserves, 1899-2010 (million barrels)
Source: EIA

From a global perspective, proven reserves have shown almost a five-fold enlargement since the 1960s, as reported by OPEC Annual Statistical Bulletin. If at the beginning of the

[99] Political and institutional interferences on reserves definition and estimation are further discussed in paragraph 1.7.

[100] Maugeri, *L'era del petrolio*, cit., p. 246.

1970s stated figures barely amounted to 600 billion barrels (bbls) of oil, 40 years later they were more than doubled, far exceeding 1,400 bbls[101]. (Figure 1.3)

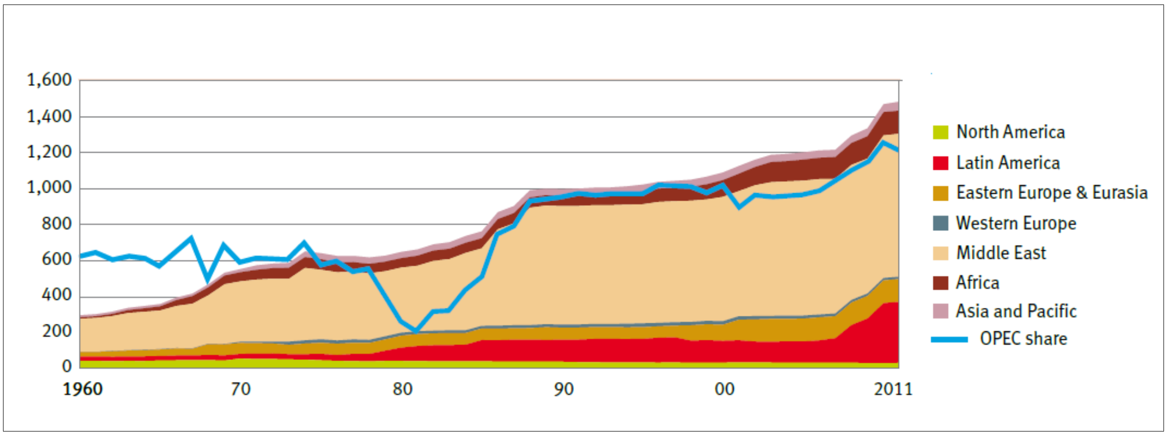

Figure 1.3. World proven oil reserves by region, 1960-2011 (billion barrels)
Source: OPEC, *Annual Statistical Bulletin 2012*

Tables 1.2, 1.3, 1.4, and 1.5 detail the latest proven reserves figures by region and aggregates[102] and for the top ten reserves holders as reported in three different publications, namely the BP Statistical Review, the OPEC's Annual Statistical Bulletin (ASB), and the World Oil and Gas Review (WOGR) by ENI; all figures refer to 2011, as at 31st December. Data reported below require a couple of clarifications, since, although not completely dissimilar, they show at least two noticeable discrepancies. The first issue concerns the inclusion or exclusion from reported amounts of Natural Gas Liquids (NGLs), gas condensate, and unconventional oils. The Statistical Review clearly specifies that "reserves include gas condensate and natural gas liquids, as well as crude oil"[103]; the ASB's figures refer to crude oil, defined as containing "small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs, but which are liquid at atmospheric pressure...small amounts of non–hydrocarbons produced with the oil, and very heavy and extra–heavy crude oils"[104]. Conversely, the WOGR much more vaguely asserts that "in some countries figures may include oil and natural gas from non conventional sources and others sources of supply"[105]; however, such countries remain unspecified throughout the report.

With reference to unconventional oils, the most relevant inconsistency concerns Canadian reserves: the ABS reports for Canada a figure amounting to 4,900 bbls, compared to the 173,625 bbls reported by the Statistical Review and the 175,200 bbls by the WOGR, a

[101] OPEC, *Annual Statistical Bulletin 2012*, Wien, OPEC, 2012.
[102] For figures referring to individual countries see: BP, *Statistical Review of World Energy 2012*, London, BP p.l.c., 2012; OPEC, *Annual Statistical Bulletin 2012*, cit.; ENI, *World Oil and Gas Review 2012*, Rome, ENI, 2012.
[103] BP, *Statistical Review of World Energy 2012*, cit., p. 6.
[104] OPEC, *Annual Statistical Bulletin 2012*, cit., p. 100.
[105] ENI, *World Oil and Gas Review 2012*, cit., p. viii.

striking divergence due to the exclusion of Alberta oil sands in the case of the ASB figure. Notably, in 2011, Alberta's declared reserves were 170.2 billion barrels, of which oil sands reserves accounted for 168,7 bbls, about 98 per cent of Canada's oil reserves and 11 per cent of total global oil reserves[106]; the Statistical Review reports for Canadian oil sands an overall amount of 169,2 bbls, of which 25, 9 bbls are under active development[107]. The same logic is not applied in the case of the Orinoco tar sands of Venezuela: the 297,571 bbls reported for the country by the ASB unmistakably incorporate the estimated 220 bbls[108] of unconventional oil settled in the Orinoco Basin.

The second noticeable inconsistency relates to geographical areas, since each publication has its own reporting classification. For instance, the Statistical Review adds Mexican proven reserves to the total for North America, whereas both the ABS and the WOGR consider Mexico as part of Central and Latin America. To provide another case in point, in each report European, Russian, and Eurasian proven reserves are aggregated by using different criteria: BP reports the total for "Europe and Eurasia", the ASB distinguishes between "Western Europe" and "Eastern Europe and Eurasia", while the WOGR favors a distinction between "Europe" and "Russia and Central Asia".

106 Alberta Energy, Facts and Statistics, http://www.energy.alberta.ca/oilsands/791.asp, accessed March 28, 2013.
107 BP, *Statistical Review of World Energy 2012*, cit., p. 6.
108 *Ibidem.*

		2008	2009	2010	2011
North America[109]		216,500	218,600	217,800	217,500
Central & South America[110]		198,900	237,500	324,700	325,400
Europe & Eurasia[111]		136,500	136,800	139,500	141,100
Middle East[112]		753,700	752,800	765,600	795,000
Africa[113]		128,100	130,300	132,700	132,400
Asia & Pacific[114]		41,800	42,200	41,700	41,300
World		**1,475,400**	**1,518,200**	**1,622,100**	**1,652,600**
of which:	**OPEC**[115]	1,028,800	1,068,600	1,167,600	1,196,300
	non OPEC	324,400	326,900	329,400	329,400
	OECD[116]	234,400	236,000	235,000	234,700
	non OECD	1,241,000	1,282,200	1,387,100	1,417,900

Table 1.2. Proven oil reserves by areas and aggregates 2006-2011, as reported by the BP Statistical Review of World Energy (million barrels)
Source: BP, *Statistical Review of World Energy 2012*

109 US(excluding Puerto Rico), Canada, Mexico.

110 Caribbean(including Puerto Rico), Central and South America.

111 European OECD members (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Republic of Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK) plus Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Former Yugoslav Republic of Macedonia, Gibraltar, Malta, Romania, Serbia and Montenegro; and Former Soviet Union (Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan).

112 Arabian Peninsula, Iran, Iraq, Israel, Jordan, Lebanon, Syria.

113 Territories on the north coast of Africa from Egypt to western Sahara; territories on the west coast of Africa from Mauritania to Angola, including Cape Verde and Chad; territories on the east coast of Africa from Sudan to the Republic of South Africa, plus Botswana, Madagascar, Malawi, Namibia, Uganda, Zambia, Zimbabwe.

114 Brunei, Cambodia, China, China Hong Kong Special Administrative Region, Indonesia, Japan, Laos, Macau, Malaysia, Mongolia, North Korea, Philippines, Singapore, South Asia (Afghanistan, Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka), South Korea, Taiwan, Thailand, Vietnam, Australia, New Zealand, Papua New Guinea, Oceania.

115 OPEC members include Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

116 Members of the Organization for Economic Cooperation and Development include: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Israel, Japan, Republic of Ireland, Italy, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, UK, US.

		2008	2009	2010	2011
North America[117]		206,488	203,610	206,086	207,017
Latin America[118]		244,981	246,837	247,532	248,977
Europe[119]		14,308	14,000	12,771	12,516
Russia & Central Asia[120]		98,281	98,281	98,281	98,281
Middle East[121]		745,998	753,358	752,918	799,608
Africa[122]		117,064	119,114	123,609	124,209
Asia & Pacific[123]		36,621	40,779	40,616	44,281
World		**1,463,741**	**1,475,979**	**1,481,813**	**1,534,889**
of which:	**OPEC**	1,051,820	1,063,070	1,064,790	1,112,850
	non OPEC	411,921	412,909	417,023	422,039
	OECD	234,216	230,761	231,849	232,301
	non OECD	1,229,525	1,245,218	1,249,964	1,302,588

Table 1.3. Proven oil reserves by areas and aggregates 2006-2011, as reported by the ENI's World Oil and Gas Review 2012 (million barrels)
Source: ENI, *World Oil and Gas Review 2012*

117 Canada and the United States, including Puerto Rico.

118 Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

119 Albania, Austria, Belarus, Belgium, Bosnia Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and United Kingdom.

120 Russia, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

121 Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen.

122 Algeria, Angola, Benin, Cameroon, Chad, Congo, Côte d’Ivoire, Dem. Rep. Congo, Egypt, Equatorial Guinea, Ethiopia, Gabon, Ghana, Kenya, Libya, Madagascar, Mauritania, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Somalia, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia and Zimbabwe.

123 Afghanistan, Australia, Bangladesh, Brunei, China, East Timor, Hong Kong, India, Indonesia, Japan, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, North Korea, Pakistan, Papua New Guinea, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Vietnam.

		2008	2009	2010	2011
North America[124]		26,217	24,021	24,021	25,582
Latin America[125]		210,210	248,820	334,881	340,782
Western Europe[126]		14,318	13,282	12,940	12,648
Eastern Europe & Eurasia[127]		125,503	126,177	126,930	126,994
Middle East[128]		752,258	752,079	794,265	796,845
Africa[129]		122,207	124,171	130,139	128,578
Asia and Pacific[130]		41,568	44,226	44,187	50,097
World		**1,292,280**	**1,332,776**	**1,467,363**	**1,481,526**
of which:	**OPEC**	1,023,393	1,064,288	1,196,720	1,199,707
	non OPEC	268,887	268,488	270,643	281,819
	OECD	56,799	53,405	53,126	56,542
	non OECD	1,235,481	1,279,371	1,143,594	1,143,165

Table 1.4. Proven oil reserves by areas and aggregates 2006-2011, as reported by the OPEC's Annual Statistical Bulletin 2012 (million barrels)
Source: OPEC, *Annual Statistical Bulletin 2012*

[124] Canada, Greenland, St Pierre and Miquelon, United States (not including Puerto Rico).

[125] Antigua, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, (including Panama Canal Zone), Paraguay, Peru, Puerto Rico, St Kitts–Nevis–Anguilla, St Lucia, St Vincent, Suriname, Trinidad & Tobago, Turks and Caicos Islands, United States Virgin Islands, Uruguay and Venezuela**.**

[126] Austria, Belgium (including Luxembourg), Cyprus, Denmark (including Faroe Islands), Finland, France (including Andorra and Monaco), Germany, Gibraltar, Greece, Iceland, Ireland, Italy (including San Marino and the Holy See), Malta, Netherlands, Norway (including Svalbard and Jan Mayen Islands), Portugal, Spain (including Canary Islands), Sweden, Switzerland (including Liechtenstein), Turkey, United Kingdom, Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Montenegro and Slovenia.

[127] Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Poland, Romania, Russia, Slovakia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

[128] Bahrain, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates (Abu Dhabi, Ajman, Dubai, Fujairah, Ras al-Khaimah, Sharjah, Umm al-Qaiwain), Yemen and other Middle East.

[129] Algeria, Angola, Benin, Botswana, British Indian Ocean Territory, Burkina Faso, Burundi, Cameroon (United Republic of), Cape Verde, Central African Republic, Chad, Comoros, Congo (Republic of the), Congo (Democratic Republic of the), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia (The), Ghana, Guinea, Guinea–Bissau, Côte d'Ivoire, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, St Helena, São Tomé and Príncipe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudans (including South Sudan and Sudan), Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia and Zimbabwe.

[130] Afghanistan, American Samoa, Antarctica, Australia, Bangladesh, Bhutan, Brunei, Cambodia, Canton and Enderbury Islands, China and Hong Kong, Chinese Taipei, Christmas Island, Cocos (Keeling) Islands, Cook Islands, Fiji, French Polynesia, Guam, India, Indonesia, Japan, Johnston Island, Kiribati, Korea (Democratic People's Republic of), Korea (Republic of), Lao People's Democratic Republic, Macau, Malaysia, Maldives, Midway Islands, Mongolia, Myanmar, Nauru, Nepal, New Caledonia, New Zealand, Niue, Norfolk Island, Pacific Islands (Trust Territory), Pakistan, Papua New Guinea, Philippines, Pitcairn Island, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tokelau, Tonga, Tuvalu, Vanuatu, Vietnam, Wake Island, Wallis and Futuna Islands.

WOGR		ASB		Statistical Review	
Saudi Arabia	267,020	Venezuela	297,571	Venezuela	296,500
Venezuela	211,170	Saudi Arabia	265,405	Saudi Arabia	265,400
Canada	173,625	Iran	154,580	Canada	175,200
Iran	151,170	Iraq	141,350	Iran	151,200
Iraq	143,100	Kuwait	101,500	Iraq	143,100
Kuwait	104,000	UAE	97,800	Kuwait	101,500
UAE	97,800	Russia	77,403	UAE	97,800
Russia	60,000	Libya	48,014	Russia	88,200
Libya	47,100	Kazakhstan	39,800	Libya	47,100
Nigeria	37,200	Nigeria	37,200	Nigeria	37,200
The World top ten	**1,292,185**	**The World top ten**	**1,260,623**	**The World top ten**	**1,403,200**
Rest of the World	242,704	Rest of the World	220,903	Rest of the World	249,400
World	**1,534,889**	**World**	**1,481,526**	**World**	**1,652,600**

Table 1.5. World top ten reserves holders according to the ASB, the WOGR, and the Statistical Review, 2011 (million barrels)

Oil is clearly characterized by an uneven geographical distribution: the top ten holders alone are endowed with about 83% of total proven reserves (Table 1.5). The richest area is the Middle East, where in 1948 the giant Ghawar field was discovered, by far the most rich oil field in the world (Figure 1.4, 1.5, 1.6). With regards to institutional aggregates, the twelve members of the OPEC own more than 80% of world oil reserves.

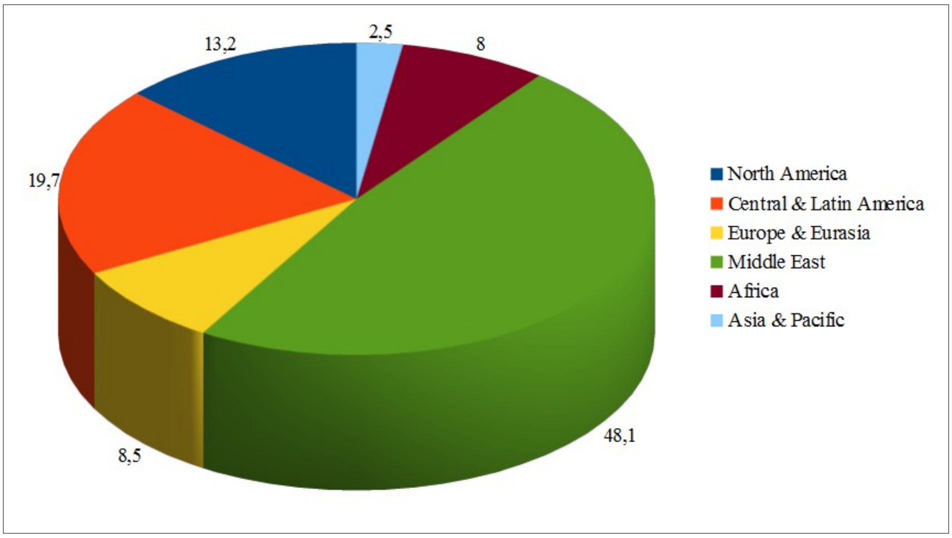

Figure 1.4. Proven oil reserves percentage by geographical area, according to the BP Statistical Review, data 2011

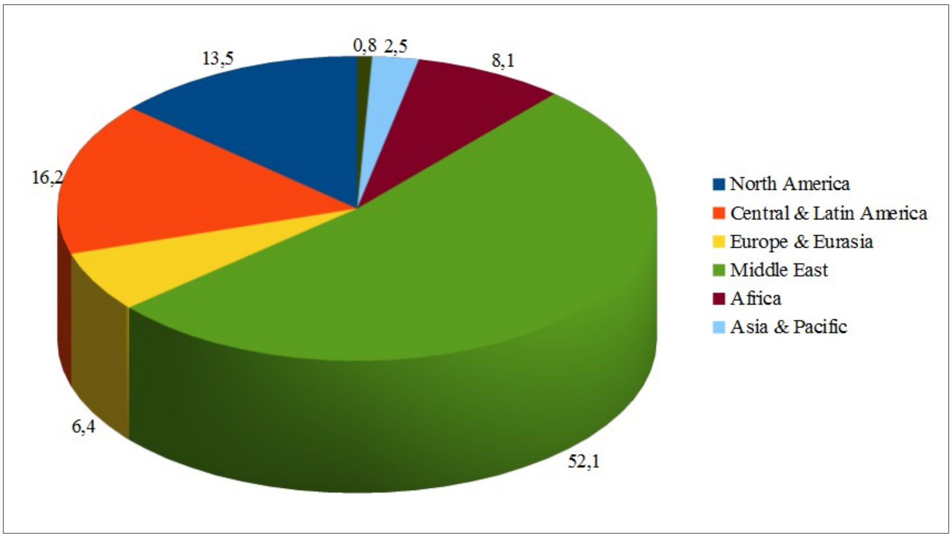

Figure 1.5. Proven oil reserves percentage by geographical area, according to the ENI WOGR, data 2011

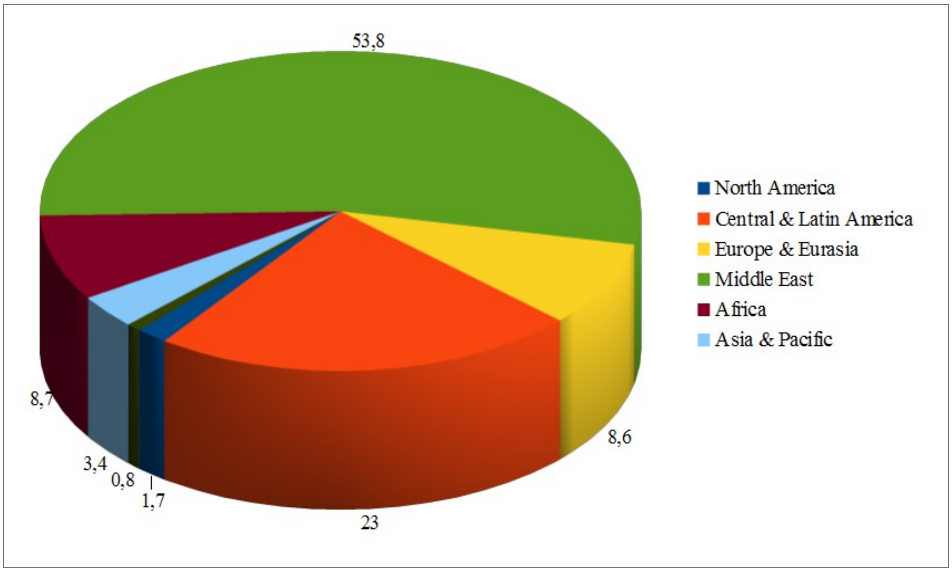

Figure 1.6. Proven oil reserves percentage by geographical area, according to the OPEC ASB, data 2011

1.6. Sources of ambiguity in proven reserves classification and reporting

The history of reserves is a history of long lasting misunderstandings[131]. Available public data is often characterized by many basic ambiguities, which not only arise from the existence of different standards for classification and reporting of figures, but are also embedded in the very concept of proven reserves and reserves estimation.

The lack of a shared and universally accepted framework of definitions can make comparison of reserve figures a challenging and tricky task. First of all, oil is often a poorly

[131] Madureira, *Estimating oil reserves*, cit., p. 162.

defined concept. Reserve estimates can include crude oil as well as condensate, natural gas liquids (NGL), refinery processing gains, or unconventional oils, such as tar sands; as a consequence, setting side by side figures from different sources requires extreme accuracy, in order to avoid the risk of comparing, so to speak, apples and oranges. For instance, as mentioned above, proven reserves figures published by the BP Statistical Review, the OPEC's ASB, and the ENI's WOGR, behave differently with respect to the inclusion or exclusion of NGLs and other components.

Secondly, despite of the possibility to assume that a general underlying framework for reserves classification exists, it is crucial to notice how existing frameworks can conceive reserves figures and estimation in very different ways. An outstanding example is represented by confronting the SEC and the SPE/WPC systems on the one hand, and the Russian classification of hydrocarbon reserves and resources on the other. The SPE/WPC classification, which reached an almost global diffusion over time, clearly reflects a business oriented view of oil reserves, grounded on technical and economic feasibility[132]. Similarly, the SEC only considers proven reserves, completely overlooking probable and possible resources; even volumes which can be produced by applying enhanced recovery techniques are included only when a pilot project supports their actual feasibility[133]. Conversely, the main factors taken into account by the Russian scheme to define resources and reserves categories are the degree of geological exploration and the methodology for the definition of calculation parameters. The classification does not consider commercial factors: such approach led in the past to a massive over-estimation and consequent downward revision of reserves figures. In 1997, Samotlar, the largest oilfield in the FSU, was conferred 27 billion barrels of URR, whereas in 1999 the estimate was attributed 24 billion barrels. As stated by Khalimov, “The resource base appeared to be strongly exaggerated due to inclusion of reserves and resources that are neither reliable nor technologically nor economically viable”[134].

In the third place, the principle of “commerciality”, which qualifies as proven reserves those volumes actually recoverable under existing economic conditions, can be rather misleading. In addition to the basic uncertainty provided by oil price volatility[135], commercially exploitable volumes of hydrocarbons are classified as reserves irrespectively of their grade: unconventional oils may become commercially exploitable over time, but there is

132 SPE, *Guidelines*, cit.

133 J.H. Laherrère, “Reserve Growth: Technological progress, or bad reporting and bad arithmetic?”, *Geopolitics of Energy*, 22(4), 1999, p. 1.

134 *Ivi*, p. 13: Khalimov, E.M., “Classification of oil reserves and resources in the Former Soviet Union”, AAPG 77(9), September 1993.

135 R. Mabro, The Peak Oil theory, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/01/Sept2006-PeakOilTheory-RobertMabro.pdf, accessed March 25, 2013.

no consistency about when such reclassification should occur. As an example, in 2010, estimates for economically exploitable Canadian tar sands ranged from 4.9 Gb, according to World Oil, to 172.7 Gb, according to the OGJ[136]. Also, since development projects which are economically viable to some companies may not be equally viable to others, oil reserves related to such projects may or may not be booked as proven reserves. Moreover, due to the volatility of oil price, production can be maintained from fields even when concerned projects are considered uneconomic; likewise, almost depleted fields can be exploited at sub-economic conditions to avoid abandonment costs. In both cases, an oil company is developing theoretically unproven reserves. Finally, as suggested by Haider, the development of a field can be driven by strategic purposes too, completely disregarding the economic aspect[137].

Poor practices in reporting proven reserves estimates and field data conjure with the lack of a standardized classification scheme in conveying potentially misleading information. As previously remarked, figures on proven reserves are usually very conservative: they tend to represent only the oil just about to enter the market, leading to substantial under-reporting if compared with actual discovered volumes that will be likely produced in the future, tallied with 2P data[138]. As a case in point, US proven reserves figures have hardly changed for decades: since the 1980s, they have stayed around 20-30 Gb. As a consequence, also the US Reserves/Production (R/P) ratio[139] has also remained virtually constant during this period, being around 10 years[140].

In addition to under-reporting, several authors warn against the opposite practice, which is over-reporting. The most quoted example[141] is the one of the OPEC countries that in the 1980s engaged in "quota wars" against each other, inflating their proven reserves figures in order to be allowed an higher production ceiling[142]. Bentley points out how 2P industry data[143] for the same countries are considerably smaller than publicly reported figures: in 2005, Iran's proven reserves accounted for 137.5 Gb, compared to 2P reserves only amounting to 71.3 Gb. In a similar fashion, Kuwait reported as proven 101.5 Gb of oil, whereas its 2P reserves only stood at 54.3 Gb[144].

136 Owen, *The status of conventional oil reserves*, cit., p. 4744.
137 Haider, *World oil reserves*, cit., p. 319.
138 Bentley, *Assessing the date of the global oil peak*, cit., p. 6372.
139 The R/P ratio is defined as reserves remaining at the end of any year divided by the production in that year: the result is the length of time that those remaining reserves would last if production were to continue at that rate.
140 *Ibidem.*
141 Campbell, Laherrère, *The end of cheap oil*, cit.; Bentley, *Assessing the date of the global oil peak*, cit., Laherrère, *Estimates of oil reserves*, cit.
142 Bentley*, Assessing the date of the global oil peak, cit.,* p. 6372. Production quotas were partly based on the size of proven reserves booked by a country.
143 *Ibidem.* Data considered are from IHS, PFC Energy, and Energyfiles.
144 *Ivi*, p. 6371.

The third issue concerning data in public domain is non-reporting. Browsing proven reserves figures published by the OGJ, BP, and the trade press in general, it is possible to notice how numbers for the majority of countries have remained unchanged for years. Sometimes, static data runs for a decade or more: from 1991 to 2002, proven reserves of Kuwait stood still at 96.5 Gb[145]. To give another example: the aforementioned figure for Canadian conventional oil reserves published by the ASB has remained unchanged since 2007[146]. It would be quite naive to assume that adjustments due to discovery and revisions simply matched production for ten years. Static figures probably are reported when a country either does not reply to survey inquiries, or returns data which are identical to the previous year[147].

Reporting practices concerning discoveries are called into question too: Adelman and Lynch[148] underline that no one knows for a long time what was exactly found in a certain field in a given year. According to Campbell and Laherrère[149], it is however necessary to constantly backdate every revision to the year in which the field was first discovered, in order to have an accurate discovery trend. Moreover, if a field extends into another country, or in the territory of another concession, it is common to rename it, and the two part of the field are given a different discovery date. As an example, the largest field in the world, the North Field in Qatar, was discovered in 1971: its extension into the Iranian territory was then drilled in 1991, and renamed as the South Pars field. Consequently, public data reports a significant increase in discoveries in 1991, even though newly added volumes actually pertained to the same field which was discovered twenty years earlier[150].

Finally, the very concept of proven reserves is often nebulous. In the public domain, proven reserves are usually conceived as a working inventory: they are the end-product of a development investment which was paid up-front, and an estimate of the amount of oil that is likely to be produced and brought to the market in the near future. Nonetheless, the term "inventory" can be misleading: the amount of reserves that a company is able to book and report is not a stock, it is instead a function of assumed costs of production, of current and future prices, and of the geological reality of the reservoir. Proven reserves are something dynamic, and their estimation is "a far cry from counting cars in a parking lot, where all the

145 BP, *Statistical Review of World Energy*, 2012.
146 OPEC, *Annual Statistical Bulletin 2010-2011*, Wien, 2011.
147 Bentley, *Assessing the date of the global oil peak*, cit., p. 6373.
148 M.A. Adelman, M.C. Lynch, “Fixed view of resource limits creates undue pessimism”, *Oil and gas journal*, 95(14), 1997, p. 59.
149 Campbell, Laherrère, *The end of cheap oil*, cit, p. 80.
150 Laherrère, *Reserve growth*, cit., p. 13.

cars are in full view"[151]. In addition, it is mandatory to remember that proven reserves are by no means a reasonable measure of remaining oil at a given date: for what concerns the actual oil endowment of our planet, they "say nothing about the true volumes discovered and no useful conclusions can be drawn by looking at their evolution"[152].

1.7. Estimation and reporting of reserves: institutional interferences

Downey quotes an old, but quite illustrative, oil industry story: "an oil company executive was interviewing as potential employees a geologist, a geophysicist, and a petroleum engineer (the kind that estimates reserves). One question asked was, "What is two times two?". The geologist answered that it was probably more than three and less than five, but the issue could use some more research. The geophysicist punched it into his palmtop computer and announced that it was 3.999999. The petroleum engineer jumped up and locked the door, closed the window blinds, unplugged the phone, and asked quietly, "What do you want it to be?""[153].

Numbers have the peculiar characteristics of being perceived by the public as objective. Nevertheless, due to their intrinsic uncertainty and ambiguity, figures of oil reserves easily lend themselves to political and institutional interferences, which are propelled by the strategic and economic relevance of oil and by its uneven geographical distribution. Vested interests can influence not only the results of the estimation process, by favoring one outcome instead of another, but also the attribution of validity to the figures which have been produced: often, consensus arises according to the existing political reality, and to the predominant organizational interests, which in turn are influenced also by external events. In addition, the reporting of reserves figures is a political act, which can be exploited by actors in order to consolidate their status, to implement their agenda, or to send a message to the market. Therefore, data always need to be critically assessed, since numbers can be more or less craftily forged by the goals of the actor or of the organization which assembles them.

First of all, some considerations are required with reference to the social perception and acceptance of quantitative data in general: on this matter, Porter[154] provides quite useful insights. Due to their quantitative nature, reserve estimates are usually perceived as objective: indeed, "objectivity arouses the passions as few other words can. Its presence is evidently

151 Hirsch, *The inevitable peaking of world oil production*, cit., p. 2.
152 Bentley, *Assessing the date of the global oil peak*, cit., p. 6374.
153 Downey, *Oil 101*, cit., p. 292.
154 T. M. Porter, *Trust in numbers: The pursuit of objectivity in science and public life*, Princeton, Princeton University Press, 1996, pp. 3-48.

required for basic justice, honest government and true knowledge"[155]. Objectivity can be identified with realism, but also with the ability to reach consensus, usually within a specialist disciplinary community; numbers in particular appear to convey fairness and impartiality, and upon these characteristics rests credibility. In the industrial world, quantitative expertise has increasingly gained space over qualitative analysis: nowadays, virtually any issue can be quantified, and this process permits reasoning to become uniform and consequently rigorous.

Resulting figures have the peculiarity to be given considerable weight and value even when nobody defends their validity with conviction: when they reach a larger audience, for example by means of publication, they are usually taken at face value, since the public lacks the proper expertise to deconstruct them. As highlighted by Porter, "newspapers and public officials wanting to discuss the numerical characteristics of a population have very limited ability to rework the numbers into different ones. They thus become black boxes, scarcely vulnerable to challenge excepts in a limited way by insiders. Having become official, then, they become increasingly real"[156]. A plausible figure backed by sufficient institutional support can become real, and thus act as a basis for policy decisions.

In order to convince an audience, it is not surprising that facts and figures are needed: due to the intrinsic power of numbers and estimates, quantification can become a way of making decisions without seeming to decide, and objectivity can lend authority to actors who have very little of their own. Of course, data should be consensually accepted as valid: the word "validity" shares its Latin root with the verb *valeo*, which means "to be powerful" or "to have influence". In our society, which can be defined an "information society", validity requires good public relations: communication of data takes usually place between people who don't know each other, and thus have no personal basis for shared understanding. Indeed, the consensus over scientific reports depend on the credibility and social standing of the author. However, the knowledge which is transmitted in quantitative terms is hardly challenged by the public: on the contrary, it often come to be accepted as truthful by nearly everyone. Porter calls this routine reliance on institutional backed figures the "technology of trust"[157].

Published figures of reserves estimates make no exception: challenged only by "insiders", they are generally accepted by everybody else, including policy makers. Anyway, given current geological knowledge and available computing technologies, there should be no room for the biases of the researcher to corrupt the results, at least in theory. However, as

155 *Ivi*, p. 3.
156 *Ivi*, p. 42.
157 *Ivi*, p. 15.

aforementioned, there is always a range of potentially valid measures when oil reserves are taken into consideration: forms of expertise and power relations within an organization can be crucial in determining the techniques of estimation or the figures selected within a range of possible outcomes, depending on the prevailing interests and goals of the institution. Therefore, the creation of information becomes a social process, determined by the relationships existing within the institution, which at the same time is embedded in a specific historical context. Generally speaking, a political influence is cast upon reported data, which can become additional means in the hands of actors pursuing specific objectives.

Two different approaches can be helpful in considering the particular case of oil reserves estimates. Dennis[158] argues that reserves estimates are the product not only of scientific knowledge, but also of complex social processes within an institution. The final values are shaped by both the economic and the institutional context, and are characterized by the specific goals and interests of the group making the estimates. On the other hand, Bowden[159] claims that also the consensus about an estimate is the result of a social process through which validity is attributed: such process is tied to the political economy of the oil industry, whose objectives can change over time depending on the historical and economic context, or on the prevailing frame within the industry itself.

When estimates are concerned, it is of paramount importance to understand why a person or a group make a specific estimate: of course, the estimation of reserves is made for general purposes[160], but it is also true that each figure takes origin in a specific historic context and relates its makers to their social environment, reflecting different institutional goals which evolve through time as circumstances change[161]. Dennis analyses the case of two divergent estimates of U.S. conventional oil reserves published in the 1920s: the first and lower estimate was produced in 1921 by a Joint Committee bringing together members of the USGS and of the Association of American Petroleum Geologists (AAPG). While the USGS wanted to demonstrate the usefulness of its expertise and ensure its institutional reliability, the geologists of the AAPG were carrying on their quest for scientific legitimacy and for maintaining their appointment as experts. Conversely, the higher estimate reported by the API in 1925 could prove useful to forestall the direct government regulation of the industry that was under discussion.[162]

The USGS was created in 1879 to "study the geological structure and economic

[158] Dennis, *Drilling for dollars*, cit.
[159] Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit.
[160] See paragraph 1.2.
[161] Dennis, *Drilling for dollars*, cit., p. 241.
[162] *Ivi*, p. 242.

resources of the public domain": its utilitarian orientation shaped its evolution. Due the massive use of oil during the First World War, the Oil and Gas Section was created in 1916. Estimates of oil resources were needed not only as to assure fuel availability for the war effort, but also for determining taxes on productive lands for the oil companies. In 1919, an USGS report under the supervision of David White estimated U.S. oil resources at 6.74 bbls, sufficient for 17 to 18.5 years if consumption remained constant, implying that production would peak within 3 to 5 years[163]. Following the publication of these figures, White advocated greater cooperation between the government and the industry, both in the exploration and research of foreign oil reserves, and in the preservation of domestic ones. Government investment in the industry would mean greater responsibilities for the USGS, who could take the lead in the conservation of resources and the prevention of waste, which then was plaguing the industry. The Survey had the opportunity to secure its status as a necessary institution, able to warn the country against imminent depletion; it could broaden its jurisdiction, or act as geological consultant to the industry, in this way fulfilling its utilitarian mission[164].

Members of the AAPG had a different goal: they all were geologists with an occupation in the oil industry, and despite the prominent importance of practical expertise at the time, many of them desired to gain scientific legitimacy[165]. They actively tried to pursue their objective by publishing articles and reports, by opening the Association only to college graduates, or by collaborating with other scientific institutions such as the USGS. As mentioned above, the U.S. oil industry was in economic collapse in the 1920s, mainly due to overproduction. In 1921, the USGS called the AAPG for a joint report, after claiming that the peak of production was near and that an earnest estimation of the country oil reserves was needed: "American oil geologists had an obligation to drive home the knowledge that our oil supply was rapidly vanishing; to render impossible any ignorance of the perilous problem confronting the American economy"[166]. The participation of AAPG would allow to justify a new estimate and to share responsibilities: the figure reported amounted to 9.15 bbls, which represented all the oil extractable with current drilling techniques. It meant a lifetime of about 20 years for U.S. reserves (if consumption remained constant), therefore implying an

[163] *Ivi*, p. 244.
[164] *Ivi*, p. 245.
[165] As mentioned in paragraph 1.3., during the 1920s the greatest value was placed upon practical geological expertise, and commercial standards were the only parameters in judging petroleum geology. Therefore, all members of the AAPG had a pragmatic occupational style, but at the same time they required recognition as a scientific group.
[166] *Ivi*, p. 250.

increasing dependence of the country on foreign oil[167]. The estimates were the result of a group process: each member of the committee polled geologists who were familiar with a specific geographical region in order to ascertain how much oil remained in producing, potentially-producing and unexplored fields; at a later stage, the committee reviewed and revised the findings, aggregating the data by State[168].

According to Dennis, the published figure embodied a conjunction of interests. On the one hand, it allowed the USGS to support its claim of exhaustion and thus the need to promote conservation and secure foreign sources of oil for the future. The Survey believed the industry needed government assistance in order to gain access to foreign reserves: this kind of support could be diplomatic or economic, perhaps performed by the USGS itself through a partnership that would expand its role and guard its institutional status. On the other hand, the AAPG saw the cooperation with the Survey as a means to obtain scientific legitimation; in addition, the impending shortage of oil depicted by the report could increase the industry demand for petroleum geologists, since "the low estimate would force the oil companies to realize that they needed geologists to find the increasingly scarce resource in the U.S., as well as in the unexplored overseas territory"[169]. Corporate employment would then provide the necessary institutional basis in their quest for scientific legitimacy.

The report published by the Joint Committee was attacked by the industry press, which pointed out "how incongruous the figure was with the current oversupply"[170]. Indeed, in the following years production continued to exceed demand, reaching in 1923 the record output of 732.5 million barrels, about 72% of world total[171].

In 1925, the API, prepared an industry-wide report, which included an oil reserves estimate, in response to a survey conducted by the Federal Oil Conservation Board (FOCB)[172]. Questionnaires sent by the FOCB to the industry contained, among the others, the following question: "How imminent do you regard any serious difficulty in meeting the country's oil requirements?"[173]. The API claimed that "no imminent danger of exhaustion of the petroleum reserves of the United States" was foreseeable in the near future, and that waste was negligible. The USGS-AAPG figure had proved to be a gross underestimate: 5.3 bbls

[167] *Ivi*, pp. 250-252. Actually, the new estimate did not differ greatly from the 1919 one: the difference, less than 3 million barrels, accounted for the unexpectedly large production of California.
[168] *Ibidem.*
[169] *Ivi*, p. 254. At that time, geologists were usually the first cut from the industry payrolls during the collapse of the 1920s: why hire more men to find more resources in a market plagued by overproduction?
[170] *Ivi*, p. 255.
[171] *Ibidem*.
[172] *Ibidem*. The FOCB, created by President Coolidge in 1923, was entrusted with the mission of gathering information for the potential regulation of the oil industry, and for the elimination of waste.
[173] *Ivi*, p. 256.

were estimated by the API as recoverable by applying current drilling techniques, whereas 26 bbls would be recoverable with only slight technological improvements. Notably, the report did not provide any estimate for resources in untested territories, since such attempt would involve "so many uncertainties that it would be grossly inadequate and misleading"[174]. Actually, the methodology applied was nearly identical to the one used for the 1921 report. The new estimate was extensively publicized by the press, but there were no direct criticisms[175].

The API, as the trade association representing the interests of the American oil industry, was claiming that oil reserves were nearly inexhaustible, and that there was no waste. The report proved that the industry was not mismanaging the country's resources, keeping prices and profits depressed: on the contrary, it was efficient, and therefore it did not need governmental interference. The Association was promoting self regulation of the industry, by minimizing its current problems.

Following this example, we can draw a first conclusion: the making of reserves estimates is a complex social process, in which institutional interests play an important role. As a consequence, even similar methods of estimation can lead to different results, depending on the specific goals of the institution concerned.

The work by Bowden allows a deeper understanding of how different organizational interests can further inform the production and reception of estimates. By examining the evolution through time of scientific controversies related to the Peak Oil theory, which Marion King Hubbert presented for the first time in 1956, Bowden argues that the validity[176] of reserves estimates is socially constructed through a process of attribution tied to the political economy of the industry, and to the surrounding historical context. Additionally, he applies the "interests model" in order to explain why communities share a belief in a particular piece of knowledge, since "interests inspire the construction of knowledge out of available cultural resources in ways which are specific to particular times and situations and their overall social and cultural contexts"[177]. Interests structure the behaviour of an organization; at the same time, changing relationships within an institution can justify different means of achieving specific goals[178].

By observing the pattern through time of different estimates for the URR of U.S. crude oil it is possible to recognize three historical clusters of estimates, defined by magnitude,

174 *Ivi*, p. 257.
175 *Ibidem*.
176 Validity can be operationally defined by the presence or absence of widespread disputes.
177 Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit., pp. 207-208
178 *Ivi*, p. 209.

variation among the estimates within a period, and the timing of the transition between one group and another. Generally speaking, estimates are higher after 1956, while they fall after 1973, following the oil market shock caused by the embargo of October 1973 (Fig. 1.7).

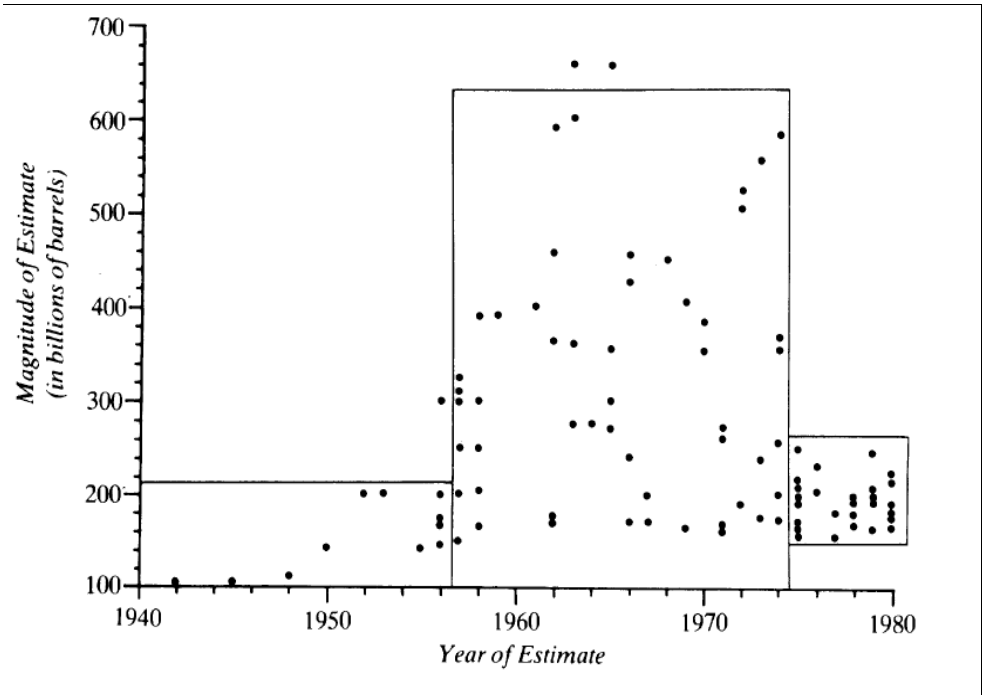

Figure 1.7. Historical pattern of estimates of URR for U.S. Conventional crude oil.
Source: Bowden, 1985

Using previously published estimates and inquiries among respected geologists, he had constructed a bell-shaped curve for the oil industry life cycle in the lower 48 states, predicting that U.S. crude oil production would peak sometime between 1966 and 1971, depending on an URR for crude between 150 and 200 bbls[179]. (Fig. 1.9) The theory was later labeled "the Hubbert Peak", and nowadays it is still object of a widespread debate.

In the following years, and until his death in 1989, Hubbert held substantially the same view: in his 1962 report to the National Academy of Sciences, he simply fitted new empirical data to the curve he described in 1956, restating that the production peak for U.S. conventional crude oil would occur in the late 1960s, and that the ultimate production would be of about 175 bbls[180]. Even his latest publications in the 1970s reported estimates ranging between 165 and 175 bbls[181].

Hubbert's estimates remained constant during the period from 1956 to 1974; conversely, consensus within the industry about their actual validity, and about their

[179] *Ivi*, pp. 22-24.
[180] M.K. Hubbert, *Energy sources: A report to the Committee on Natural Resources*, Washington, National Academy of Sciences-National Research Council, 1962, p. 73.
[181] Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit., p. 215.

implications, shifted through time. As suggested by Bowden, if we assume that the magnitude of an estimate is someway determined by institutional interests, “then Hubbert's estimates are the product of interests which differ from those that account for the estimates of others”[182].

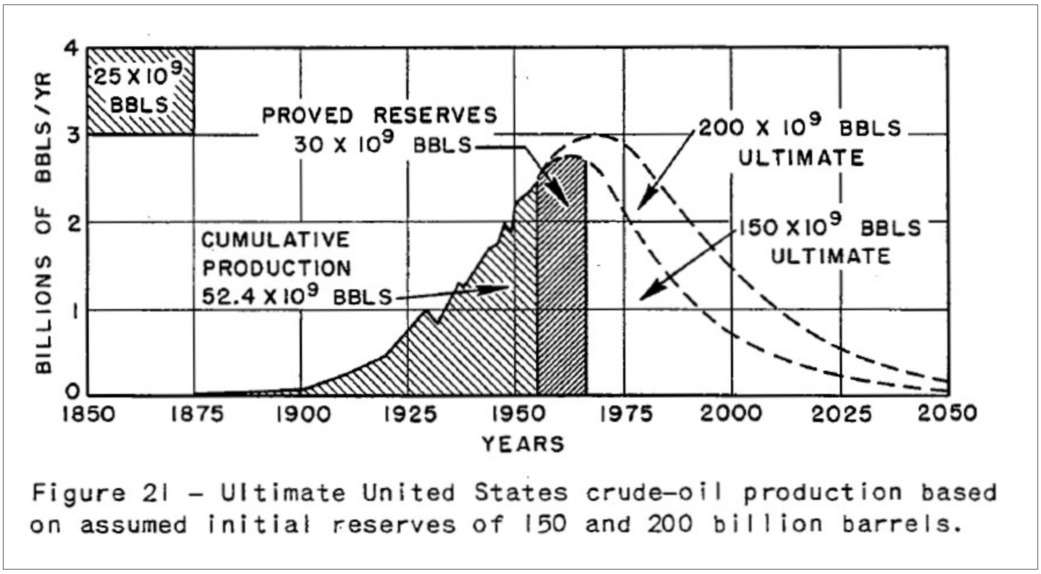

Figure 1.8. The Hubbert Peak
Source: Hubbert, 1956

Remarkably, predictions of an impending peak of U.S. crude oil production were considered invalid when they were in contrast with the general opinion within the industry; conversely, they were later considered valid when they could support the existing organizational interests[183]. The estimate by Hubbert was completely accepted as valid only in the 1970s, even if it did not differ significantly from the one he made twenty years earlier: a new element of the historical and economic context, namely the oil embargo and the following price increase, influenced the new criteria applied by the industry for the attribution of validity to Hubbert's predictions.

In 1956, the first estimate of ultimately recoverable resources produced by Hubbert was based on available data already held as valid by the informed public of the time: therefore, it was not contested. However, the prediction of an impending peak of production cast a shadow on the future of both the U.S. oil industry and the U.S. oil-based society. Despite innumerable attempts by institutions such as the API to foster the belief in an almost never-ending expansion of oil production, the peak oil theory was suggesting that, sooner than later, fossil fuels would have to be substituted with alternative sources of energy, and, in addition, a reorganization of policy priorities would prove necessary. Hubbert was drawing

[182] Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit., p. 211.
[183] *Ibidem.*

"social implications that contradicted the conventional wisdom of the entire industry", which in the 1950s was experiencing a stunning growth. Shell, at the time Hubbert's employer, called the geologist on the phone just after the paper was presented in San Antonio, telling him to "please, tone it down some"[184]. The company even censored the report before its publication[185].

From 1957 to 1974, critics surrounding Hubbert's theories came from both industry personnel and governmental agencies: they discredited not only his life cycle interpretation of the oil industry, but also the magnitude of his estimates. Following Hubbert's presentation, Morgan Davis and Richard Gomez, both working for the Humble Oil, repeatedly claimed that the magnitude of U.S. oil discoveries suggested that "the estimates of ultimate production in the U.S. will continue to be pushed upward and the predicted date of running out of oil will be forced further into the future"[186]. They had a price-oriented perspective of oil estimates and production, which was shared by John Ryan, an economist working for the Standard Oil: Ryan argued that Hubbert's curve was a mere statistical exercise, and it completely ignored the role of economics[187]. Notably, in 1962 an alternative estimation technique was developed by Zapp, directly questioning the magnitude of Hubbert's estimates. By assuming a constant rate of return per foot of exploratory drilling[188], Zapp predicted that about 590 bbls of crude oil would be discovered in the 48 continental states by the time exploration was completed[189]. The method, the validity of which was repeatedly questioned by Hubbert in the following years, was used by the USGS until 1974. It makes no wonder that Vincent McKelvey, Director of the USGS, proved to be one of Hubbert's harshest critics: not only he supported Zapp's findings and other people's criticisms of Hubbert, but he also produced his own alternative estimates. In addition, even if starting from 1963 Hubbert worked as Research Geophysicist for the USGS for 15 years, during this period nothing he published received formal approval by the Survey[190].

By questioning the consistency of the method applied by Hubbert, such critics dismissed as incorrect also its policy implications, and its prediction about the bleak future of the oil industry. Yet, in 1973 everything changed: the Arab oil embargo disrupted U.S imports of Middle East oil, jointly provoking a sharp increase in oil and gas prices. The industry was

184 E. Hemmingsen, "At the base of Hubbert's Peak: Grounding the debate on petroleum scarcity", *Geoforum*, 41, 2010, p. 534.

185 Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit., pp. 219-220.

186 *Ivi*, p. 221.

187 *Ibidem*.

188 On average, in 1961, 118 barrels of crude oil per foot of exploratory drilling were found.

189 *Ivi*, pp. 217-218. Hubbert's criticisms were directed mainly to the assumption of a constant rate of return per foot of exploratory drilling.

190 *Ivi*, p. 222.

living a crisis, unable of fulfilling its short term requirements of supply. Suddenly, there was no longer space for optimistic resource estimates, and Hubbert's theories appeared as prophetic, since they were now conveying results that corresponded to the observable world, where it was acknowledged that the peak had indeed occurred: according to EIA data, the U.S. crude oil production peaked in October 1970, at the level of 310.403 thousand b/d[191]. In September 1974, the USGS published a new appraisal of U.S oil resources, featuring a significantly lower estimate; a few months before, John Moody, president of the Mobil Oil, had publicly attacked the Survey's estimates, which according to him were tenfold higher than he could ever justify[192]. In 1977, McKelvey was forced to resign, whereas Hubbert received a major public award, for his "early and persistent attempts to bring the energy crisis to public attention"[193].

If before 1974 the criteria used by Hubbert were perceived by the industrial community as geologically and economically irrelevant, now the emphasis was no longer on the methodology of estimation applied but on the results that were delivered. The oil industry played the key role in this transition: it abandoned the price-cost framework, based on the belief that growing prices and investments would neutralize all geological constraints, and adopted a storehouse interpretation of estimates, with the declared strategic goal of securing the domestic supply of oil. The shift was triggered by the disruption following the oil embargo, and implied a change in the means used by the industry to pursue profit, no longer based on volumes but on high prices. Soon, Hubbert's technique became just one more method that justified an estimate of URR around 190 bbls[194]: in addition to support the retaining of profits by the companies and the impossibility of raising production, the relentless depletion of U.S oil reserves would also stimulate government concessions for new investments in technology and exploration, enabling the industry to "capitalize on the generous fossil resources with which North America was endowed"[195].

In conclusion, an organization shapes its localized culture, which in turn changes through time according to the surrounding context, influencing "the production of scientific knowledge by leading to selective perception and differential interpretation of particular pieces of evidence"[196]. In the case of oil reserves estimates, the embargo acted as a watershed,

191 Energy Information Administration, U.S. field production of crude oil, http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS1&f=M, accessed March 28, 2013
192 *Ivi,* p. 225.
193 *Ivi*, p. 211.
194 In 1974, to support this view Moody reported several estimates obtained with different techniques, all asserting that U.S ultimately recoverable oil resources amounted to about 190 bbls.
195 *Ivi*, p. 231.
196 *Ivi*, p. 231.

bringing to a realignment of institutional interests and, as a consequence, to the reevaluation of Hubbert's estimates, in a way that supported the new goals of the oil industry.

Practical reasoning is always a synthesis between the knowledge of facts and the application of values to those facts; when oil reserves are concerned, uncertainty is so high that values and vested interests quite inevitably play a significant role in shaping the final estimates, which then are made available in the public domain[197]. However, as repeatedly argued by Laherrère[198], it is the very act of reporting such estimates which has to be considered as political: it is by delivering the desired information to specific addressees (the government, other institutions or organizations, the industry, the consumers, the public opinion, the market) that an actor tries to reach its objectives, since the data he shares depend considerably upon the image he wants to give. Notably, it was the perceived politicization of the estimates reported by the USGS in the 1910s and 1920s, which were deemed to support a call for government intervention in the oil industry[199], that paved the way for the institutionalization of innumerable competing reports on the extent of oil reserves. In the U.S., since 1922, each major institution, from the government to specialized trade journals and business associations, started publishing its own forecasts: everybody was trying to promote its own interests[200].

Therefore, the reporting of reserves estimates becomes one of the many means an institutional actor can unsheathe to reach a particular purpose, whether it be consolidating its status, or influencing the future behavior of the market. Such exploitation is allowed by the inborn uncertainties of oil reserves estimates, and by their quantitative nature, which makes them resemble cryptic black boxes for oil outsiders. As previously observed, reported estimates can be flawed by conservative biases, by over-reporting or, on the contrary, by non-reporting[201]: within a range of possible values, an institutional actor will likely choose to report the one which best fits its goals, “high if he wants to look big, low if he wants to look small”[202].

Under-reporting, or the backing of conservative estimates, by conveying an idea of future scarcity, will likely support the interests of those actors who advocate government

197 O. Balaban, A. Tsatskin, "The paradox of oil reserve forecasts: The political implications of predicting oil reserves and oil consumption", *Energy Policy*, 38, 2010, p. 1340.

198 Laherrère, *Forecasting future production from past discovery*, cit., p. 1; Laherrère, *Reserve growth*, cit., p. 5; Laherrère, *Estimates of oil reserves*, cit., p. 9.

199 The surveys, which omitted enhanced oil recovery and prospective or untapped reserves, were criticized by the industry for their conservative nature, which could be used to justify government interference through regulation, pro-rationing, production controls, or even partial nationalization.

200 Madureira, *Estimating oil reserves*, cit., p. 151.

201 See paragraph 1.6.

202 Laherrère, *Estimates of oil reserves*, cit., p. 9 and p. 90.

intervention, perhaps in the form of conservation measures, or of subsidies allowing the exploration and development of new oil resources or of alternative fuels. In the meantime, the belief that we are running out of oil can be of service also to companies willing to make more profits from escalating prices[203]. A plain example is the previously analysed attitude of the oil industry towards Hubbert's predictions of impending scarcity after the 1973 Arab embargo. To quote another case in point, in 1977 the Carter Administration raised awareness about the energy crises that was afflicting not only the U.S., but also the entire world: supplies of oil and gas were decreasing, and without a timely adjustment, the nation's economic security and its way of life would be severely endangered. Indeed, the government could remedy what was perceived as a market failure: adopted measures included price controls for domestic oil and gas, standards for fuels used for transportation, and subsidies to alternative sources of energy[204].

Conversely, other organizations or institutions may have an interest in reporting higher, or even exaggerated, estimates for oil reserves: in addition to consolidating an actor's status and providing him considerable leverage, over-reporting allows to maximize production, at the same time propelling consumption, due to decreasing prices. The most widely quoted example refers to the conspicuous increases experienced by the proven oil reserves of six OPEC countries in the late 1980s: overnight, figures were literally inflated, even doubling or trebling. The staggering total addition amounted to 300 bbls of oil[205]. OPEC countries had inherited previous estimates of their reserves from private companies: probably, such figures were conservative, therefore requiring an upward revision. However, in the absence of major discoveries or technological breakthroughs, nothing justified an increase ranging from 42 to 197 per cent of existing estimates[206]. Most likely, such additions were part of an internal struggle between members of the organization, seeking to boost their production quota: according to the allocation system introduced by OPEC in 1982, the amount of oil which a member could produce was determined in part by the size of a country's reported proven reserves[207]. Moreover, according to Campbell, OPEC countries did “everything possible to foster the notion that they could flood the world with cheap oil at the flick of a switch. It was a strategy aimed to inhibit investment in gas, non conventional oil, renewable

203 Balaban, *The paradox of oil reserves forecasts*, cit., p. 1341.

204 Porter, *Are we running out of oil?*, cit., p. 39.

205 Campbell, Laherrère, *The end of cheap oil*, cit., pp. 79-80.

206 *Ibidem*. Other authors hold the view that an effort of exploration and development carried out by the governments of OPEC countries actually took place in the years following the nationalizations of the oil sector, therefore justifying the wholesale appreciation. See: M. Radetzki, "Peak oil and other threatening peaks – Chimeras without substance", *Energy Policy*, 38, 2010, p. 6569.

207 Bentley, *Assessing the date of the global oil peak*, cit., pp. 6372-6373.

energy or energy saving, that they feared might undermine the market for their oil, on which they utterly depend"[208].

Understandably, an institutional actor may have an interest in not reporting a decline in the size of its proven reserves: it is possible to notice how figures of a country's proven reserves reported by statistical bulletins and surveys, maybe based on direct communications with governments and companies, sometimes run unchanged for a decade or more[209]. As noted above, it would be quite unrealistic for adjustments due to discovery and revisions to simply match production every year: a possible reason for static figures can be an attempt to conceal a decline in reserves, which would weaken a country's political and economic position, lessening its ability to obtain loans and subsidies[210]. Why to invest if oil is not there to be found?

According to Laherrère, also the growth of reserves in time is nothing else than an artifact of reporting, which can become also a political device[211]. About 80 per cent of the oil produced today flows form field that were discovered before the 1970s, and the majority of them are now declining[212]. Since no major discovery has taken place in the last decades, the main cause of the growth lies in revisions of early estimates, usually justified by improved recovery, technological development, and more favorable economic conditions. As a consequence, historical evidence shows that more oil is produced and consumed, the more is discovered: Balaban calls this amazing coincidence of the consumption and the discovery of oil growing proportionately "the paradox of oil reserves predictions"[213]. Laherrère claims that such growth is mainly political, a reporting expedient used by institutional actors to promote a reassuring image of everlasting expansion, which perfectly suits our culture of growth[214]. Such appealing prospect is used to explain why conservative estimates for crude oil reserves are so popular within the oil industry: they allow a smooth and orderly increase, proving the good management of resources, at the same time providing a positive stimulus to new investments. For instance, in the 1980s BP, the operator lifting gas from the Forties Field in the North Sea, used to report very conservative figures for reserves, well below the URR derived from the decline curve analysis, which amounted to about 420 million cubic meters (M.m3). Therefore, despite a constantly declining trend for production, reserves were

208 C.J. Campbell, Peak oil: A turning for mankind, http://hubbert.mines.edu/news/Campbell_01-2.pdf, accessed March 28, 2013.
209 See paragraph 1.6.
210 Campbell, Laherrère, *The end of cheap oil*, cit., p. 80.
211 Laherrère, *Estimates of oil reserves*, cit., p. 47.
212 Campbell, Laherrère, *The end of cheap oil*, cit., p. 80.
213 Balaban, Tsatskin, *The paradox of oil reserves forecasts*, cit., pp. 1341-1342.
214 Laherrère, *Reserve growth*, cit., p. 12.

periodically revised in order to provide the image of a slow growth. In 1986, BP was reporting only 330 M.m3 against an URR estimate of more than 400 M.m3: only in 2002, before selling the field to Apache, the real figure was reported[215].

Everything considered, a critical analysis of the estimates of oil reserves, of their evolution over time, and of the organizations or institutions that produce and report them, provides two sets of information, the first one concerning existing interests and power relations within the institutional framework creating the estimates, and the second one reflecting a specific planning for the future. Estimates of oil reserves can disclose the predictor's way of intervening on the present: they serve an operative purpose, and are also an expression of the predictor's political ends, the proof of his actual values and circumstances, of the status he wants to consolidate, of the message he wants to convey. The very focus of reporting becomes the desired behavior of those to whom the information is directed: political estimates are always present in every consciously planned action intended to influence the minds of others, or their decision making processes. In this way, "predictors constitute the very future that was the content of their prediction"[216]. Therefore, rather than focusing on the content of the reported data, the real question is: how this information will be received by its audience? Will it be able to change or maintain the mental state of market players, in accordance with the needs of the estimator? In this perspective, reported estimates of oil reserves must be evaluated as political statements: once they are supported by the institutional status of their creator and consensually accepted as valid, they gain practical force, and what is real becomes irrelevant[217].

[215] J.H. Laherrère, Comments by Jean Laherrère on the OAPEC – IFP seminar on 28-30 June 2005, http://www.hubbertpeak.com/laherrere/comm-oapec-ifp2005.pdf, accessed March 28, 2013.

[216] Balaban, Tsatskin, *The paradox of oil reserves forecasts*, cit., p. 1343.

[217] *Ibidem*. Nonetheless, it is necessary to bear in mind two further things: first, the concreteness of oil reserves place an ultimate limit on their overstatement and, eventually, such limit will be reached; second, other actors can be ready at any time to bet against the validity of a specific estimate.

2
OIL PRODUCTION

2.1. A brief history of oil production

Oil was the fundamental driver of 20st Century economic growth. At first, it was largely produced in the United States, which opened up its territories to capitalist exploitation; however, discoveries in the U.S. peaked in the 1930s, after the finding of the East Texas oil field. The bulk of oil production then shifted to the Middle East, where the majors controlled upstream operations thanks to widespread concession agreements: such control was lost in the 1970s, when a series of nationalizations returned to the producing countries the full sovereignty on their hydrocarbon resources. After the oil shocks of 1973 and 1979, international companies started to diversify their sources of oil, as a cushion against further supply disruptions: oil started to flow from new productive provinces in Alaska, the North Sea, and Africa, thanks to the high oil prices which allowed the exploitation of the large deposits that had been discovered in the 1950s and 1960s. Technological progress, above all in the realm of oilfields development, greatly increased the average recovery factor, opening new frontiers in offshore exploration and in the exploitation of unconventional oils.

Since at least 4000 B.C., crude oil seeping to the surface served many different purposes: in the Middle East, it was used to waterproof boats and to make roads and buildings; around 1000 BC, it was refined in minor quantities to obtain lamp and heating oil in China; the Byzantines used it to produce a weapon known as Greek fire in 600 AD[218]. However, it was not until the 19th Century that oil started to be lifted from the ground in considerable quantities for commercial purposes. The modern oil industry was born in the United States, apparently as a result of a scarcity of whales: due to overfishing, whale oil, which at that time shed the purest light of all available lamp fuels, was becoming increasingly expensive[219]. Hoping to profit from the market situation, a businessman named George Bissel and his partner set up the Pennsylvania Rock Oil Company in 1855: the needed capital was raised thanks to the results of an analysis of a sample of crude oil, which the two had skimmed from a surface pool in the northwestern part of the State. Indeed, the substance could be distilled to produce kerosene, the perfect low cost substitute for whale oil: obviously, they now needed large quantities of rock oil. Colonel Edwin Drake was hired to carry out the

[218] Downey, *Oil 101*, cit., p. 1.
[219] *Ibidem.*

drilling, which he did by using the first derrick specifically designed for this purpose: on 29 August 1859, oil started to flow from a 69 feet deep well in Titusville. The well yielded less than 30 barrels per day, which were sold for $40 each, about $700 in current terms[220]; however, due to unrestrained extraction, by the end of 1861 the price had already collapsed to 10 cents per barrel, about $3 in current terms[221]. An oil rush had started, and by November 1960 oil was already flowing from seventy-five wells[222]. In 1861, the first U.S. refinery entered into function, and the first oil cargo left the port of Philadelphia towards London. By 1866, wooden pipelines connected most of the wells in the Oil Region to the railroad system[223].

In 1863, a man named J.D. Rockfeller purchased his first refinery in Ohio: it was the first step of a much larger process of monopolization of the American oil industry. Rockfeller did not believe in market competition: his aim was to eliminate it through the acquisition of the entire downstream sector; central management would then erase any eventual bottleneck in the supply. In 1870, he established the Standard Oil Company (SOC), which, between February and March 1982, acquired 22 out of the 26 refineries based in the city of Cleveland[224]. By 1890, SOC was controlling 90% of the American downstream market, at a time in which 85% of world oil production and refining was located in the U.S.[225]. Two main elements contributed to the completion of Rockfeller's design: first, a secret agreement with the principal railroad companies, awarding the SOC of massive discounts for the transportation of its barrels; second, the creation in 1882 of the Standard Oil Trust, a device which overcame the legal impossibility of creating a company at the federal level, and in which the tycoon detained the dominant share[226]. However, the anti-competitive practices of SOC were revealed by a series of journalistic reports published between 1902 and 1904[227]: the Sherman Antitrust Act of 1890 provided the legal basis for the dismemberment of the company into 34 competing firms in 1911. Unpredictably, such outcome proved extremely profitable to Rockfeller, since many of the new companies soon emerged as the dominant majors in the world oil market[228]; on the other hand, since then "oil" and "monopoly" have been considered as inherently related, and almost indivisible.

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220 Maugeri, *L'era del petrolio*, cit., p. 25.
221 Downey, *Oil 101*, cit., p. 3.
222 D. Yergin, *The prize: The epic quest for oil, money and power*, New York, Free Press, 1991, p. 13.
223 *Ivi*, p. 17.
224 Maugeri, *L'era del petrolio*, cit., pp. 27-29.
225 *Ivi*, p. 30-32.
226 *Ibidem.*
227 Reports were by journalist Ida Tarbell, and were collected in a volume: I.M. Tarbell, History of the Standard Oil company, New York, McClure, Phillips &Co., 1904.
228 Downey, *Oil 101*, cit., p. 4.

As the 19th Century drew to a close, new oil discoveries were made in the states of Texas, Oklahoma, Colorado, and California; yet, rates of production were not impressive, as the output of few wells exceeded 50 barrels per day (b/d). Then, in 1901, the Spindletop field in Texas started to gush over 50,000 b/d, about 20% of total U.S. daily production[229]. In the meantime, oil started to be commercially developed in other parts of the world. In Baku, on the Caspian Sea, production started in 1870: rapidly, Russia became the second largest producer of crude oil after the U.S.. In 1900, worldwide production reached 430,000 b/d, of which 200,000 were coming from Russian oilfields, and about 165,000 from the States; however, in 1905 American production was again predominant, having reached 340,000 b/d[230]. In addition, in the 1890s, Royal Dutch found oil in the island of Sumatra, while Shell discovered a big deposit in Borneo, making the Asian region the third oil producer by the end of the century[231]. Finally, in 1908 the Anglo-Persian Oil Company (APCO) hit oil in Persia, starting the Middle East saga[232].

During the first half of the 20th Century, economy and society were shaped by the pace of oil production and by the application of crude and its derivatives in an increasing number of industrial sectors. Cheap and abundant oil launched the automotive age, at the same time transforming consuming habits and geographical landscapes: the new Ford T created the demand for gasoline, made available to customers through an expanding network of oil service stations, situated along brand-new, vast, and asphalted road networks[233]. In 1910, for the first time more gasoline was sold than kerosene[234]: oil had officially become a transportation fuel, later imbued of strategic importance by the burst of the First World War[235]. By the 1950s, two thirds of the produced crude were refined to obtain transportation fuels; the remaining third was used for roads, for the production of plastic and other petrochemicals, and for heating[236].

In the 1920s, alarmist claims about the imminent exhaustion of American oil resources pushed the oil companies into looking for the acquisition of new productive areas outside the boundaries of the country, not only in the Middle East region, but also in the nearer Latin America: in the previous decade, Mexico and Venezuela, in the context of several concessions held by the majors, had already started to develop a flourishing oil industry. Just before the

229 *Ivi*, p. 5.
230 Maugeri, *L'era del petrolio*, cit., pp. 34-35.
231 *Ibidem.*
232 Downey, *Oil 101*, cit., p. 6.
233 *Ibidem.* U.S. Crude oil production in the same year reach its maximum in December at 114,810 b/d.
234 Maugeri, *L'era del petrolio*, cit., p. 44.
235 Oil Strategic importance mainly derived from the fact that gasoline remained the only fuel choice for powered flight until the 1940s.
236 Downey, *Oil 101*, cit., p. 7.

first world conflict, Mexico was producing 100,000 b/d, an output which placed the country at the third place, after Russia and the States; in 1921, given the disruption of Russian production following the 1917 revolution, it became the second largest producer, with an output of 530,000 b7d[237]. Similarly, between 1919 and 1929, the amount of oil produced in Venezuela jumped from 19,000 to 523,000 b/d, even reaching 779,000 b/d in 1939, year in which the country became the world third producer and first exporter[238]. Notably, three majors, namely Standard oil of New Jersey, Shell, and Gulf, controlled about 90% of the Venezuelan production[239].

In the inter-war period, new and groundbreaking technologies, such as seismic prospecting and gas reinjection, gained more and more ground; at the same time, the Russian oil industry was gradually recovering from the post-revolution and post-war disruption. In 1929, Russian oil reached 275,000 b/d, a remarkable expansion compared to the 75,000 b/d minimum reached in 1918[240]. As U.S. and Venezuelan production rose too, followed in the market by the first barrels of Middle Eastern oil, world production upsurged to 4 mb/d, abundantly outpacing demand, which was further slowed down by the 1929 Great Depression. In such context, the oil industry started to pursue a new strategy that envisaged a secure and preferential access to Middle East reserves, vertical integration through the building of refineries and the development of service stations networks, and enlargement through mergers and acquisitions[241].

In 1930, the East Texas oil field was discovered by Dad Joiner: known as the Black Giant, the field yielded 900,000 b/d, and in 1931 was the largest producing area in the world. On the one hand, the Texan discovery triggered a second oil boom; on the other, it also made prices plummet to 10 cents per barrel, slightly more than $1 in current terms[242]. In an attempt to invigorate the U.S. industry, the federal government entrusted the Texas Railroad Commission (TRC) with the imposition of a system of oil production quotas in each state. Eventually, prorationing would not be completely successful, due to the overestimation of the volumes of oil needed to satisfy demand; however, the control of East Texas spare capacity and of the majors output decisions made the TRC one of the main key actors influencing the price of oil until the 1970s[243]. In the meantime, the nationalization of the Mexican oil industry in 1938 and the creation of its national oil company Pemex, marked the temporary exit from

237 Maugeri, *L'era del petrolio*, cit., p. 54.
238 *Ivi*, p. 56.
239 *Ibidem.*
240 *Ivi*, pp. 66-69.
241 *Ibidem.*
242 Downey, *Oil 101*, pp. 8-9. In 1930, prices were over $1 per barrel, about $10.95 in today's money.
243 *Ibidem.*

the international oil market of the country: according to a policy of conservation of natural resources, Mexican oil mainly served domestic consumption for the next 30 years, reappearing on the scene after the massive discoveries of the 1970s[244].

Just before the Second World War, oil production amounted to 5.7 mb/d, with the U.S. providing more than 60% of it, about 3.5 mb/d[245], followed by the Soviet Union, Venezuela, and the Middle East[246], which at the time was producing less than 500,000 b/d, mainly under the control of the British and American majors[247]. Notably, coal was still the primary energy source both in the United States and Europe, but the upcoming conflict was about to radically change the balance. After 1945, everybody acknowledged that an abundant and safe supply of oil was an essential feature of military, economic and political dominance. Between 1941 and 1945, the U.S. provided 6 out of the 7 million barrels consumed by the allies[248], stretching production up to 4.695 mb/d in 1945[249]. Undoubtedly, the turning point was the reconstruction funded by the Marshall Plan, which boosted European demand not only for petroleum products, but also for other materials, such as iron and steel.

Nonetheless, a big shift was recorded in the second half of the 1940s, when the U.S. became a net importer of oil: the massive impact on collective psychology was testified by the principle of oil self-sufficiency for the two hemispheres, adopted in conjunction with the Marshall Plan, and recommending that European oil imports "to the maximum extent practicable, be made of petroleum sources outside the United States".[250] At the beginning of the 1940s, the Middle East was still a marginal area for American diplomacy; in addition, it was potentially exposed to Soviet influence. However, after 1948, it became the only viable option to satisfy burgeoning oil demand. The U.S. majors were encouraged by the government to make a special effort for the development of the Saudi oil resources: such stimulus paved the way for the creation in 1948 of the Arabian American Oil Company (Aramco)[251], and for the construction in 1949 of the Trans-Arabian pipeline (also called Tapline), transporting Saudi oil to the Mediterranean port of Sidon[252].

In the 1950s, a new cycle of economic growth, fueled by overabundant and affordable oil, begun: in 1950, over 60 billion barrels had already been produced. Until the 1970s,

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244 Maugeri, *L'era del petrolio*, cit., p.74.
245 EIA, International energy statistics, http://www.eia.gov/countries/data.cfm, accessed 28 March, 2013.
246 Maugeri, *L'era del petrolio*, cit., p. 76.
247 Maugeri, *Petrolio*, cit., p. 28.
248 Maugeri, *L'era del petrolio*, cit., p. 78.
249 EIA, *International energy statistics*, cit.
250 Maugeri, *L'era del petrolio*, cit., p. 81.
251 Aramco was jointly owned by Standard oil of New Jersey, Standard Oil of New York, Texaco and Standard oil of California.
252 *Ivi*, p. 81.

exploration and production of crude oil would be dominated by the so-called Seven Sisters, a group comprising the five American majors (Standard Oil of California, Gulf, Standard Oil of New York, Texaco, Standard Oil of New Jersey), primarily through the ownership of the network of Middle Eastern concessions[253]. It was oil golden age: coal was almost completely substituted, while mass motorization and the use of oil in the production of new materials, such as plastic, drove world crude consumption from 9.3 mb/d in 1948 to 56 mb/d in 1973[254]. Despite of an almost two-fold increase in production, from 5.520 mb/d in 1948 to 9.637 mb/d in 1970[255], U.S. oil was displaced by the extremely cheaper Middle Eastern crude: combined production from the area totaled 20.5 mb/d in 1973, with an average cost of 11 cents per barrel[256]. Thanks to the concessionary system, the majors had free hand in the management and schedule of upstream operations: in order to contain overproduction, the seven sisters set up a strategy made of under-reported reserves and of a system called Aggregated Programmed Quantity (APQ), which involved a production quota for each country, and allowed increases only in case of strong demand or exceptional circumstances. The APQ and the conservation policy implemented by the TRC lead to the most high level of spare capacity ever reached by the industry, estimated in 1960 to amount to over 42% of total production capacity, with the exclusion of the Soviet industry[257]. In addition, the control over the rates of supply in the entire Middle East area enabled the Seven Sisters to successfully counteract sudden shortages, such the one caused by the British embargo on Iranian oil in 1951.[258]

The 1950s were characterized by the presence of two further actors on the scene. The first one, already mentioned, was the Soviet Union, which was experiencing a new oil bonanza after large discoveries were made in the region between the Volga and the Urals: in 1973, the country had an output of 8.5 mb/d, compared to a daily production of 616,000 barrels in 1948[259]. Secondly, there was the group of the so-called independents, leading U.S. domestic production and struggling against the much cheaper Middle Eastern imports: in 1959, following pressures by such firms, the federal government introduced the Mandatory Import Program, consenting a maximum volume for imports equal to 13% of domestic consumption. It must be considered that, at the time, the U.S. consumed more or less 40% of the oil produced worldwide: only the American market was able to absorb the excess of

253 See paragraph 2.3.
254 *Ivi*, p. 100.
255 EIA, *International energy statistics*, cit.
256 Maugeri, *L'era del petrolio*, cit., p. 103. Average costs exceeded $1 per barrel in Venezuela, whereas amounted to about $1,3 per barrel in Texas.
257 *Ivi*, p. 104.
258 Downey, *Oil 101*, cit., p. 11.
259 Maugeri, *L'era del petrolio*, cit., p. 105.

supply, which was exerting a continuous downward pressure on oil market prices, heavily discounted if compared with the official posted prices.[260]

The 1960s were marked by the creation of the OPEC, and by the internal struggle between its members, each one eager to expand its own production, and consequently its revenue, by pressuring their concessionaire firms, still detaining control of all upstream operations. In 1961, Kuwait was the largest producer, with an output exceeding 1.7 mb/d; both Iran and Iraq were producing 1.2 and 1 mb/d respectively, whereas Saudi production amounted to 1.4 mb/d[261]. In the meantime, Africa emerged as a new producer, as a result of important discoveries in Nigeria, Algeria, Egypt and Libya: in 1972, the area was already yielding 5 mb/d; in 1970, with 3.3 mb/d, Libya was the third world producer.[262]

The 1970s witnessed a major event for the history of the oil industry: U.S production peaked in 1970, reaching the maximum rate of 9.637 mb/d[263]; in 1971, for the first time, the TRC gave producers free reign to produce at full capacity[264]. The whole of world spare production potential was now concentrated in the hands of the OPEC countries, which started gaining contractual strength, as Europe was now dependent on them for almost 75% of its oil needs. The confluence of supply in a handful of distant and politically unstable countries, the peaking of U.S. production, and the alarmist claims of the Club of Rome, which in 1972 published the famous report "The limits to growth", all contributed to increase general uncertainty about the security of oil supplies, virtually putting an end to the long phase of overabundance.

On 17 October 1973, 11 days after the joint attack by Egypt and Syria against Israel, the Arab OPEC producers implemented an immediate cut by 5% in their oil production rates, to be followed by further 5% cuts on a monthly basis, with the aim of obtaining Israeli withdrawal from the territories he had occupied in 1967; in addition, a selective embargo was imposed upon Israel supporters, namely the United States and the Netherlands. The cuts would assure a decrease in the absolute level of available oil supplies, since the embargo alone would not have prevented oil from being moved around between the consuming countries[265]. Both embargo and the cuts lasted three months and, eventually, actual reductions were far less than the declared targets. Before the Kippur war, the volumes of Arab oil totaled 20.8 mb/d, decreasing to 15.5 mb/d in December at the acme of the embargo; the net loss in

[260] *Ivi*, p. 107.
[261] OPEC, *Annual Statistical Bulletin*, 1980.
[262] Maugeri, *L'era del petrolio*, cit., p. 109.
[263] EIA, *International energy statistics*, cit.
[264] Downey, *Oil 101*, cit., p. 11.
[265] Yergin, *The prize*, cit., p. 590.

supply in December was 4.4 mb/d, about 9% of the total 50.8 mb/d available in September, and more or less 14% of internationally traded oil[266]. However, we must recall that, in 1973, the U.S was importing about 3.2 mb/d[267], mainly coming from the Middle East, and there was no spare capacity to provide a cushion against the disruption. Therefore, despite the modest entity of the shortage, the psychological impact of the 1973 crisis was overwhelming, since it was fed by the lack of precise information, and by the perception of an immutable reversal of power relationships between consuming countries, Western majors, and exporting countries.

For all the 1970s, the OPEC controlled about 50% of global oil production, which at the end of the decade reached 66 mb/d[268]; nonetheless, dominance in the upstream sector was not matched by an equal weight in the midstream and downstream, where the seven majors were still unparalleled, and therefore able to retain a key role in the provision of outlets for the massive flows of Middle Eastern oil, even after the demise of the big concessions[269]. In 1974-1975, as demand was falling reflecting conservation policies and the change in consumption patterns triggered by the 1973 shortage, the industry found itself plagued again by oversupply: in 1974, OECD oil consumption dropped to 39 mb/d, 3 mb/d less compared to levels prior to the Arab embargo; in the same year, world oil production amounted to 58 mb/d. As a consequence, OPEC reduced produced volumes by 35% in the spring of 1975. Despite such temporary abundance of oil without demand, throughout the second half of the decade, uncertainties about the future of oil supply supported an increasing trend of prices, which reached a plateau of about $13 in 1978. At the same time, unpredictability and rising prices gave a boost to the expansion of the spot market[270], where the exporters were able to channel the oil volumes exceeding their long term contracts with the majors by selling them to firms eager to expand their oil stocks, and to speculators eager to expand their returns.

Between 1978 and 1980, four events triggered a second oil shock, namely the Iranian revolution and the crisis involving the U.S. embassy in Teheran, the Soviet invasion of Afghanistan, and the Iran-Iraq war. In 1978, Iran was the fourth world largest producer, with an output amounting to 5.3 mb/d out of the 59.7 mb/d produced globally[271]; 80% of Iranian oil was destined to the international market, making it the second largest exporter after Saudi Arabia[272]. During the last three months of the year, the Iranian internal situation imploded: the crisis knocked down the oil industry too, affected by a paralyzing strike in December, and

[266] *Ivi*, p. 596.
[267] EIA, *International energy statistics*, cit.
[268] BP, *Statistical Review of World Energy*, 2012.
[269] Maugeri, *L'era del petrolio*, cit., p. 142. About the end of the concessions system, see paragraph 2.3.
[270] In 1978, the spot market represented only 3-4% of the total market.
[271] OPEC, *Annual Statistical Bulletin*, 1980.
[272] Maugeri, *Petrolio*, cit., pp. 56-57.

panic spread quickly in the market, caught by surprise, after the collapse of the Shah regime in January 1979. Iranian production decreased sharply: at first, it was compensated by increases in the production rates of Saudi Arabia, whose output reached 10.5 mb/d, and other OPEC members with spare capacity; by April, Iran itself had partially recovered its upstream operations, and the Saudi cut back their production by 2 mb/d. The net loss of barrels was not impressive, amounting to 5,5% of the world total, about 66 mb/d in 1979; at all events, prices kept raising. In the final months of 1979, tension did not ease off: the seizure of the U.S. embassy in Teheran by a group of revolutionary militants in November and the Soviet invasion of Afghanistan in December, followed by the outbreak of the Iran-Iraq war in September 1980, inflicted the final straw to Iranian crude output, which hit the bottom at 1.3 mb/d in 1981; simultaneously, also Iraqi production was disrupted by the conflict, sinking to 907,000 b/d[273]. The loss in production roughly equaled 10% of total oil consumption[274], but undoubtedly triggered an oil rush in the spot market: prices were skyrocketing, as inauspicious predictions of an impending peak and decline of oil production were taking root in the market and in the public opinion[275].

The first half of the 1980s was characterized by two relevant dynamics. The first one is the declining trend in oil demand after it reached its maximum in 1979, when it amounted to about 64mb/d[276]; by contrast, four years later it would reach its minimum level, about 58 mb/d. Such inversion was the result of both declining purchasing power, which made high-priced oil unaffordable, and of energy saving policies implemented by many OECD countries to reduce their dependence from oil and its derived products[277]. The second crucial development in the market was an unanticipated surge of oil from new productive regions, Alaska and the North Sea respectively, and from an old acquaintance, Mexico: the new flow was a direct result of high oil prices in the 1970s, which allowed the development of those deposits previously dismissed as prohibitive, due to technical difficulties as well as to considerable production costs. In addition, new technological breakthroughs, such as 3D seismic, horizontal drilling, and mobile drilling rigs allowing exploration and production operations in the deep and ultra deep offshore, completely changed the wherewithal of the oil industry in the 1980s, increasing recovery and accuracy in oilfields operations, while at the same time lowering average costs.

273 BP, *Statistical Review of World Energy*, 2012.
274 Maugeri, *Petrolio*, cit., p. 58.
275 Maugeri, *L'era del petrolio*, cit., pp. 151-152.
276 *Ivi*, p. 149.
277 *Ibidem.* Energy saving measures included new standards for vehicles, preservation of national mineral resources, and the transition to alternative energy sources, such as natural gas and nuclear energy.

In the 1970s, environmentalist protests about the construction of a pipeline[278] prevented upstream operations in the Prudhoe Bay field of the North Slope region, Alaska; however, in 1974 an agreement was reached, and the construction of the pipeline completed in 1977. By 1978, 1 mb/d were flowing through it: within a few years, Alaskan production reached 2 mb/d, a quarter of total U.S. production[279].

Exploration activities had been carried out in the North Sea since the 1920s, albeit with disappointing results: for a long time, production in the area did not exceed 250,000 b/d. Interest was renewed by the discovery of a large gas field in Groningen, Holland, in 1959: exploration in adjacent waters gave the first significant result in 1969, when Phillps Petroleum hit oil on the Norwegian side of the sea[280], in the Ekofisk field. Furthermore, at the end of 1970, BP announced the discovery of oil in the Forties field; straightaway, Shell and Exxon came across the huge Brent Field. After the boost given to investments by high oil prices, on the whole, production from the area reached 3 mb/d, making the North Sea not only the biggest oil play for the world oil industry, but also a technological marvel[281].

After the nationalization carried out in the 1930s, the Mexican oil industry turned inwards, virtually supplying only the domestic market: until 1972, production never exceeded 500,000 b/d, and the country even became a minor importer. In 1972, Pemex was implementing a deep-drilling exploration program, in the attempt to give relief to its strained finances by incrementing the resource base: the Reforma oil field was discovered, so huge that the region was dubbed “Little Kuwait”; shortly after, another massive structure was found in the Bay of Campeche[282]. Thanks to such discoveries, placed at the center of the economic strategy envisaged by the new government of José Lopez Portillo, investment was poured into the Mexican industry, and production rose quickly to 894,000 b/d in 1976, and even up to 3 mb/d in 1982.[283]

The new abundance of supply in the market further drove spot prices down, leading the OPEC to the decision to impose an overall production ceiling for its members of 17.5 mb/d[284]: each one of them was assigned a quota, with Saudi Arabia taking the role of swing producer, increasing its rate of production in case of tight market and decreasing it in case of an excess of supply. However, the system soon proved to be untenable: Iran announced its

278 The pipeline would connect Prudohe Bay with the port of Valdez, for a total length of 800 miles.
279 Yergin, *The prize*, cit., p. 648.
280 In 1965, as far as mineral rights were concerned, Norway and Great Britain had formally agreed to divide the North Sea right down the middle between them.
281 *Ivi*, pp. 649-652.
282 *Ivi*, pp. 648.
283 BP, *Statistical Review of World Energy*, 2012.
284 For reference, in 1981 OPEC production had amounted to 22.59 mb/d.

intention to produce at full capacity, whatever the price obtained on the market, and at the end of 1982 it was producing nearly 3 mb/d. In a likely manner, Nigeria started to sell discounted oil under-the-counter, in order to regain its share against the increasing flow crude from the North Sea[285]. In August 1985, as a consequence of continuously declining prices, Saudi Arabia decided to raise its production rate from 2 to 5 mb/d, literally flooding the market with unnecessary oil. The country was acting according to a short time perspective, since it needed more revenues to fund its large welfare programs: indeed, despite falling prices, its income rose due to the more than doubled production[286]. In December, OPEC production was half the level reached in 1979, and its share of the market plunged to 25%[287]. A compromise between member countries was reached only in December 1986, when a new and more flexible quota system was adopted, with an overall production ceiling of 24 mb/d. Still, at the closure of the 1980s, the excess of supply appeared as a permanent feature of the oil market.

On 2 August 1990, Iraq invaded Kuwait: a few days later, the United Nations adopted a resolution imposing an oil embargo on the two countries, a move that would result in the subtraction of 4 mb/d of crude, about 7% of global demand at the time, which amounted to 65 mb/d[288]. As the OPEC hurried to suspend its production quotas, the USA decided to introduce, in subsequent steps, about 35 mb from the SPR: at the end if 1990, the market was again experiencing a situation of oversupply. The output of OPEC countries, with the exclusion of Iraq and Kuwait, had already increased by 5 mb/d: Saudi Arabia even exceeded 9 mb/d at the beginning of 1991. After the end of the conflict, Iraq remained excluded from the world oil market since 1996, due to the economic sanctions imposed by the UN; its production and exports were considerably reduced, and Iraqi output never went beyond 580,000 b/d[289] between 1992 and 1996.

The beginning of the new decade was also marked by the collapse of the Soviet Union and the internal disarray of its oil industry: its production fell from 12.6 mb/d in 1988 to about 7 mb/d in 1996-98; at the same time, also consumption and exports crumbled down, with the latter hitting 1.5 mb/d in 1991, compared to a peak of 3.5 mb/d in 1988.[290] Russian production reached again a level of 9 mb/d only in 2004[291]. However, consumption did not suffer, since it was primarily fueled by the North Sea oil and by the OPEC, acting as swing producer.

The 1990s also witnessed the internal reorganization of the oil industry through

285 Maugeri, *L'era del petrolio*, cit., pp. 156-157.
286 Downey, *Oil 101*, cit., p. 19.
287 Maugeri, *Petrolio*, cit., p. 66.
288 EIA, *International energy statistics*, cit.
289 BP, *Statistical Review of World Energy*, 2012.
290 Maugeri, *L'era del petrolio*, cit., p. 175.
291 BP, *Statistical Review of World Energy*, 2012.

mergers and acquisition[292], an evolution deemed necessary for the majors to survive in the current international environment for oil, characterized by high cost ventures, low refinery returns, and decreasing production capacity. The new frontier for the upstream sector was along the shores of the Caspian Sea, even if the area was already an oil producer at the beginning of the 20th Century: up to the 1950s, Azerbaijan represented the primary oil source for the Russian territory, but poor engineering practices led to the over-exploitation and damage of its deposits, subsequently abandoned until after the oil shocks of the 1970s.[293] In the 1990s, the massive reserve estimates produced by the FSU[294] and the worries induced by the dependence of the oil industry on the resources of the Persian Gulf, perceived as permanently unstable after the Iraqi invasion of Kuwait, contributed to the image of the Caspian Sea as the new oil Eldorado, and to an increasing flow of investments directed towards the exploration and development of its hydrocarbon deposits[295]. The first results, however, were not as satisfying as expected: Azerbaijan production exceeded 1 mb/d only in 2009, after a production that ranged between 100,000 and 300,000 b/d for years[296]. Therefore, the focus gradually shifted to Kazakhstan, and to its two super-giant fields, Tengiz and Karachaganak. Tengiz, which started to be developed in 1993, is currently the country's largest producing field, with roughly 520,000 b/d, as well as the world's deepest operating giant field, drilled at 12,000 feet. Karachaganak, on the other hand, is currently producing nearly 250,000 b/d. Kazakhastan also includes the the offshore Kashagan field, apparently the largest known oil field outside the Middle East area[297]. Despite the increasing weight of the Caspian area in the current level of world oil production, its development in the 1990s was greatly frustrated by the uncertain legal status of the area, by the ethnic tensions within these countries, and by high costs related to the harsh operating environment, especially in the case of the Kashagan field. In the meantime, the industry also shifted its attention to new offshore and deep-offshore prospects in West Africa, Brazil, the Gulf of Mexico: in particular, Brazilian offshore development experienced a staggering expansion, which led the country to produce more than 2 mb/d in 2009, a three-fold increase since the mid-1990s, when its output ranged around 650,000 b/d[298].

After years of restrained capacity, in 2005 demand finally caught up with oil production, wiping out any buffer against unexpected supply shortages. Currently, this

292 See paragraph 2.3.
293 Maugeri, *Petrolio*, cit., p. 171.
294 Recoverable oil was estimated to amount to about 200 mb.
295 *Ibidem.*
296 BP, *Statistical Review of World Energy*, 2012.
297 EIA, *International energy statistics*, cit.
298 BP, *Statistical Review of World Energy*, 2012.

cushion has not been recovered yet, despite a huge increase in exploration and development effort by the OPEC countries between 2000 and 2008, both onshore and offshore.[299] According to the supporters of the Peak Oil theory, since the peak of discoveries of hydrocarbon resources verified in the 1960s, it is just a matter of time until a corresponding peak will be registered in the rate of world oil production. It ensues that, in the future, supply shortages could be not short-term episodes, as in the past, but a permanent feature of the oil industry. Indeed, the major challenges will be finding plausible substitutes to oil products, lowering energy storage costs, and reducing the scale of consumption, above all in the case of the newly industrialized countries, such as China and India. As stated by Downey: "one way or the other, in the 22nd Century there will be transportation energy. It may be much more expensive, perhaps not. It is almost certain that the source of that energy will not be conventional petroleum"[300].

2.2. Oil production: the current state of affairs

Oil is not a homogenous resource: several hundred grades of crude are produced worldwide, each one defined by its physical characteristics, namely sulphur content, density, acidity, and viscosity (Figure 2.1) The qualities possessed by a particular crude determine the products it can yield once refined and, as a consequence, its value.[301] In particular, the assessment of density provides the most relevant information, since the lighter the crude, the worthier the products that will be obtained through the refining process, and the less the refinery waste. The most common measurement for density is the API gravity index, created in 1921 and ranging from 0° to 100°, 0° being the heaviest[302]; the index is applied to every hydrocarbon product too. Accordingly, crude oils can be classified as extra-light (with a density >50° API) or light (40°-50° API), medium (30-39°), medium-heavy (25-29° API), heavy (<25° API) or extra-heavy (<10°). Nowadays, intermediate crude oils are the most widely produced, and the major part of refineries is configured to process them: not by chance, the West Texas Intermediate (WTI) crude and the Brent Blend crude, both used as price benchmarks and traded in the stock exchange, belong to the medium category, with a density of 39.6 and 38.3° API respectively[303]. Furthermore, at the extremes crude oils tend to be either light-sweet or heavy-sour, where "sweet" and "sour" refer to the level of sulfur content, sweet oils

[299] Downey, *Oil 101*, cit., pp. 23-24.
[300] *Ivi*, p. 29.
[301] Downey, *Oil 101*, cit., p. 30.
[302] Water, used as a benchmark when assessing the density of crude oil, is assigned a density of 10° API.
[303] *Ivi*, p. 32-35.

containing less sulfur than the sour ones[304].

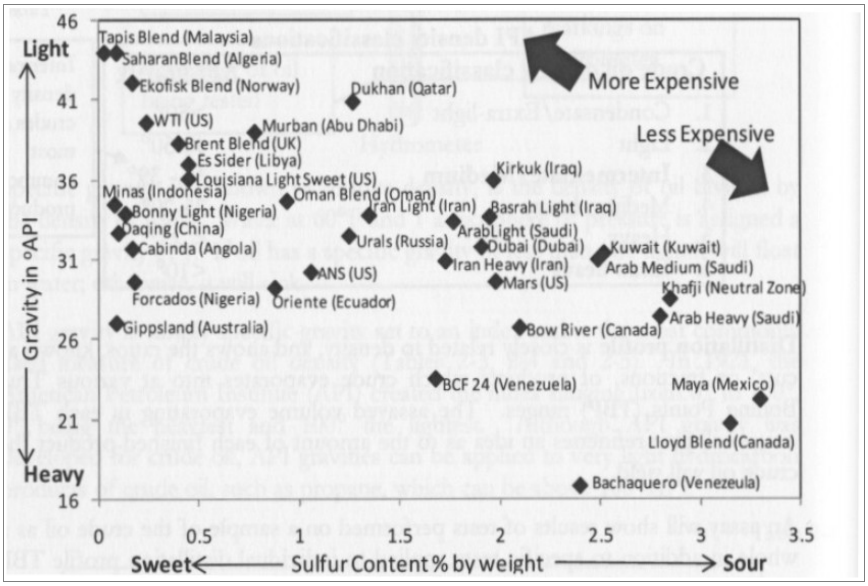

Figure 2.1. Crude oils classification by density and sulfur content
Source: Downey, 2009

Currently, 60 per cent of global oil production comes from 317 giant oil fields, of which only 54 are referred to as super giant[305]: most fields produce less than 100,000 b/d, and the majority of them is marginal, with an output not even reaching 10 b/d. Often, for cost saving purposes, production from individual wells in an oil field is combined for pipeline transportation, creating a stream of crude; in addition, several streams can be combined not only to reduce transportation costs but also to adjust crude qualities, or to stretch the life of a particular crude, as in the case of the Brent Blend[306]. Therefore, it is common for a specific crude quality to be actually the result of the production of many different fields in a certain geographical area; additionally, the same country can produce many different qualities of crude[307].

The output of an oilfield can be broken into different hydrocarbon components: in addition to conventional crude oil, the production process delivers condensates, Natural Gas Liquids (NGLs), refinery gains, plus minor quantities of other liquids, like ethanol or Methyl tertiary-butyl ether (MTBE).[308]

A further distinction is made between conventional and unconventional oils, a category comprising those hydrocarbons which have to be treated with particular procedures

[304] *Ivi*, p. 36.
[305] *Ivi*, p. 31. A field is considered as super giant when estimated 2P reserves exceed 5 billion barrels, and as giant when estimated 2P reserves range between 0.5 and 5 billion barrels.
[306] The Brent Blend is a mixture of oil streams produced by different oil fields and collected through two pipeline systems, the Brent and Ninian, located in the North Sea.
[307] Maugeri, *Petrolio*, cit., p. 79.
[308] *Ivi*, pp. 41-42.

before running through a refinery: as a result, their production is much more expensive compared to the extraction of conventional crude. Oil sands are the most common source of unconventional oils: the largest volumes are located in the Canadian region of Alberta, in the Venezuelan Orinoco belt, and in the Olenek deposit in Siberia.[309] Two methods for the recovery of unconventional oil are applied to oil sands: surface mining, which involves the extraction of the sands, usually located near the surface, and their processing in a separation facility, where water is used to detach hydrocarbons; and in-situ production, which involves the removal of bitumen from the well in a liquid form, followed by its separation from the sand and by its upgrading to a lighter product, in order to be processed in a conventional refinery[310].

With reference to conventional oil, after the presence of a commercially valuable deposit has been ascertained, several test wells are needed in order to decide where to drill; subsequently, development wells are used to begin production, whereas infill drilling allows, in a second time, to place additional wells, and to reach deposits that were previously inaccessible from the original well, speeding up the extraction rate and reducing the amount of gas and water produced by the process[311]. Drilling rigs and all the related equipment are usually owned and handled through the entire process by independent companies, specialized in such operations[312]. Once the drilling is completed, the final installation of the facilities to actually produce crude, referred to as completion, is arranged. There are three main forms of completion: dry hole completions are used when a well is not producing quantities of oil sufficient to justify the construction of production facilities; production well completions involve the building of all the surface installations needed for extraction, storage, and transportation of oil; finally, injection well completions are required to apply Enhanced Oil Recovery (EOR) methods, such as gas or liquid injection, which aim at maintaining the necessary level of pressure inside the reservoir[313].

It is precisely reservoir pressure which allows the extraction of oil from the subsoil, causing hydrocarbon molecules trapped in the pore spaces of the source rock to flow towards the bottom of the well[314]. It is actually impossible to recover all the oil present in a reservoir: currently, the average recovery factor (RF) is around 30%, but in the early days of the oil industry it was definitely lower due to indiscriminate drilling, which literally made pressure

[309] *Ivi*, pp. 43-46.
[310] *Ibidem.*
[311] *Ivi*, pp. 101-102.
[312] *Ivi*, p. 103.
[313] *Ivi*, pp. 108-109. See paragraph 2.3.
[314] *Ivi*, p. 84.

collapse within the reservoir, wrecking production. As a better understanding of the physics of oil deposits was developed, it became perfectly clear that production was maximized by that rate of extraction which allowed an efficient use of the existing reservoir pressure; undoubtedly, an important role has been played by technological progress too.[315]

If until the 1920s the majority of exploration and drilling activity was focused on land deposits, since the 1930s operations started to move also offshore: in 1933, the first mobile offshore drilling rig was employed by Kerr McGee on Lake Pedro, Louisiana, by Texaco, followed by the first bottom-supported platform in 1947, located one mile from the Louisiana coast in the Gulf of Mexico[316]; in Europe, 1969 witnessed the kick-off of oil production on the North Sea, thanks to the development of a new generation of technology, allowing to reach depths much greater than everything envisaged heretofore[317].

There are three stages of oil recovery. The first stage is referred to as primary recovery, and involves both flush production, which simply exploits the natural pressure inside the reservoir, and settled production or artificial lift, which allows to continue the extraction of oil after pressure decreased through the use of pumps. On the other hand, secondary recovery implies push mechanisms, such as water or gas injection, which maintain or increase reservoir pressure; finally, attempts to increase reservoir rock permeability, to displace oil contained in the deposit, or to lower crude viscosity, are classified as tertiary or EOR methods. After this final stage, production can continue at a very slow and low rate from marginal wells; however, it has to be considered that up to 75% of remaining oil may not be recoverable[318]. After production has ceased, the whole completion is dismantled, all wells are closed, and site remediation takes place, restoring the area to its original state.[319]

Overall, the lead in times for oil production are quite demanding: from the initial exploratory phase, even 10 years can pass before the first barrel is produced; furthermore, production itself can last up to 20 or 30 years, so much as 50 in the case of some supergiant fields. Therefore, investments in the upstream sector will yield their results after a considerable time lag[320].

Production does not follow a regular pace: many short-term factors can cause variations and peaks in production rates, ranging from technical and geological hitches, to economic evaluations driven by price, demand, or the presence of a prorationing system, to

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315 *Ibidem.*
316 *Ivi*, p. 115.
317 Yergin, *The prize*, cit., pp. 650-651.
318 Downey, *Oil 101*, cit., pp. 128-141.
319 *Ivi*, p. 42.
320 Maugeri, *Petrolio*, cit., p. 96.

political and legal instances, such as wars and international sanctions.

According to the EIA, world liquid hydrocarbon production amounted to about 89 mb/d in 2012, 28% more compared to total production in 1980, when world output totaled 64 mb/d. Since 2011, the overall figure rose by 1.7 mb/d. In the 30 years period between 1980 and 2010, the biggest contribution was provided by Central and South America, Africa and Asia: their combined share of production totaled 32% of world output in 2010, compared to 23% in 1980(Figure 2.2). However, in absolute terms, the area with the largest production was the Middle East: in 2012, its output averaged 26.977 mb/d, roughly 30% of the world total(Figure 2.3).

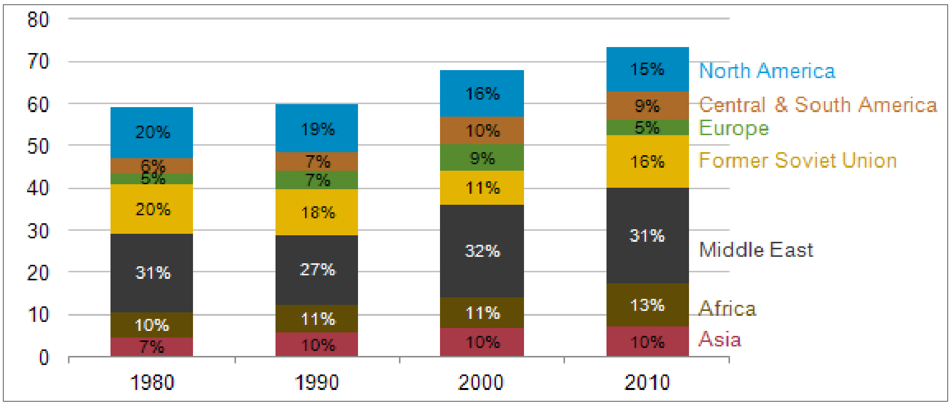

Figure 2.2. Share of world crude oil production by region, 1980-2010[321]
Source: EIA

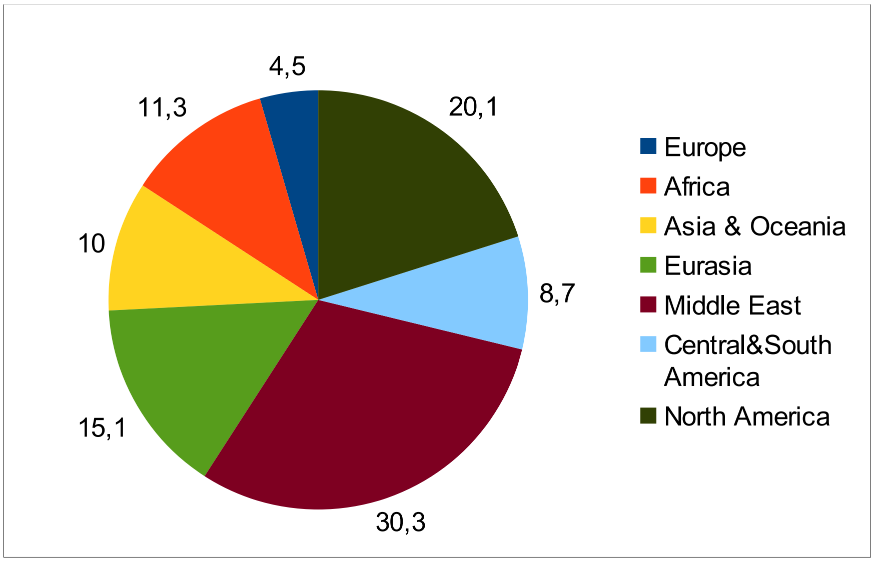

Figure 2.3. Share of world production by geographical area, 2012
Source: EIA

Based on the EIA data, the only region presenting a constantly declining production trend between 1980 and 2010 was North America: its output decreased by 1 mb/d in the considered interval, whereas its share of global production fell from 20% in 1980 to 15% in

[321] Percentages do not sum up to 100%, since Oceania is omitted, its share amounting to roughly 1%.

2010. Nonetheless, this trend recently inverted: North American production in 2012 totaled 17.9 mb/d, mainly due to increased production in North Dakota and Texas fields, starting from 2011; in January 2013, the EIA reported for North American production a figure of 18.5 mb/d.

In 2012, the world largest producer was Saudi Arabia (11.545 mb/d), closely followed by the U.S. (11.095 mb/d) and Russia (10.397 mb/d): notably, the combined output of the 10 largest producers[322], based on EIA figures, amounted to 56.79 mb/d, nearly 64% of overall global production[323]. In the same year, Saudi Arabia was also the largest exporter, followed by Russia and the UAE. Conversely, the U.S was estimated to be the biggest importer, followed by China and Japan[324]. For reference, oil consumption in 2011 averaged 87.6 mb/d: the major consuming areas were Asia and Oceania, whereas the United States still held the highest rate of consumption, with 18.9 mb/d, followed by China, which in the same year consumed about 8.9 mb/d[325].

This brief data round up allows to highlight some features of the current situation of world oil production: the Middle East, Saudi Arabia in particular, still holds a preeminent position in supplying world oil markets, even if new areas are coming up beside the traditional ones, as exemplified by the increasing weight of China. The U.S. need a dual consideration: if on the one hand, it is the second largest producer of crude oil in the world, on the other it is also the biggest consumer: its output remains mainly confined within the national boundaries. Remarkably, the latest IEA estimates forecast the overtaking by the U.S. of the Arab countries as first producing area by 2020[326].

Two further considerations can be helpful in gaining an insight into the upstream sector. The first one involves the loss of spare capacity: the closure of the gap between oil demand and supply in the 1990s marked the disappearing of spare capacity in the upstream sector. Until today, it has not been recovered yet, despite huge increases in exploration and production ventures in the 2000s. This circumstance has three main consequences: first, a premium is incorporated into the price of oil as a cushion against potential supply disruption, now perceived as more likely to burst; second, price volatility increases, since there is not an actor which can compensate for supply shortages by increasing his output; finally, production

322 According to EIA data, the 10 largest producers in 2012 were: Saudi Arabia, the U.S., Russia, China, Canada, Iran, UAE, Iraq, Mexico, Kuwait.

323 EIA, *International energy statistics*, cit.

324 ENI, *World Oil and Gas Review 2012*, cit.

325 *Ibidem.*

326 IEA, *World Energy Outlook 2012*, http://www.iea.org/publications/freepublications/publication/English.pdf, accessed April 29, 2013.

and inventories can not be built up in response to price hikes[327]. In addition, the preference for upstream investments, and the need to cut costs resulting in the closure of refineries and in the merger frenzy of the 1990s, has created a shortage of spare capacity and general constraints in the downstream sector, already tried by the increasing bearing of heavy and sour oils on available volumes of oil; however, due to increasing profits between 2002 and 2007, spare refining capacity is catching up again with consumption[328]. Given that the main element impacting investment decisions is uncertainty, not only about the future course of oil demand, but also on the actual growth potential of production, the result is a vicious circle, which hampers the future flexibility and resilience of the entire industry.

The second and final remark points out how the control in the upstream sector appears to be firmly in the hands of the NOCs and, more interestingly, of the so-called International NOCs. The new generation of state-owned companies represent the emerging leading actors of the upstream sector, such as the Chinese PetroChina and the Brasilian Petrobras, or old actors, such as in the case of the Norvegian StatoilHydro, the world leading firm in offshore exploration. In 2011, 40.1% of world production was delivered by the NOCs, 8.4 by the iNOCs, whereas the majors were left with a "mere" 13.1%. (Figure 2.6).

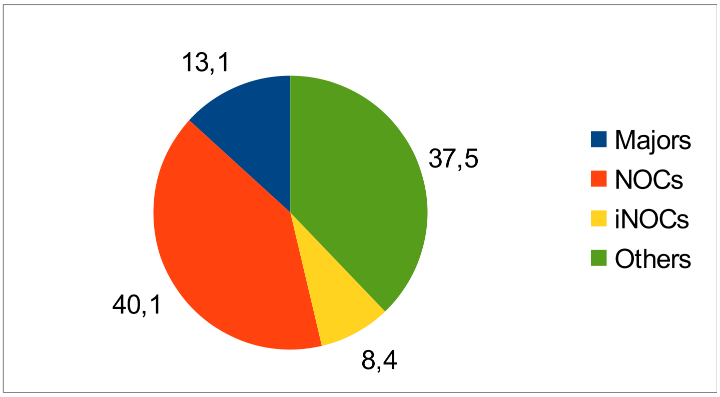

Figure 2.4. Share of production by cluster of companies, 2011
Source: ENI, 2012

As a consequence of the consolidation of the industry in the 1990s, only four of the Seven Sisters remain, consolidated in the so called International Oil Companies (IOCs), namely ExxonMobil (initially Standard oil of New Jersey and Standard oil of New York), BP (formerly Anglo-Iranian Oil Company), Chevron (formerly Standard oil of California), and Royal Dutch Shell; IOCs comprise also the megafirm ConocoPhillips, created by the merger of two large independents[329]. With the addition of the French Total S.A. And the Italian ENI,

327 Downey, *Oil 101*, pp. 23-24.
328 *Ivi*, p. 25.
329 A.M. Jaffe, R. Soligo, International oil companies, http://www.bakerinstitute.org/publications/NOC_IOCs_Jaffe-Soligo.pdf, accessed March 28, 2013.

the group is referred to as the supermajors[330].

The supermajors are still among the largest oil producers worldwide; however, 14 out of the top 20 upstream oil and gas companies are NOCs, and state monopolies represent the top ten reserves holders worldwide[331]. In the last 20 years, the major producing countries have been disinclined to share their exploration and development business with the IOCs; on the other hand, the same NOCs often collaborate in the operations relative to foreign oil plays[332]. In particular, since 1996, the nine iNOCs[333] actively participating in international exploration have invested abroad more than $66 billion in upstream operations[334].

2.3. The governance of oil production

Oil production is always carried out within a contractual framework, which is not only negotiated (or imposed) by the actors involved, but also shaped by the surrounding historical, economic and social environment. Governance structures, which can be defined as sets of political and legal rules based on power relations, are "set up at a time when a dominant player can exercise power in favourable circumstances"[335]: they consists of various elements, such as the licensing and fiscal regimes, the issues relative to sovereign taxation, and the methods of dispute settlement[336]. Any attempt to trace an history of production requires a brief overview of how the relationships between the main agents of the oil industry, namely the oil companies, the governments of the producing countries, and the governments of the consuming countries, have evolved through time: indeed, the contractual frameworks for the production of oil that emerged, embodying such relationships, well represent this evolution. During the last 40 years in particular, the framework which was established in the first half of the 20th Century has undergone a complete transformation, shifting from a compromise between the main western majors to a confrontation between the interests of oil exporting countries, foreign oil firms, and consuming countries.

What is the main rationale behind the various contracts which rule oil production? First of all, an actor, may it be a private or a national oil company, must be entitled to carry

330 *Ivi*, p. 17.
331 *Ivi*, p. 10.
332 *Ivi*, p. 11.
333 The nine NOCs are: Lukoil (Russia), StatoilHydro (Norway), Petrobras (Brasil), PETRONAS(Malaysia), China National Petroleum Corporation (CNPC), China National Offshore Oil Corporation (CNOOC), Sinochem Corporation (China), Rosneft (Russia), and India's Oil and Natural Gas Corporation Ktd. (ONGC).
334 *Ivi*, p. 16.
335 B. Mommer, The governance of international oil: The changing rules of the game, Oxford Institute for Energy Studies, http://www-personal.umich.edu/~twod/oil-ns/articles/research-07/research-ven/mommer_governance_intl_oil_2000WPM26.pdf, accessed March 28, 2013, p. i.
336 *Ibidem.*

out exploration and production: he needs permission not only from the owner of the surface property, but also from the owner of the mineral rights to the petroleum contained under that surface. In most countries, oil is regarded as a national property, even if the land containing it is subject to private ownership: the mineral is considered a potential source of ground rent, and the state acts as a landlord, engaging in contractual relationships with foreign or domestic actors, allowing for the production of the resource in exchange for such rent. On the other hand, the U.S and Canada are among the few countries in which also mineral resources in the ground can be owned by privates and organizations, whereas the government only owns the right to minerals located in federal lands and beyond individual State offshore boundaries[337]. A contract concerning mineral ownership and development rights can be negotiated bilaterally, for example between a firm and a country's government or between a firm and a national oil company (NOC) representing the government; otherwise, the contract can be obtained through a bidding process, where the bid is based on elements like royalties and bonus payments, whereas the terms of the agreement are prescribed by legislation[338].

Secondly, contracts and agreements always try to include every possible source of conflict between the parties involved. It is important to bear in mind that, for a long time, the core interests concerning oil production, namely profit maximization and revenue maximization, were pursued by competing actors, who were the governments of the producing countries and the concessionary foreign companies: as a consequence, disagreements often arose from demands for renegotiation of the existing contractual terms[339]. Actors constantly seek to foster their goals within the framework in force, eventually trying to stretch and replace existing rules with new and more favorable ones[340].

The governance structure of the oil industry in its earliest American days was shaped by the rule of capture, a doctrine based on the English Common law, stating that the owner of the land had the right to draw out whatever wealth laying beneath it, namely all the oil he could get[341]. If on the one hand the rule of capture fueled the Pennsylvania oil rush and the consequent waste and rapid depletion of the mineral resources of Oil Creek, on the other it allowed the staggering expansion of the American oil industry, which by 1890 came to be consolidated and monopolized by John D. Rockfeller and his Standard Oil Company (SOC).

The first decade of the 20th Century proved to be crucial for the development of the

337 Downey, *Oil 101*, cit., p. 83.
338 K. Bindemann, *Production sharing agreements: An economic analysis*, Oxford, Oxford Institute for Energy Studies, 1999, pp. 7-8.
339 *Ivi*, p. 5.
340 Mommer, *The governance of international oil*, cit., p. 5.
341 Yergin, *The prize*, cit., p. 16.

framework which characterized the governance of world oil production until the 1970s, mainly for two reasons. First, a series of investigative reports published from 1902 to 1904 spotlighted the anti-competitive practices of the SOC, leading in 1911 to the split of the company in 34 competing firms, according to the Sherman Antitrust Act of 1890[342]. From the ashes of the SOC five of the majors later known as the Seven Sisters emerged[343], destined to rule almost unchallenged the exploration and production activity of the crude oil industry for the following 60 years. The second relevant circumstance was the discovery of oil in Persia by the Anglo Persian Oil Company (APOC) in 1908, undoubtedly the hesitant beginning of what would become the race of the western majors towards Middle East oil in the 1920s and 1930s.

In the aftermath of the Second World War, the Seven Sister were the main architects of the staggering expansion of the international oil industry, largely based on the development of the abundant and cheap reserves of crude oil discovered in the Third World countries of the Middle East and Latin America. As aforementioned, subsurface mineral rights are generally property of the State: the government can either explore for and develop the mineral by itself or enter an into an agreement with a company to do so. The latter solution was generally adopted in the case of Middle East countries: at that time, they were poor and economically backward, lacking both the infrastructure and the human resources needed for the development of an oil industry[344]. As a consequence, the relationship with the investing firms was clearly marked by colonialist undertones[345], and the existing contracts ruling the extraction of oil eventually became vital cornerstones for those countries endowed with large or potentially large crude deposits[346].

The legal framework for the development of Middle Eastern reserves was then provided by concession agreements, which secured the consolidation of the oil industry in the 1950s and the almost undisputed dominance of the majors until the late 1960s. Such contracts are still in use today, even if under the name of exploration and production (E&P) agreement. When entering a concession agreement with a company, may it be foreign or not, the government of a country grants to this firm an exclusive right to explore, develop, and dispose of the hydrocarbon resources in a defined area for a limited period of time, in return for

342 Downey, *Oil 101*, cit., p. 4.
343 The Seven Sisters included five American firms, namely Gulf Oil, the Standard Oil of California, Texaco, the Standard Oil of New Jersey, and the Standard Oil of New York, and two European companies, the Anglo-Persian Oil Company and the Royal Dutch Shell.
344 F. Parra, *Oil politics: A modern history of petroleum*, London, I.B. Tauris, 2010, pp. 6-7.
345 *Ivi*, p. 1. Notably, many of those countries were still colonies or protectorates: Iraq declared independence only in 1930, whereas other countries, namely Kuwait, Barhain, and Qatar, only in the 1960s and 1970s.
346 Bindemann, *Production sharing agreements*, cit., p. 11.

certain payments in the form of taxes or royalties[347]. It is precisely the amount of these payments which makes a concession attractive to investing companies, in addition to the possibility for them to book oil reserves and produced volumes in their own balance sheets as equity reserves[348]. Examples of modern concession agreements are the ones developed in Oman and Abu Dhabi in 1967 and 1974 respectively: in addition to the previously mentioned rights, they provided a work obligation, a relinquishment clause relative to idle areas, higher royalties, bonus payments, and a relatively shorter contract period if compared with the historical concessions, from which they substantially differ.

The concessionary system, which ruled all crude oil production in the Middle East by 1950, was distinguished by four main features. First, agreements covered vast areas, and sometimes even an entire country, such as in the case of Iraq, entirely enclosed by three concessions, all owned by the same group of majors[349]. Second, all contracts envisaged an exceptional longevity: for instance, in 1950 their validity even stretched to the 1980s in the case of Venezuela, and to 2025 in the case of Kuwait[350]. A third feature was the complete control exercised by the majors over the schedule and ways according to which crude oil reserves had to be developed: firms were not subject to any requirement to produce, and therefore were able to restrain output whenever necessary to increase prices. Finally, the host government, despite formally being the owner of its resources, had almost no actual rights over them, except for being entitled to a revenue proportioned to the produced volumes[351]. In the earliest concessions, ground-rent could indeed take the form of either a percentage of net profits, usually between 15 and 20 per cent, or a tonnage royalty[352]. The archetypal concession was the one obtained in 1901 by William Knox D'Arcy from the Shah of Persia, on behalf of the APOC: the contract allowed access to 500,000 km^2 of land, almost the entire Persian territory with the exclusion of four northern provinces, in order to “search for, produce, exploit, develop, transport, and sell natural gas and oil”; it had a duration of 60 years[353]. In return for the concession, the Persian monarchy was granted an immediate payment amounting to 40,000 pounds, the right to 16 per cent of annual net profits, and a tonnage royalty of four shillings per unit sold. The APOC was exempted from the payment of any other tax or levy.

347 *Ivi*, p. 9.
348 Maugeri, *Petrolio*, cit., p. 94.
349 Parra, *Oil politics*, cit., p. 10.
350 *Ibidem.*
351 Bindemann, *Production sharing agreements,* cit., p. 9.
352 Mommer, *The governance of international oil*, cit., p. 8. The tonnage royalty imposed by the Iraqi concession amounted to four shillings; under U.S. pressure, it became the reference for the entire region.
353 Bindemann, *Production sharing agreements*, cit., p. 9; Maugeri, *L'era del petrolio*, cit., p. 46.

The governance structure provided by the concessions, though not eliminating the ground-rent due to the governments of the host countries, guaranteed abundant and cheap oil supplies, at the same time limiting the powers of the landlords to the advantage of the tenant companies. Two additional elements secured the position of the Western firms, namely a choice of law clause and a corollary arbitration clause: artfully combined, they lifted Middle East concessions out of the jurisdiction of the host country by making them subject to international law and arbitration; in addition, they denied any modification of the terms of the contract lacking the consent of the concessionaire[354]. Landlord states were deprived of their sovereign rights, also with reference to taxation: the security of company profits required the inapplicability of the governments' discretionary power to levy taxes from the foreign companies. The threat was removed by the inclusion in the contract of a fiscal stability clause, preventing the host country from increasing taxes or tax rates during the life of the agreement[355]. Iraq provides a striking example. The original IPC concession of 14 March 1925 recognized the right of the government to impose on the concessionary companies the same taxes "ordinarily imposed from time to time upon other industrial undertakings"[356], thus allowing potentially unlimited tax increases in the future. However, the agreement was revised on March 24, 1931: the Iraqi Prime Minister, Nuri Said, and the Iraqi Parliament agreed to the exemption of the IPC from all taxation due on or after 1st April 1931 "in return for certain additional but relatively minor payments on production", thus giving up the last sovereign right recognized by the concession. The government needed cash, and Nuri "sold out his country for 400,000 pounds"[357].

The almost complete absence of competition was probably the most important element leading to the consolidation and survival of this exploitative governance structure until the 1970s: by 1951, all the principal concessions in the Middle East were held by various combinations of the seven majors, which consequently were more inclined to cooperate rather than to compete. The first formal step towards collusion, resulting from both historical accident and design, was taken as early as 1928. After having struck oil on the Iraqi soil at Baba Gurgur and having obtained a concession for its development, the companies who jointly owned the Turkish Petroleum Company bound themselves by signing the so-called Red Line Agreement: they committed not to engage in any oil operation except in cooperation with each other within the vast territory formerly ruled by the Ottoman empire. The main goal

354 Parra, *Oil politics*, cit., p. 10.
355 *Ivi*, pp. 11-12. This feature distinguished the Middle Eastern concessions from those granted by Venezuela, which never gave up the sovereign right of taxation.
356 Mommer, *The governance of international oil*, cit., p. 8.
357 Parra, *Oil politics*, cit., p. 13.

of the agreement was to hold down ground-rent and avoid contracts more favourable to the landlord States[358]. The territory, delineated on a map by a red line, included Turkey and almost all the Middle Eastern areas, with the exclusion of Iran, Kuwait and the Neutral Zone between Saudi Arabia and Kuwait (Fig. 2.7); in addition to the Compagnie Française des Pétroles (CFP), the signatory firms included the Royal Dutch Shell, the APOC, and the Near East Development Company, a consortium representing five American firms, including the Standard Oil of New Jersey, the Standard Oil of New York, and Gulf Oil[359].

Figure 2.7. The Red Line Agreement, 1928
Source: Yergin, 1991

During the 1930s, all the crucial oil producers in the Middle East were netted into the concessionary system managed by the International Petroleum Cartel, as the seven majors were referred to during the anti trust proceedings that were run against them by the Federal Trade Commission in the 1950s[360]. In 1933, the Standard Oil of California and Texaco were granted by Ibn Saud, the king of Saudi Arabia, a 60 years concession covering the entire eastern part of the country, soon to reveal itself as the oil richest region of the world; the following year, the Kuwaiti Oil Company, jointly owned by Gulf Oil and the Anglo Iranian Oil Company (AIOC)[361], obtained a contract for the production, development and transportation of the country's oil expiring in 2025.[362]

The governance structure was finally consolidated with the creation of the Iranian consortium in 1954. In 1933, the APOC was the sole owner of a 60 years concession covering

[358] *Ibidem.*
[359] Parra, *Oil politics*, cit., p. 348; Yergin, *The prize*, cit., p. 188.
[360] Parra, *Oil politics*, cit., p. 10-11.
[361] As the APOC was renamed in 1935.
[362] Maugeri, *L'era del petrolio*, cit., p. 60.

the southern part of the country, an area of 100,000 km^2. In 1947, the Iranians sought the renegotiation of the agreement: they claimed that it was null and void having being signed under duress, that the AIOC had systematically evaded due payments, and that the contract had been frustrated by British regulations concerning the distribution of dividends and the choice of the sterling as currency. Therefore, Iran was demanding higher and retroactive royalty payments, lower prices for oil products intended for domestic consumption, and a preference for the employment of Iranians by the company[363]. Even if a Supplemental Agreement was signed by the AIOC and the Iranian government on 17th July 1949, the situation quickly got out of control as Mohamed Mossadegh and its nationalist group, whose influence on the country's political scene was rapidly increasing, opposed the ratification of the bill by the Majlis, the Iranian parliament, introducing instead a formal bill for the nationalization of the oil industry. Shortly after the assassination of the Prime Minister Razmara and his substitution by Mossadegh himself, amid political turmoil and increasing discontent towards the AIOC, on 15th March 1951 the Majlis then passed a bill approving the nationalization, which was implemented on the 1st of May. The following two years were marked by several rounds of negotiation and talks, with the AIOC trying at first to get back into the country with an offer similar to the 50/50 deal which was becoming the standard in Middle East concessions, and subsequently to obtain compensation and a contract guaranteeing a long term supply of Iranian oil. In the meantime, Iran's production dropped virtually to zero, but an eventual supply disruption was avoided by the other majors, who increased production in the surrounding countries. In August 1953, Mossadegh was overthrown by a coup that is now known to have been staged by the CIA, primarily driven by the British and American concern about a possible Communist takeover in Iran. In September 1954, a settlement for the governance of Iranian oil was eventually reached: a new agreement was signed between the government and a consortium named National Iranian Oil Company (NIOC), in which AIOC only had a minority share in order to avoid popular resentment. The NIOC consortium was in fact established by the AIOC with 40%, Royal Dutch Shell with 14%, the five U.S. majors[364] with 5% each, and the CFP with 6%. The Iranian oil industry remained nationalized, but was operated and managed by the subsidiaries of the new consortium; the agreement had a life of twenty-five years and allowed three eventual five-year renewals, providing a 50/50 profit sharing clause, provisions for fiscal stability and international arbitration, and a commitment to the gradual increase of production[365].

363 Parra, *Oil politics*, cit., pp. 22-23.

364 The Standard Oil of California, Texaco, Gulf Oil, the Standard Oil of New Jersey, and the Standard Oil of New York.

365 *Ivi*, pp. 23-29. Notably, this last commitment was based on the power of disposal the majors could exercise

The replacement of the AIOC by a partnership comprising all the majors meant that “no company could act entirely independently anywhere in the Gulf: nothing could be decided without at least a majority consensus of the companies involved in a given country; and nothing could be done in one country that did not affect all the majors' interests in the other countries”[366]. Therefore, the governance structure based on the concessionary agreements was marked by compromise, which took the shape of a series of off-take agreements, according to which crude companies that were short of crude could take the unwanted amounts of oil deriving from the shares of crude-long companies, in return for an additional payment over and above the cost including taxes[367].

Concessionary contracts were bound for ruling the bulk of world oil production for the next twenty years; nonetheless, the 1950s witnessed the emergence of several elements that would eventually lead to the creation of a new governance structure on completely different premises. Undoubtedly, the existing framework could not result unscathed after the demise of colonial power in the Third World: the emerging issues of participation, nationalization, and sovereignty led to the renegotiation of many Middle Eastern contracts from the 1950s onwards, for example providing the inclusion of the famous 50/50 profit sharing clause, first introduced in Venezuela in 1943 and then quickly inserted in all Middle Eastern concessions[368]. Actually, the majors were quite compliant in restructuring the existing system through renegotiation, mainly for two reasons: first of all, they knew that the original terms of the concessions were unreasonable, and a refusal to renegotiate them could not only increase the hostility of the host countries against them, but also trigger nationalization measures; in the second phase, the existing agreements were so profitable that even less favourable terms would still provide massive revenues[369]. The 50/50 clause held out until the 1970s, event though it started to be breached in 1957, when the Azienda Generale Italiana Petroli (AGIP) offered Iran a 25-75 profit split in favour of the host country[370].

However, the host countries' collective stand against the tenant companies proved to be increasingly successful, above all after the creation of the OPEC in 1960: at the end of the decade, the governments' take in the Middle East amounted to about 75% of real profits. Still, it was not enough: the exporting countries aimed at the relinquishment of idle areas by the foreign firms, pursuing a strategy of increasing participation and, eventually, of

on the produced volumes of the whole region, since Iranian output would be eventually increased at the expense of another host country.

366 *Ivi*, p. 30.
367 *Ivi*, pp. 69-70.
368 *Ivi*, pp. 14-20.
369 Bindemann, *Production-sharing agreements*, cit., pp. 9-10.
370 Downey, *Oil 101*, cit., p. 11.

nationalization of the oil industry. Indeed, as nationalistic feelings arose, oil was more and more perceived as a means to get free of western influence and domination. The key concept was that of permanent sovereignty[371] over natural resources: the OPEC's Declaratory Statement of petroleum policy, adopted on 25th June 1968, recommended that Member countries should "endeavour, as far as feasible, to explore and develop their hydrocarbon resources directly. [...]However, when a Member Government is not capable of developing its hydrocarbon resources directly, it may enter into contracts of various types (…) with outside operators for reasonable remuneration, taking into account the degree of risk involved. Under such an arrangement, the Government shall seek to retain the greatest measure possible of participation and control over all aspects of operations"[372].

The unilateral increase in oil prices and the following production cutbacks implemented by Arab OPEC countries in October 1973 constituted the first instance in which legislation replaced negotiation with the foreign oil companies (FOCs); as Johany defined it, it was a "de facto nationalization of all oil deposits"[373]. Anyway, 1973 events quickened also the pace of official resources nationalization: FOCs' concession shares and producing facilities were either purchased or sized compulsorily by governments or their national oil companies (NOCs), in some cases abruptly, as when Algeria announced the nationalization of all French interests in the country in 1971, and in other instances more gradually, as it happened in Saudi Arabia during the 1970s[374]. After Iraq in 1972 and Libya in mid-1973, also Kuwait proceeded with the expropriation of the Kuwait Oil Company in 1974-75, followed by Venezuela: despite the Oil Reversion Law of 1971 establishing that only starting from 1983 the government would size all the expired concessions, in January 1976 nationalization was already effective and the new national company, Petróleos de Venezuela, was born. Finally, in 1981, also the nationalization of the Saudi oil industry was accomplished[375].

The early 1970s were marked by the development of a different governance structure for the production of crude oil: on the one hand, the new framework was marked by the demise of the old concession system and by the end of the dominance of the seven sisters; on the other, it still had an oligopolistic nature, with a new dominant group, the exporting countries, taking the lead in the upstream sector[376]. New contractual forms were needed in

371 Sovereignty is defined as the exclusive right of the government to exert its authority on all individuals and goods within its jurisdiction. See: C. Focarelli, *Lezioni di diritto internazionale: Vol. I*, Padova, Cedam, 2008, p. 261.
372 OPEC, *OPEC: Official resolutions and press releases , 1960-1983*, Vienna, Pergamon Press, 1984, p. 62.
373 A.D. Johany, *The myth of the OPEC cartel and the role of Saudi Arabia*, Dhahram, J. Wiley and Sons, 1980, p. 44.
374 Downey, *Oil 101*, cit., p. 14.
375 Maugeri, *L'era del petrolio*, cit., p. 140.
376 Maugeri, *L'era del petrolio*, cit., p. 141. On the other hand, exporting countries had a very weak presence

order to translate the new relationships between the host countries, often represented by a NOC, the Western majors, and the so called independent oil companies, who with their increasing presence in the producing countries were rising the level of competition in the market[377]. Initially, the exporters were still bound to their former concessionaires by supply contracts, like the one reached in 1976 between Saudi Arabia and its former tenant, the Arab-American Oil Company (Aramco), who would market 80% of Saudi production in exchange of a payment amounting to 21 cents a barrel[378]. Actually, the NOCs retaining some services from the foreign companies were able to obtain a better optimization of their oil production, as the departing firm would provide the transfer of relevant data and know-hows in exchange for a fee[379]; yet, these connections were going to be loosened, as alternative ties gained space and application in the market.

In 1966, after refusing to grant new concessions, because of the increasing criticism towards FOCs and the spreading of nationalistic tensions, the Indonesian government introduced for the first time the Production Sharing Agreement (PSA), nowadays one of the most common arrangements for oil exploration and development. Two main features distinguished the PSA from other existing contracts: first, the government upheld complete ownership of his hydrocarbon resources and of all the industry infrastructures; second, the entire exploration risk rested upon the foreign company[380]. Remarkably, the first PSA was signed by a consortium representing several U.S. independents, the Independent Indonesian American Petroleum Company: this new kind of relationship could become an additional opportunity to break the dominance of the big oil companies, initially reluctant to invest their capital in a venture they did not own and manage. By the mid 1970s, PSAs were defining the international governance of oil production, spreading from Indonesia to other oil producing countries in Africa, in the Middle East, in Asia, and in Latin America, to become popular also in the FSU in the 1990s[381]: they were deemed acceptable since the government retained the national ownership of its resources, and at the same time was provided with the finance, technology and know-how it lacked for their development[382].

PSAs, like concessions, involve two parties, a FOC, often in the form of a joint-

midstream and downstream; therefore, the majors were still playing a crucial role in supplying domestic and international markets with oil.

377 The independents were a variegated group, including national oil companies based in the consuming countries, such as the Italian ENI, but above all U.S. firms; the term “independents” basically distinguished them from the seven integrated majors.

378 Yergin, *The prize*, cit., p. 633.

379 Downey, *Oil 101*, cit., p. 14.

380 Bindemann, *Production-sharing agreements*, cit., p. 1.

381 *Ivi*, p. 10.

382 *Ivi*, p. 68.

venture or consortium, and a government representative, like a ministry or a NOC. Under a standard PSA, the FOC operates the oilfield, managing its exploration and development and carrying all the pertaining risks and costs; the PSA may provide the payment to the government of a royalty on gross production, which can be either in cash, meaning a direct source of revenue, or in-kind, therefore providing a free amount of crude available for domestic consumption or for export. Subsequently, the FOC can recover some of its cost by receiving an agreed share of production, referred to as cost oil, the amount of which usually varies depending on the oilfield characteristics. Profit oil, as the remainder of production is called, is then split between the two parties at a fixed percentage, and the FOC will usually pay an income tax on its share[383]. PSAs can be not only extremely profitable for an investing company, for example thanks to a particularly favourable share of profit oil: they also allow the operator to book its percentage of production as equity reserves for their entire duration[384].

In practice, PSAs can vary greatly due to the presence of several variables. For instance, the agreement can envisage further investment incentives for the FOCs, such as tax or royalty holidays exempting the operator from all the due payments for an initial period. Conversely, they can also include signature bonuses, i.e. one-off payments on signing the contract which capture a revenue regardless of the success in developing the field; or production bonuses, due where produced volumes reach a certain level. Royalties, cost oil, profit oil, and bonuses can be levied as fixed shares of production or with reference to sliding scales, commonly based on either average daily production or on the ratio of the FOC's revenue to its expenses. A Domestic Market Obligation (DMO) can specify that a certain share of production has to be made available for the host country's consumption, or that, in case of need, the NOC can obtain up to 100 per cent of the operator's profit oil[385].

Contract duration, the definition of commerciality, and the participation of the NOC in the venture are other factors that impact the actual enforcement of the PSA. The parties agree on a minimum exploration period, that can potentially be extended; if no commercial discovery is declared, at the end of each exploration phase the FOC has to relinquish a percentage of the contract area. On the other hand, if an hydrocarbon deposit is found and deemed to be commercial, the production period starts. For instance, Indonesian PSAs in the 1960s were awarded a total duration of 30 years, with an initial exploration phase lasting from 6 to 10 years[386]. All the FOC's commitments during these phases are outlined in a work programme, the definition of which is of crucial importance due to the risk factors it implies.

383 *Ivi*, pp. 13-14.
384 Maugeri, *Petrolio*, cit., p. 94.
385 Bindemann, *Production-sharing agreements,* cit., pp. 15-18.
386 *Ivi*, p. 68.

Usually, it is the government or the NOC itself who sets a benchmark for declaring a discovery commercial, in order to avoid an excessive reduction in its share of gross production, above all under those PSAs without limits to the costs recoverable by the operator. In addition, most of PSAs dispose a participation option to be taken up by the NOC if the operated field is declared commercial: all exploration costs and risks still rest upon the FOC, whereas the NOC is only carried through the production phase. The participation rate can vary greatly, from a mere 5 per cent in the case of some Indonesian PSAs, up to 50 per cent in some Algerian PSAs negotiated in the 1990s[387].

As illustrated by the case of Indonesia, where in 1988 third generation PSAs were introduced, all these factors have evolved through time, resulting in increasingly flexible arrangements: for instance, first generation PSAs allowed the FOCs to recover up to 40 per cent of exploration and operation costs each year, whereas second generation PSAs, introduced in 1976, provided no cost recovery limit for difficult areas; third generation PSAs, negotiated in a period of declining oil prices, increasing production costs and scarce availability of risk capital, even offered improved incentives for the FOCs, who explored and developed marginal fields[388].

The oil shortage (real or perceived) and the price hikes of 1973 not only quickened the formation of the new governance structure that placed oil exporting countries at the helm: they also triggered the reaction of the consuming countries. In 1974, the OECD formed the International Energy Agency (IEA), with the aim of coordinating the response of developed nations to sudden supply restrictions. Specifically, the IEA recommended to build up strategic oil stockpiles, and an increasing effort in the development not only of each country's hydrocarbon resources, but also of alternative sources of energy. In 1975, the U.S. Strategic Petroleum Reserve (SPR), to store an amount of crude oil up to 1 billion barrels, was established by President Gerald Ford as a cushion against supply emergencies[389].

After the end of the 1970s, subsequently to the 1979 oil shortage caused by the Iranian revolution, and above all after the price collapse of the mid 1986, a third governance structure emerged, marked by the diversification of oil supply sources, the complete restructuring of the oil industry through a series of mergers and acquisitions, an increasing trend towards the outsourcing of oil services, the abandonment of huge investment projects, and the growing perception of oil as simply a commodity like any other[390]. After the rule of the majors and then of the OPEC, the governance of oil finally lose its rigid structure, leaving room for free

[387] *Ivi*, p. 17.
[388] *Ivi*, pp. 68-69.
[389] Downey, *Oil 101*, cit., p. 14.
[390] Maugeri, *L'era del petrolio*, cit., p. 162-164.

market, new commercial actors, and innovative connections between all the elements of the system. Nowadays, such structure is still in force and in continuous evolution.

In the 1990s, sovereignty was no longer an issue. Producing countries were, and still are, pursuing economic and industrial development: due to general backwardness, growth was largely based on the oil sector. However, their political instability and the legal regime en force generated a substantial closure to foreign investments, as in the case of the FSU, where investments in the newly privatized oil sector was hindered by local barriers and interests, excessive and discriminatory taxes, and the lack of legal guarantees about the enforcement of contracts and property rights[391]. Underinvestment in oil field development can reduce significantly the amount of oil eventually recoverable, and even encourage bad practices aiming to maximize short term revenues regardless of the consequences for production in the long term.

At the end of the 20th century, a most relevant change affected the structure of the oil industry, which underwent a process of substantial de-integration, followed by consolidation through mergers and acquisitions. At the time of the concessionary system, most of crude oil moved internationally within the vertically integrated channels of the big oil companies, or between them according to long term offtake agreements. The de-integration of this framework, caused by the demise of the concessionary system, the shift of control to the producing countries and, in sequence, by the increase of the outside market, was then followed by a process of concentration of the industry, which in 2001 had already involved transactions worth almost $ 300 billion. In 1998, in a climate of decreasing prices and low refinery margins, British Petroleum (BP) and the American Oil Company (Amoco) announced their merger, realized through the acquisition of Amoco by BP; the transaction involved the transfer of $56 billion, and was the first of a series of operation of this kind, without considering some atypical acquisitions during the 1980s[392]. Four main reasons lied behind this new trend: the reduction of costs, reached through downsizing and the creation of synergies; the ambition to reach a better industrial and strategic position, maybe through the acquisition of companies who had already developed fruitful assets; the aim of a better market appeal, fostered by the development of economies of scale; and a reduction of competition, since its increase in the previous decade was perceived to have negatively impacted both on

[391] M.A. Adelman, "World oil production & prices 1947-2000", *The quarterly review of economic and finance,* 42, 2002, p. 186.

[392] For example the acquisition of Gulf Oil by the Standard Oil of California in 1983; such operations were however dictated by the mayhem resulting from the Iranian crisis, and later from the collapse of the market in the middle of the decade.

contractual terms and profitability in the industry[393].

In addition to IOCs and NOCs, both OPEC and non OPEC, the upstream oil industry is characterized by the presence of integrated private companies, who do not have the reach and the scale of the supermajors, by independent Exploration and Production (E&P) operators, dealing with the most risky and high-return part of the oil business, and by many actors who can be grouped under the label of upstream support, such as drilling rig contractors, oil equipment providers, and oil service providers. During the last decade, thanks to the outsourcing policies more and more often implemented by both NOCs and IOCs, such service contractors have played an increasingly important role in the development of new prospects around the world[394]. Drilling rig contractors rent oil rigs and crews to operate them, since most upstream producers do not own these infrastructures, whereas oil equipment providers rent and sell tools like drill bits and pumps; on the other hand, oil service providers act as external specialists in support to oil production in niche areas of expertise, such as seismic analysis or oil field equipment maintenance[395].

As a consequence of the high number of participants in the upstream sector of the industry, the current governance structure of oil production is provided by a network of contracts between them, which undoubtedly reflects the decisive trend towards outsourcing and high specialization. In particular, the IOCs have become more similar to general contractors, who coordinate the services of various subcontractors who supply technologies, expertise, infrastructures; at the same time, the big firm provides management and organizational skills, in addition to the vast amounts of capital needed for oil prospects, which more and more frequently are developed in difficult environments. Some authors, like Jaffe and Soligo, wonder whether this would be the new role for the IOCs in the present governance structure, acting as service contractors and providers of organizational and management skills, while the NOCs search and develop resources in new oil fields[396].

Many different contracts reflect the features developed by the oil industry in the last two decades: three widespread arrangements are the service contract, the joint-venture, and the production contract. Under a service contract, in return for a flat fee an oil company carries out E&P operations on behalf of the owner of the right on mineral resources, usually a government or a NOC lacking the necessary capital or technologies. The fee may be paid in cash or in kind; in addition, the operator is compensated for exploration costs and eventual risk capital. Service contracts have a short life, in general not exceeding ten years, and the

[393] Maugeri, *Petrolio*, cit., pp. 219-222.
[394] Maugeri, *L'era del petrolio*, cit., pp. 254-256.
[395] Downey, *Oil 101*, cit., p. 73.
[396] Jaffe, Soligo, *International oil companies*, cit., pp. 36-37.

property of all the oil produced is retained by the owner of the developed resource, without the possibility for the operator to book reserves and produced volumes. In addition, the flat fee is paid only if production takes place, making this kind of agreement quite risky for an operator and, therefore, not very popular. Nonetheless, service contracts can be considerably profitable, and represent the first step towards a greater involvement in a country[397].

On the other hand, joint-venture agreements split the costs and risk capital relative to E&P activities between one operator and the NOC or another oil company, and are usually set up when investing in high risk oil plays, such as those involving offshore and deep offshore exploration. In a joint-venture, one of the parties acts as field operator, and runs the oilfield processes daily for a payment. This kind of agreement can be required by some governments in order to increase employment rate, in addition to favour the transmission of technical knowledge to less experienced NOCs by partnering with skilled operators.

Finally, through a production contract, a contractor provides all the infrastructures necessary for the implementation of EOR techniques, usually expensive to install and maintain; in return, the owner of the mineral rights grants him a share of the revenue obtained from any production increase brought by the applied EOR methods[398].

It is also possible to have hybrid contractual forms, like in the case of Iran's buy-back agreements, halfway between a PSA and a service contract, which were tendered in 1998 for 17 exploration blocks and 24 oil and gas development projects, plus several downstream operations. Under a buy-back agreement, all risk capital necessary for the exploration and development of the oil play is provided by the FOC, who is then refunded through the sale of the produced volumes of oil and gas; the NOC acts as supervisor. Gross production is translated into gross revenue, and net revenue is obtained by deducting operating costs; each party's share is then calculated by splitting the net revenue according to an agreed formula. The contract envisages two phases: at first, the exploration of the field is carried out by the operator, and the NOC retains the right to declare if the resource deposits are commercial or not; in the latter case, the FOC will bear all the costs, and the contract will end. Conversely, if the prospect is declared commercial, the NOC will award a development contract, but not necessarily to the first stage FOC, which "has merely the right of first negotiation"[399].

PSAs and buy-back agreements present four main differences. The first one is that according to a buy-back the FOC is only awarded an exploration contract, which will not necessarily become a development one. Secondly, these contracts have a shorter duration,

397 Maugeri, *Petrolio*, cit., p. 94.
398 Downey, *Oil 101*, cit., pp. 87-88.
399 Bindemann, *Production-sharing agreements*, cit., pp. 75-78. In case the development agreement is awarded to another FOC, the first one will receive its expenditure plus an additional fee.

usually among five and seven years. Third, profit oil is calculated in a very different way with respect to a PSA. Last but not least, if the price drops significantly during the life of the contract, with the result that the revenue is not sufficient to cover the FOC's monthly share, the NOC will reduce its own share. However, the absence of an assurance of being awarded with the development contract and the short duration are the main reasons of an aloof reception of such arrangements; on the other hand, buy-back contracts are undoubtedly low cost and low risk, albeit with an high rate of return[400].

Lately, large areas have been reopened to international exploration and production, in Algeria, East Africa, Norway[401], and many other countries; often, the investors are NOCs based in developing states, such as China, India, Russia. Such openings are possible thanks to partnerships between governments, and to reasonable tax and fiscal regimes, which recognize both the long lead in times required by the development of a prospect and the risks involved. Indeed, risk allocation has become the main discriminating factor between the different contractual arrangements currently available to the actors of the upstream sector, even if many contract forms present overlapping features. The maintenance and strengthening of the present relationship network will be crucial for the future of the oil industry and for the evolution of its international governance structure in the coming years.

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400 *Ivi*, pp. 80-81.

401 J. Njiru, Firms get in line to finance drilling of oil in East Africa, http://www.nation.co.ke/Features/smartcompany/Financiers-and-insurers-line-up-for-oil-billions/-/1226/1697482/-/iwpy3pz/-/index.html, accessed March 28, 2013; Oil Review Middle East, Sonatrach and Anadarko launch production at Algeria's El Merk oilfield, http://www.oilreviewmiddleeast.com/exploration-production/sonatrach-and-anadarko-launch-production-at-el-merk-oilfield, accessed May 10, 2013; The Norway Post, Oil&Gas: New areas opened for exploration, http://www.norwaypost.no/index.php/business/15-oil-a-gasshipping/28445-oilagas-new-areas-opened-for-exploration, accessed 26 April, 2013.

3
OIL PRICES

3.1. A brief history of oil pricing systems

The history of the oil industry has been marked by a succession of oil pricing regimes, each one anchored to a peculiar set of price concepts conceived to rule different transactions between different parties. Such concepts did not always have a clear (or existing) economic meaning; additionally, they were constantly observed from different standpoints by the several actors involved.

The 1970s can be considered a watershed in the meaning and perception of oil prices: before 1973, the central issue in pricing crude oil was the generation of an income transfer from consuming countries to producing countries in terms of taxes and royalties; accordingly, price concepts had essentially a fiscal meaning, and where deprived of their allocative function. Conversely, after 1973, depletion, the necessity of developing alternative sources of energy, and the increasing dependence on Middle East oil became the crucial issues haunting the minds of producers and consumers: administered prices were still disconnected from the economic fundamentals of supply and demand, but increasingly paralleled price movements in the already expanding spot market, which eventually became the only sustainable device to manage transactions.

Therefore, four subsequent pricing systems can be identified. The first one, established as soon as in the 1920s and characterizing the industry until the mid 1950s, aimed at preserving the position of high cost U.S. oil against the increasing volumes of cheap crude imported from the Middle East. The second system, born approximately in 1955, relied on two basic concepts, posted prices and tax paid cost: during such phase, oil prices became mere fiscal concepts, as their primary role was to act as the basis for the calculation of royalties and taxes due to the governments of the Middle East countries. Remarkably, both the first and the second framework were directly linked to the level of U.S. domestic prices. In the 1970s, after the October 1973 shock, OPEC emerged as the new administrator, adopting a system that was partly a carbon copy of the previous one: price levels were set in an economic vacuum, with the significant difference of the exclusion of the majors from the negotiations. After the 1986 collapse, the OPEC pricing system was finally dismissed, in favour of prices directly linked to actual market trends.

Until the 1970s, the pricing system for internationally traded oil was rooted in what

Parra defines as fig-leaf economics: “an economic logic that never corresponded to reality but which at first was close enough to be invested with a measure of plausibility”[402]. Such system was fiction, but nevertheless an operational fiction, since it allowed the companies to reap a bonanza of profits and to finance their vertical and horizontal expansion[403]. Specifically, in the period going from the Second World War to the mid-1950s, three pricing formulas came in succession, all related to the prices as posted in the U.S. Gulf of Mexico; interestingly, they reflect the attempt to protect high cost U.S. crude from being displaced by cheaper Middle East oil, which was gaining a considerable weight not only in the overall amount of transactions, but also in domestic U.S. consumption.

The U.S., cradle of the oil industry, was a net exporter of crude until 1948. Within the country, the powerful majors operated alongside a bunch of smaller independent firms: produced oil, or at least the share that was not channeled into the vertically integrated big firms, was bought at well-head by refiners, who used to give notice of the price they were willing to pay for each grade of oil by posting it at the gate of their plant[404]. The market was open and stable, due to controls on the level of output imposed by various conservation commissions in each state, as in the case of the TRC; eventually, these agencies started to take into account also the level of demand, thus becoming “surrogate oligopolists”, providing constant and satisfying incomes to the companies[405]. Their decisions affected the level of domestic US oil prices, which in turn were used as the starting point in calculating international prices.

In such a framework, the Middle East was still a small producer compared to the topnotch U.S. oil industry and its neighbours, Venezuela and Mexico; in addition, all upstream operations in the area were under the control of the American majors, at the time securing their dominance through the consolidation of the concessionary system. Accordingly, the region acted as a price taker, and the price adopted by the majors for all oil produced outside the U.S. and then exported simply matched the Gulf coast price free on board (f.o.b.)[406] plus the freight rate to the terminal of the buyer wherever located. Such formula was referred to as Gulf plus, or Single Basing Point, and had the effect of making any “foreign” crude perfectly replaceable by U.S. exports, since the cost of substitution resulted annulled. For instance, a buyer in France would pay for Venezuelan oil a f.o.b price equal to the U.S. Gulf price plus

402 Parra, *Oil politics*, cit., p. 56.
403 *Ibidem.*
404 R. Mabro, "The international oil price regime: origins, rationale and assessment", *The Journal of Energy Literature*, 11(1), 2005, pp. 3-20, p. 5.
405 Parra, *Oil politics*, cit., p. 58.
406 F.o.b price is the price not including loading costs and freight rates.

the freight from the U.S. to France. Undoubtedly, it was not a fair system: if their production costs happened to be very low compared to American ones, other exporters located closer to the buyer were able to enjoy great margins of profit by reaping the difference in the freight rates (the so-called "phantom freight")[407].

Then the war burst out, and the situation quickly changed as more and more Middle Eastern oil started to reach the European market. During the conflict, both the allies and the U.S. navy made pressures for a reduction in the price of the so much needed oil; the navy even tried, without success, to ascertain the real level of the majors' producing costs[408]. According to the firms, there was no reason to modify the ongoing system, since imports from the Middle East were just an "extraordinary circumstance". However, to calm down the purchasers, another fictitious device, the Double basing point, was contrived**:** the first basing point in the Gulf of Mexico was mirrored by a second one in the Persian Gulf, with a resulting equalization of the price for Middle East oil and of the price for U.S. oil at the terminal. For the first time, European buyers started paying considerably lower prices for the volumes of oil coming from the Persian Gulf: estimates suggest an actual reduction from $2.95 to $1.05[409].

The aftermath of the war, characterized by the European process of reconstruction funded through the Marshall Plan, and by the shift of U.S. oil trade position from net exporter to net importer in 1948, required a further effort by the majors: they faced the strenuous task of protecting U.S. high cost oil from the competitive Middle Eastern, Venezuelan and Mexican crudes that were now supplying Europe; at the same time, they were compelled to provide the demanding consumers with adequate low prices (given that there was no reason to increase them). The selected new formula was the so-called Equalization Point**,** which set up an hypothetical competitive interface between U.S. and the other crudes at a specific location. London was chosen as equalization point: in practice, the price f.o.b. for Middle Eastern exports was the f.o.b. U.S. price plus the transport freight from the U.S. to London, minus freight to the Middle East[410]. The Middle East price was thus reduced by an amount equivalent to the difference between the transportation charges.[411] However, in 1949, due to the increasing amounts of Middle East oil actually moved by the majors to their refineries on the Atlantic coast, the London equalization point was no longer the best option, since it would have resulted in a price for Gulf coast oil paradoxically lower then the Atlantic coast one. For

407 *Ivi*, p. 58.
408 *Ivi*, p. 61.
409 F.J. Al-Chalabi, *OPEC and the international oil industry: A changing structure*, Oxford, Oxford University Press, 1980, p. 62.
410 The same reasoning was applied to exports from Venezuela.
411 Parra, *Oil politics*, cit, p. 59.

a short period the majors absorbed the difference, but the resulting two tier pricing f.o.b. for Middle East oil was not sustainable, mainly because of the repercussions on the level of products prices. The solution was to make Eastern Hemisphere consumers pay the London Equalization price, while charging Western Hemisphere buyers with a priced equalized in a second location, namely New York. After pressures from the U.S. Economic Cooperation Administration, the agency which disbursed Marshall Plan funds to Europe, all f.o.b prices were taken down as to equal the New York price: the \$2.03 price was decreased to \$1.88 in April 1949, and again to \$1.75 in July. However, the linkage to U.S. crude prices was not questioned again until 1955. Remarkably, New York equalization prices became the basis for the official postings for the trade of the huge amounts of oil produced by the majors under the concession agreements during the following decade[412]. However, after the creation of the OPEC, the link between Middle East and U.S. prices was definitively severed: in 1961, posted prices were approximately 54% of prices for similar qualities of American crudes, compared to a 100% under the double basing point pricing system[413].

If we put this evolution into an historical perspective, it emerges clearly that the Second World War gave the ultimate stimulus to the international trade of oil: Venezuelan and, above all, Middle Eastern crudes definitively replaced U.S. oil exports to Europe and Asia; protection of the U.S. industry was ensured by a system of mandatory import quotas finally becoming effective in April 1959, which allowed to maintain an high price for the oil produced domestically[414]. The lifting of oil by the majors according to the terms of the concessions was generating increasing revenues to the governments of the host countries: it must be recalled that, at the time, prices had no relations at all with the determination of their shares, which consisted of a fixed tonnage royalty, usually amounting to 4 shillings per tonne[415]. Oil was sold to buyers according to long term contract prices[416], also embedded in the concessions, and eventual changes, unilaterally implemented by the seller, were notified just from time to time[417]. In addition, oil trading, even at the international level, was mainly an intra and inter-company issue, and a proper outside market for oil did not exist[418].

In the first half of the 1950s, many features of the outlined framework evolved, thus

412 *Ivi*, p. 61.
413 Al-Chalabi, *OPEC and the international oil industry,* p.63.
414 Parra, *Oil politics*, cit., p. 46. Crude and products imports were restricted to approximately 9% of estimated demand; imports from Mexico and Venezuela were exempted.
415 Al-Chalabi, *OPEC and the international oil industry*, p. 65.
416 Prices were still based on the New York Equalization point.
417 Parra, *Oil politics*, cit., p. 61.
418 B. Fattouh, An anatomy of the crude oil pricing system, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/03/WPM40-AnAnatomyoftheCrudeOilPricingSystem-BassamFattouh-2011.pdf, accessed March 28, 2013, p. 14.

leading to the emergence of a new pricing system. First of all, it became of primary importance to manage, and somehow lock in, the massive income transfers determined by the majors' fiscal liabilities towards the host countries; in addition, the introduction of the 50/50 profit sharing clause in the concessionary framework made it necessary to establish what the actual income of the companies was, so that the governments could be sure of actually receiving the right share[419]. Secondly, there was the need of uniform and public prices available to all newcomers, buyers and producers, giving the general impression that, at least officially, there was one price for all.

The result was a new set of price concepts, the core of which was constituted by those elements ruling the peculiar relationship between concessionaire and host, namely the posted price and the tax-paid cost. Furthermore, there were two more concepts related to the flows of oil within the vertically and horizontally integrated channels of the oil industry, off-take prices and transfer prices. Lastly, also the concept of realized market price appeared on the scene for the first time.

By definition, posted prices are those made public in some conventional way by a seller or a buyer to give notice that he is prepared to accept or offer a certain sum for a barrel of crude oil or tonne of petroleum products[420]. In the case of the oil exported from the vast concessions in the Middle East and Venezuela, postings were an unilateral decision of the seller, alias the Western major (who actually happened to be also the main buyer). In October 1950, Mobil was the first firm to post its price for the Iraqi Kirkuk crude, followed in November by a posting for Arabian Light crude; postings for Venezuelan, Kuwaiti, and Iranian crudes were then introduced between 1952 and 1954[421].

The introduction of posted prices was partly related to the spread in the Middle East of the so-called 50/50 agreement, based on the idea that the host country deserved to receive as rent an amount at least equal to half the net profits earned by the companies operating in its territory under the concessions; such result was reached through the imposition of an ad hoc tax rate to the concessionaires' net income. The first deal of this kind was introduced in Venezuela by the 1943 Hydrocarbon Law, whereas the first country in the Middle East to adopt it was Saudi Arabia in 1950[422].

However, posted prices were not initially used in all the 50/50 deals. The arrangements relied on different pricing basis: for instance, Iraq's deal was on posted prices from the start, whereas Saudi Arabia obtained posted prices as basis for 50/50 only in 1955: before, the

419 *Ivi*, p. 62.
420 Mabro, *The international oil price regime*, cit., p. 5.
421 Parra, *Oil politics*, cit., p. 62.
422 *Ivi*, pp. 14-21.

arrangement was based on the price at which Aramco sold its oil to the parent companies, namely $1.43 per barrel in 1951, or 18.3% off the posted price, at the time set at $1.75[423]. By 1955, all concessions contained a 50/50 clause based on the posted prices. According to what the companies told their concessionaires, "no buyer would pay more" than the established price level; in addition, eventual discounts would not sort any effect since governments' take was based entirely on posted prices[424].

After the introduction of the 50/50, royalties were no longer calculated as a fixed fee per quantity produced: they became ad valorem, and were calculated as a share of the posted price per barrel. Likewise, posted price were the basis to compute the overall profits of the company, on which the income tax was calculated after the estimated costs of production were deducted[425]. Posted prices were the only suitable option to compute the fiscal liabilities of the companies: prices attached to spot transactions were either not assessed and reported or not representative, due to the extreme thinness of the spot market at the time; on the other hand, prices agreed in long term contracts binding the oil majors and third parties were guarded as precious commercial secrets, and as a consequence they were not gladly disclosed[426]. In accordance with 50/50, the posted price was not completely immutable: it could be modified at discretion of the companies, but only by putting forward a justification somewhat rooted in the market[427].

The system based on posted prices, royalties and income taxes had several advantages. First, clauses on financial stability and similar financial treatment of the companies by the various host countries determined the general uniformity of tax and royalty payments. In addition, thanks to the United States Internal Revenue act of 1919, the tax portion of the payments could be used as credit against the corporate taxes normally due by the majors to the American government[428]. Finally, it resulted much easier for the integrated oil firms to resist eventual requests and pressures for increases in posted prices and tax rates: the exporting countries would not have the necessary strength to form a common front until the 1960s, when the OPEC was born; even then, the first concrete results were reached only after a few years, as exemplified by the case of royalties expensing.

Until the mid 1960s, the royalties were credited against the income tax; therefore, total government take per barrel was:

423 *Ivi*, p. 349.
424 *Ibidem.*
425 Mabro, *The international oil price regime*, cit., p. 5.
426 *Ivi*, p. 7.
427 Parra, *Oil politics*, cit., p. 63.
428 *Ivi*, p. 15.

$T = (P – C)t + Pr – Pr$

or

$T = (P – C)t$

where P is the posted price, C is the estimated cost of production[429], whereas $t(0<t<1)$ and $r(0<r<1)$ are the tax rate on notional profits[430] and the royalty rate respectively[431]. It was only in 1964 that the young OPEC succeeded in changing the treatment of royalties as demanded by Resolution IV.33, adopted two years before by the Fourth OPEC conference[432]: accordingly, royalties were no longer credited against the income tax, but were treated as costs in its computation and paid in addition to it. The government's take became:

$T = (P – C – Pr)t + Pr$

or

$T = (P – C)t + Pr(1– t)$

As can be easily deducted, royalty expensing resulted in an increase of T, since a share of the royalty, namely $Pr(1 – t)$, was now paid on top of the tax on notional profit[433]; specifically, the increase amounted to 11 cents per barrel (Table 3.1)[434]. However, benefits were slow to appear, since the arrangement allowed the companies to phase out the increase in the tax-paid cost by discounting posted prices[435].

	Royalty credited	**Royalty expensed**
Posted price	1.80	1.80
Royalty at 12.5%	0.225	0.225
Cost of production	0.20	0.20
Tax revenue (t = 0.5)	0.80 = (1.80 – 0.20)0.5	0.6875 = (1.80 – 0.20 – 0.225)0.5
Total government take	0.80	0.9125 = (0.6875 + 0.225)

Table 3.1.Government per barrel take calculation: royalty credited vs. royalty expensed ($/b),1964
Source: Skeet, 1988

Yet, it is necessary to take a step back and make a distinction between the Middle East

429 At the time, average costs of production in the Middle East were extremely low, around 11 cents per barrel.
430 Under the 50/50 clause, t = 0.5.
431 R.Mabro, *On oil price concepts*, Oxford, Oxford Institute for Energy Studies, 1984, p. 7.
432 OPEC, *OPEC: Official resolutions and press releases*, cit., p. 17. "Each member country affected should approach the company or companies concerned with a view to working out a formula whereunder royalty payments shall be fixed at an uniform rate which Members consider equitable, and shall not be treated as a credit against income-tax liability".
433 Mabro, *On oil price concepts*, cit., p. 8.
434 I. Skeet, *OPEC: Twenty-five years of prices and politics,* Cambridge, Cambridge University Press, 1988, p. 27.
435 *Ibidem.*

case and the Venezuelan one. In the Latin American country, not only royalties were expensed right from the start: their calculation, along with that of the income tax, was grounded on realized market prices. Such solution was made possible by the the fact that the bulk of Venezuela oil production was managed primarily by unrelated companies, a fact that increased the country's bargaining power[436]. As a consequence, posted prices only acted like a façade, showing that there was basically one minimum prices to all newcomers[437]. In the Middle East, where production was managed by the interrelated majors, the optimal solution was to use posted prices for the computation of the due taxes, which was also a way to not antagonize the host countries. In the meantime, oil sold in arm's length sales to independent refiners was subjected to heavy discounts: however, such price was still enclosed within the framework created by the majors, and transactions on the so-called spot market were extremely spare until the 1970s, mainly consisting in attempts by the firms to correct minor imbalances at the margins of their supply, such as volumes of oil in excess due to planning errors.

As observed by Mabro, “prices used as numbers in fiscal formulas tend to become something other than prices”[438]. Indeed, this is exactly what happened to posted prices: from the moment they were chosen as reference for the computation of companies' liabilities in the 1950s, and increasingly in the 1960s after the introduction of royalty expensing, they underwent a process of fiscalization, which deprived them of any contact with the actual market trends. If in the 1950s the majors still kept an eye on the market when administering oil prices, and governments' revenue was just a dependent variable, after the establishment of the OPEC, tax revenue became the prime mover and determinant of the price. Remarkably, between 1950 and 1960, posted prices underwent only 4 changes, loosely reflecting changing conditions in the U.S. market[439]; however, after 1960, the OPEC made sure that no further change in posted prices would take place. Notably, the Organization was created in 1960 in reaction to the cuts to posted prices implemented by the majors in 1959 and 1960: taxes and royalties had become a national interest which had to be protected, the prime source of the host countries' newly found riches. The relationship between the companies and the host countries were thus reduced to the one between a tax payer and tax collector; in addition, buyer and seller were embodied by the same entity, the vertically integrated oil company. As a consequence, posted prices in the 1950s and 1960s did not have an allocative function, and

436 We have to recall that, for a short period of time, also independents operating in Libya had their liabilities calculated on the basis of actual realizations on the market.
437 Parra, *Oil politics*, cit., p. 63.
438 Mabro, *The international oil price regime*, cit., p. 6.
439 Parra, *Oil politics*, cit., p. 64.

the only relevant considerations were those related with the distributional and fiscal effects between exporting countries and companies. Anyway, inter-temporal allocation was not an issue at the time, since there was no perception of resources scarcity, and there was no actual competition in the upstream market[440]. According to the oil companies, the only prices that needed to be allocative in some measure were those of petroleum products, although distorted by excise taxes imposed by the governments of the consuming countries.[441]

Therefore, the second and crucial concept embedded in this current system was the one of tax-paid cost, defined as the sum of a government's share of prices and a company's share of expenses (T + C)[442]. As in the case of posted prices, its nature was exquisitely a non-price one. As illustrated by Mabro, in the framework provided by the 50/50 clause, the tax-paid cost "tells us that the concessionaires, in compensation for their exploration, development and production effort acquired oil at half of the posted price and were reimbursed half of the expenses.[443] In addition, the tax-paid cost could be read as an approximation of a company's opportunity cost, defined as "the lowest price at which a company can acquire an incremental barrel of oil from an alternative source"[444]. For the companies, the real significance and importance of the posted price lied in determining the cost of lifting in terms of taxes: it was just one component of the global costs of integrated operations. On the one hand, the tax paid cost became the floor price for the sellers: after the addition of adequate profit margins, the majors were thus able to finance their vertically and horizontally integrated operations[445]. On the other hand, such pricing system cast an irrevocable spell also on the host countries, representing their personal Eldorado in the form of massive income transfer generated by rent payments. Not to mention that it was a stream of gold completely insulated from market conditions[446].

Two additional concepts completed the picture of this second pricing system, and they were a direct consequence of the integrated structure of the industry. The first one is the concept of transfer price, used for the transactions between subsidiaries of the same parent company: due to its internal nature, it did not need to reflect economic conditions or sustained costs. For instance, transfers allowed to move oil from high to low tax jurisdictions, in order to decrease tax liabilities; prices were needed just to comply with reporting obligations, since

440 Mabro, *On oil price concepts*, p. 3.
441 *Ivi*, p. 11.
442 *Ivi*, p. 13.
443 *Ibidem*.
444 *Ivi*, p. 14. In the 1950s and 1960s, alternative sources to Middle East and Venezuelan oil were Soviet exports, distress cargoes sold on the spot market, and third party sales.
445 Al-Chalabi, *OPEC and the international oil industry*, cit., p. 65.
446 Parra, *Oil politics*, cit., p. 64.

it was compulsory to attach a value to every transaction, in order for authorities to make sure that neither the exporting company or the subsidiary were declaring an artificial price to decrease their taxable income[447]. Thus, also the transfer price ended up as a mere fiscal concept. In addition, another price was applied under the off-take agreements between different companies. Such long-term contracts basically aimed at to correcting crude-long or crude-short positions: the used prices were specified in the deal, and were probably much lower of the official posted price[448]. However, as aforementioned, they were not disclosed[449].

Undoubtedly, the oil price revolution enacted by the OPEC in 1973 can be considered the turning point in the emergence of a new regime for international oil pricing. Nonetheless, the seeds of the shift were already planted in the first years of the decade, which can be considered as a sort of transition period, and they soon determined the blossom of new price concepts.

The first cracks in the system started to appear as early as the OPEC was established: the success of the new Organization to put a stop to any further change in the nominal value of official prices implicitly stated a change in the way their level was set; however, the OPEC was still a sleeping partner in process. More relevant was the previously illustrated modification in the treatment of royalty payments, since its actual effect was to raise the tax-paid cost of the companies and therefore their price floor. In addition, between 1965 and 1973, global demand increased at a fast rate, and production was expanded accordingly, leading to an increase of OPEC market share from 44% to 51%. The tightening up of supply due to the cuts in oil production imposed by the government in Libya and to the disruption of the Tapline in Syria, created the conditions for a strong sellers' market and for a greater increase in OPEC governments' power[450]. Notably, for the first time, realized market prices for short-haul crudes substantially exceeded official posted prices.[451]

Meanwhile, new elements started to intrude in the exporters countries' conception of the role and management of oil prices, increasingly seen as deeply intertwined with their future as sovereign actors on the international oil scene. First of all, producing countries developed concerns about the exhaustible nature of their primary, and often sole, source of income: such feature was soon perceived as one of the crucial parameters bound to rule their long term production and pricing policies. Another one was the acknowledgment of the

447 *Ivi*, p. 56.
448 Quite ironically, such prices probably reflected the real bargaining power of the two parties.
449 Mabro, *The international oil price regime*, cit., pp. 4-5.
450 Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 15.
451 Al-Chalabi, *OPEC and the international oil industry*, cit., p. 73. Short-haul crudes included Iraqi and Saudi crudes from the East Mediterranean terminal of Sidon, and North African crudes from Libya, Algeria and Nigeria.

inescapable relationship between oil prices and their future economic development: it was necessary to set fair terms of trade, and to prevent their erosion of prices caused by both inflation and the decreasing value of the dollar. Finally, prorationing was considered as a possible means in the regulation of prices, albeit such option would not receive actual application until the 1980s.

In the early 1970s, the first significant shift in the pricing power relationship between producing countries and oil companies took place; in addition, a specific development in the governance of oil production, not directly related with the pricing system, determined the emergence of new price concepts.

The shift was represented by the signing of the Teheran and Tripoli Agreements in 1971 between OPEC Members' governments and the firms operating in their territories. Necessary premise had been the claims on various oil issues raised by Libya in 1969, the most pressing being the pricing of light and low-sulfur Libyan crude, deemed to be priced at a level too much similar to other heavier and high-sulfur crudes traded in the terminals of the Eastern Mediterranean. In 1970, after the negotiations with the companies failed, the government imposed a 30% cut to the production rates of many independents operating in Libya[452]: as a result, the exporter obtained an increase in the posted price level amounting to 30 cents per barrel, along with an increase of 5% in the income tax rate (from 50% to 55%), and annual price additions amounting to 2 cents per barrel through 1975[453].

The Libyan episode gave the final push to the OPEC, which eventually took a definitely more active role: its Resolution 120, adopted in Caracas in December 1970, urged all the Members to undertake negotiations with the oil companies aimed at increasing the tax ratios and the posted prices, at deleting any premium or discount enjoyed by the firms, and at revising price differentials[454].

The negotiations, held on a regional basis[455], led to the Tripoli and Teheran Agreements, both designed to last until 1975. The Teheran agreement, the first to be concluded in February 1971, provided, among the other things, for an increase in the posted price for Gulf crudes amounting to \$0.35/b, to be followed by annual increases in the postings of \$0.05/b, plus an annual increase of 2.5 per cent to compensate for inflation and decreasing value of the dollar. Similarly, the Tripoli agreement, signed in April 1971, provided for an

452 At the time, more than 20 companies, mostly unrelated to each other, operated in the country.
453 *Ivi*, p. 73.
454 *Ivi*, p. 74.
455 Iran, Iraq, and Saudi Arabia would negotiate in Teheran on behalf of the Gulf countries; Iraq and Saudi Arabia would also join, together with Algeria and Libya, negotiations in Tripoli on behalf of short-haul exporters.

increase of $0.95/b in the postings, which raised the official price of a barrel of 40° API crude f.o.b. Libyan ports to $3.45; in addition, the income tax rate was increased to 55%, and a surcharge had to be paid by the companies in exchange of retroactivity. Finally, also the Tripoli deal envisaged a $0.05 annual increases in the postings, plus a 2.5 per cent increase in compensation of inflation and declining purchasing power of the dollar.[456]

The real significance of the two deals did not reside in their financial impact: actually, as stated by Parra, "financially, the whole thing had been a storm in a teacup"[457]. Indeed, OPEC countries' tax revenues increase by about 40 cents, but its also true that they had not increased since the 1950s. Additionally, companies' profits were not significantly affected, since the rise in the tax-paid cost was promptly passed to the consumer in the form of crude and product prices increases; conversely, the net after-tax profits of the seven sisters rose by about 11% in 1971[458]. Also consumers' fears of a possible production shutdown by the exporting countries soon faded away.

On the other hand, the psychological impact of such events was enormous. Not only OPEC was formally recognized as an institutional actor: it had also been able to jointly make threats that were taken seriously about cutting off production if its requests remained unheard. At the same time, the companies had submitted promptly to the demands of the producing countries for the first time, since a confrontation would not be backed by their home governments. Furthermore, they committed to annual, albeit small, increases in the payments over the following five years[459].

Nonetheless, the two agreements entail an extra, but crucial, remark: in practice, they established a plan for the administration of prices to last until 1975. Once again, prices would evolve irrespective of market variations[460].

Furthermore, in the 1970s, a "non price" circumstance led to the emergence of new oil pricing concepts, destined to characterize the system for the following years: the governments of the OPEC countries sought, and obtained, a participation share in the upstream operations led by their concessionaires, following the signing of the General Agreement on Participation on 5 October 1972[461]. Participation not only involved an apportionment of costs; it also gave the governments a share in current production equal to the proportion of the equity held[462]. Therefore, even if after a few years they proceeded to outright nationalization of their

456 Parra, *Oil politics*, pp. 130-133.
457 *Ivi*, p. 134.
458 *Ibidem.*
459 *Ivi*, pp. 135-136.
460 Al-Chalabi, *OPEC and the international oil industry*, cit., p. 82.
461 Parra, *Oil politics*, cit., p. 158
462 Mabro, *On oil price concepts*, cit., p. 17.

hydrocarbon resources and oil industries, in the meantime the producing countries were for the first time endowed with a quantity of crude at their disposal. Notably, the Agreement provided for the government share of crude to be split in three: the first part, labeled bridging-oil, had to be compulsorily bought back by the companies at a price approximating the official one, in order to allow the host government to comply to its new cost obligations; the second part, called “phase-in oil”, had to be bought back by the companies if requested by the government, on a further discount off the buy-back price; finally, the third share would be sold directly by the government to third party buyers[463].

As a consequence, two new concepts joined the posted price in determining the configuration of the crude pricing structure. The first one was the Official Selling Price (OSP) or Government Selling Price (GSP)[464], to be applied by the governments to the transactions with third party buyers, usually set at 93% of the posted price; its relevance grew considerably in the second half of the decade. The second one was the buy-back price, at which the companies could buy the very oil they had previously produced: the buy-back was a convenient device, since oil did not need to change hands, and governments were able to sell their share even without disposing of adequate market outlets on their own[465].

However, such framework was responsible of considerable confusion and distortions in the first half of the 1970s. The crucial problem was that the same barrel of crude could be acquired by a company at three different prices. In addition, oil firms were able to compete successfully on the market against the crude sold directly by the governments, since they could simply add further discounts on their prices: soon, they were drawing windfall profits. Finally, the lack of transparency and information meant that there was no adjustment mechanism that allowed an eventual convergence of the various prices[466].

From a wider perspective, the participation issue was one of the first steps away from the vertically integrated industry structure, and towards the emergence of a real international market for crude oil.

By 1975 the outlined pricing system no longer existed. In September 1973, the OPEC countries, concerned about rampant inflation, and above all annoyed by the companies' windfall profits, demanded a revision of the 1971 Agreements: specifically, they requested a substantial increase in the posted price level, since the prices specified in Tripoli and Teheran were “no longer compatible with prevailing conditions and trends”[467]. A ministerial

[463] Parra, *Oil politics*, cit., p. 158.
[464] Some exporters, namely Abu Dhabi and Qatar, still use an OSP.
[465] Mabro, *On oil price concepts*, cit., p. 18.
[466] Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 16.
[467] OPEC Resolution XXXXV.160.

committee representing Gulf member countries was established to negotiate the new terms with the representatives of the oil companies. The talks started in Vienna on 8 October: 2 days before, Egypt and Syria had launched their surprise attack against Israel, kick starting the Fourth Arab-Israeli war. For the exporters the moment was propitious, to say the least. The companies proposed an increase amounting to 8% of the posted price, at the time set at \$3.011, later raised to 15%. On the other hand, the exporters proposed an increase of 100% . The firms refused, and the talks collapsed. Then, on 16 October, the ministers of the Gulf states announced an unilateral increase amounting to 70% of the posted price for Arabian Light f.o.b., which was raised from \$3.011/b to \$5.119/b, outright effective[468]. Cuts in production and an oil embargo towards the U.S. and the Netherlands were to follow.

After 1973, OPEC became the sole administrator: until 1985, oil prices would be agreed upon by its ministerial conference. However, it was not a long time before the new system became dichotomized, in more than one way: there were OPEC prices and non-OPEC prices, an official price and a spot market price, plus several splits within the Organization itself.

In December 1973, the OPEC met in Teheran: the purpose was to establish a new level for the posted price. Notably, there were three different proposals, albeit sharing a common feature: the supported price levels resulted from specific revenue targets. In particular, Saudi Arabia proposed a government take of \$5, which would require a price of \$8; Iraq and Algeria aimed at a revenue amounting to at least \$10, implying a posted price of no less than \$14; Iran supported a take of \$7, that is a posted price of \$11.65. The Iranian proposal distinguished from the others, since at the basis of the proposed price level stood the Shah's belief that it should be set at the value of alternative energy sources: oil was a noble fuel, and it had to be preserved[469].

Eventually, the conference not only opted for the \$7 government take, therefore for a posted price set at \$11.651; it also attributed such price level to a Marker Crude, namely to the Saudi Arabia's Arabian Light 34°API, thus introducing a new, and indeed enduring, concept within the oil pricing system. All the OSPs of the Member Countries would be linked to the price of the Marker Crude, that would act as a benchmark in setting differentials, that is to say discounts or premiums off the price of each crude, depending on a variety of factors, such as the relative supply and demand for a particular crude quality, its refinery yield, its location, etc[470]. Unquestionably, administering the differentials was not so simple: there was a timing

[468] Parra, *Oil politics*, cit., pp. 177-179.
[469] Skeet, *OPEC*, cit., p. 101.
[470] Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 17.

problem, stemming from the necessary assessment of past information to determine discounts and premium for a present situation; there was not a typical refiner, and in the presence of different technologies and markets the only option was approximation; finally, spot prices for products would inevitably differ between locations.[471]

Without doubt, the overall situation was rather complex. The posted price remained the basis to calculate the companies' fiscal liabilities on their equity oil, at the time a share around 75%; also buy-back prices were retained, set at 93% (later 94%) of the posted price; governments' take was made up by the royalty (at 12.5%) and by the income tax (at 55%) on non equity oil, plus realizations minus production costs on equity oil; finally, the average cost sustained by the companies resulted from the tax-paid cost of their equity crude, plus the actual price paid for buy-back crude[472]. Actually, the profit margin of the companies was also increased by the raised posted price; as for the OPEC countries, "it was as if they had found the crock of gold at the end of the rainbow"[473].

However, as new economic and political elements started to intrude the international oil market, the new system soon proved to be not easy to manage at all. One of the main consequence of the OPEC taking possession of its oil resources through nationalization measures was the disruption of the integration between the upstream and the downstream sectors of the industry: the oil companies were increasingly crude-short and dependent on OPEC supplies, even if until 1978 they still retained preferential access to Middle East oil, due to the inability of the new NOCs to manage alone the lifting and disposal of their crude.

In the late 1970s, the situation quite subverted, due to the emergence on the scene of new actors, such as independent oil companies and refiners, and oil traders; in the meantime, a new and non-OPEC stream of supply appeared on the market. When, as a consequence of the Iranian crisis in 1979, the majors saw their access to oil definitively precluded, they inevitably turned to the spot market, where for the first time the prices were leveling well above the OSPs[474]. Companies still holding long-term contracts with the producing countries were thus able to capture the differential between spot and posted prices by selling their oil to the firms that had lost their direct access to it. The rising profits of the companies resulted quite unacceptable to the OPEC producers, who also started to sell their oil directly to third

[471] Mabro, *On oil price concepts*, cit., pp. 35-36. It must be considered that the more rigid the system, the bigger the possible distortions: indeed, in 1983 the Organization tried to establish a set of differentials based on guesses about several market parameters, thought not to differ very much from the prevailing buyers' perceptions at the time: soon, the set lost relevance compared to the actual market conditions; nonetheless, it was extended through 1984.
[472] Skeet, *OPEC,* cit., p. 103.
[473] *Ivi*, p. 105.
[474] Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 17.

party buyers on the spot market.

Under such pressures, splits soon emerged within the OPEC members that led, in the context of the OPEC Doha conference in 1976, to the adoption of a two-tiered pricing system, with Saudi Arabia and the UAE setting a lower price for the marker crude than the rest of the producers: specifically, Saudi Arabia and the UAE agreed to an increase of only 5% of the posted price level (at the time $11.51/b), whereas the other Members decided to increase it by 10%, to $12.70/b[475]. Obviously, such decision meant that Aramco partners had access to the lower priced Saudi crude (the so-called "Aramco advantage"), and that Saudi Arabia was able to maximize its produced volumes: a rush to gain access to Saudi oil started in the market. The issue was quickly settled after a few months, when in July 1977 also the Saudis and the UAE accepted the new $12.70/b price[476]. However, price unification was far from reached: from then on, Saudi Arabia constantly advocated a lower price level, and a common decision on the issue was to be taken by the Organization only after years, in 1982. In the meantime, two new price concepts emerged: the one of Deemed Marker Price (DMP)[477], that is to say the price level set by the OPEC conference; and the one of Actual Marker Price (AMP), fixed by Saudi Arabia. Until the early 1980s, the AMP was set below the DMP.

The OPEC extraordinary conference held in Vienna in March 1982, came out with two strong decisions: the posted price for Arabian Light was unanimously set at $34/b; at the same time, an OPEC production ceiling of 18 mb/d was established, and quotas were allocated between the members. Saudi Arabia had no official quota, but instead accepted to act as swing producer, increasing or decreasing its production rate in order to maintain prices stable.[478]

The new OPEC policy was dictated by the recent market conditions: since 1980, demand had been constantly declining due to economic recession, leading to a situation of over-supply, since, at the same time, non-OPEC production had substantially expanded. By 1985, the Organization's market share had plummeted to 28%, from a 51% peak in 1979. The OPEC marker was just one variety of crude competing with other crudes on the international market: many producers started to set their price according to the prevalent conditions in the spot market, where more and more oil was flowing at heavily discounted prices off the official Arabian Light posting. Within the Organization, disagreements became harsher: soon Saudi Arabia, facing a relentless decrease in its revenues, was no longer keen to perform its role of swing producer, neither was favourable to any increase in the posted price level. Demand for

[475] Skeet, *OPEC*, cit., p. 135.
[476] *Ivi*, p. 136.
[477] No transaction took place at this price, it was simply used as benchmark to set all the other OSPs.
[478] *Ivi*, p. 184.

its oil had fallen from 10.2 mb/ din 1980 to 3.6 mb/d in 1985: a contributing factor, in addition to the much lower non-OPEC prices, was the cheating on production quotas perpetrated by the other member countries.

In an attempt to regain at lest a slice of its lost market share, in 1985 Saudi Arabia moved “from a defense of price to a defense of volume”, introducing a new (or almost new) pricing formula, deemed adequate to raise the competitive level of its own oil: net-back pricing[479]. According to the new deal, Saudi Arabia would not impose a fixed price on the buyer/refiner, who, conversely, would pay a sum based on the actual earnings realized by selling the crude or the refined products on the market, minus refining and transportation costs. The formula accounted for a guaranteed profit margin for the refiner, whose only concern was, as a consequence, to sell as much product as possible; in addition, he did not need to concern about the price level, since its profit was perfectly locked in within the net-back formula. Undoubtedly, the system was very complex, since a great number of variables needed to be set in advance. In addition, net-back pricing provided the perfect basis for over-supply and therefore falling prices: trying to avoid such eventuality, Saudi Arabia also established a volume cap for the amount of oil that would be sold under this kind of arrangement. Indeed, net-back deals were perceived by both sellers and buyers of crude as highly competitive, and spread quickly in the industry[480].

The incentive for refineries to run at full capacity led to an over-supply of petroleum products, which dragged down also the market price for crude: the collapse was painful, and market prices fell from $26.69/b on 1 July 1985 to $9.15 on 21 July 1986[481]. In 1987, after the crisis, the OPEC tried to revert to a fixed price-reference point, set at $18/b, for its Members' OSPs, and to production quotas; once again, Saudi Arabia had to resume the role of swing supplier. However, the system soon proved to be untenable, and the Saudis did what other exporters had already done: in January 1988, under threat from its Aramco customers, they officially adopted prices related to the spot market. The other Member countries followed suit, and by the end of March the OPEC fixed price system had sunk, leaving the stage to the current “administrator” of international oil pricing, the market.[482]

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479 An antecedent net-back pricing solution had been already envisaged by the contract between the Kuwaiti government and a Gulf-Shell partnership in ANNO: by applying a complicated formula, the 50/50 split of profits between the parties was defined by the final selling price minus all sustained costs.
480 Yergin, *The prize*, cit., p. 729.
481 Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 19.
482 Parra, *Oil politics*, cit., p. 321.

3.2. The evolution of the spot market: a short account

The current pricing system for crude oil and its derived products definitively emerged in the mid-1980s; nonetheless, the control on oil prices exerted by the seven majors, and later by the OPEC, had never prevented the presence of a spot market, where arm's length deals were concluded at prices differing from the administered ones.

If in the 1950s such one-off transactions were indeed spare, and only conceived as a quick and convenient way to correct minor planning errors in the produced volumes of crude, in the 1960s and 1970s the size and scope of the spot market considerably enlarged, due to a host of factors. First, an increasing number of actors, other than the majors, entered the international oil scene, many of them being independent companies and refiners with no direct access to crude; at the same time, the exporting countries started to look for third party buyers on the spot, lacking the necessary outlets and downstream infrastructures to dispose of their newly acquired participation oil. Inevitably, when buyer and seller were face to face, the tendency was to bargain: as a consequence, the governments' equity oil was sold during arm's length deals at prices lower than the OSP. Room for bargaining was even greater in the case of non-OPEC countries: they also set OSP, but were definitely more inclined to discounts in order to gain market share versus the cheaper Middle East oil.

In the first half of the 1970s, the growing number of transactions certainly contributed to increasing transparency of the spot market. However, it is difficult to know exactly how much oil was actually traded: estimates indicated an average of ten to twenty cargoes per month for Middle East and African crude, equivalent to a volume between 250,000 and 500,000 barrels. Price data is also uncertain: when a level for spot price was reported in the trade press, it was not specified if it referred to bids, offers or actual sales; most of the time, reports were just an assessment based on observations by traders and brokers.[483]

Indeed, it was still too early for "market-oriented" prices, since the market was still very thin, not institutionalized, and there were no solid reference points. In any case, spot prices were already regarded as a good indicator of the way the wind was blowing in the market: in mid-December 1973, right after OPEC had taken the lead, Algerian and Nigerian crudes were sold for over $16 per barrel, whereas 470,000 barrels of Iranian oil were sold at prices up to $17.04/b (against a posted price of $5.11/b). Undoubtedly, the posted price increase of 130%[484] that was announced by the OPEC on 22 December somehow took into

[483] *Ivi*, p. 210.
[484] Posted price was raised from $5.11 to $11.651, effective 1st January 1974.

account the prices realized on the spot.[485]

At the end of the 1970s, the disruption of the vertically integrated structure of the oil industry that followed the demise of the last concessions, and above all the Iranian crisis that had started in 1978, greatly hastened the emergence of the market, where panic buying took prices from $12.80 in September 1978 to $21.80 in February 1979, and even up to $40 in November of the same year, against an official price that lingered between $13 and $19 until 1981, when OPEC prices were reunified around a $34 price level for the marker crude. Paradoxically, it was the same OPEC, generally hostile towards the spot market, to compel the majors to resort to it[486]: the oil companies were thus able to take advantage of the boosting prices, and raised their profits by almost 70% in 1979 over 1978, an increase that Parra defines "the biggest give-away in history"[487].

The OPEC's general concern primarily arose from a perception of the spot market as mainly ruled by speculation, a practice that clashed with the Organization's stated mission of keeping under control and efficiently administering oil prices. However, the single members presented different grades of compliance with such official position: if Saudi Arabia, Algeria, and Venezuela abstained completely from spot crude sales, others, such as Abu Dhabi and Kuwait, were not able to resist the temptation of reaping the difference between their OSP and the spot price, which could reach even $20 million for a single cargo of crude.[488] Probably, the Organization's biggest mistake was to suppose that the spot market could be erased by the simple refusal to participate in it: several members even forbade their buyers to resell the acquired oil on the spot market, where the declining oil availability pushed prices at new heights; in turn, such upward trend was then put forward by the Organization as a justification to raise its own price floor, in a never-ending inflationary spiral.[489]

During the Iranian crisis and the following burst of the Iran-Iraq war, information about the spot market was "sparse, uncertain, and sensational"[490]. Assessment on the traded volumes, reported by Petroleum Argus based on daily communication with clients, indicated a rise from 460,000 b/d to 730,000 b/d in the two year period between 1979 and 1981, and a greater increase in 1982, when estimated sales volume reached 1.4 mb/d. Exxon even estimated that 1.8 mb/d of crude had been traded on the open market during the fourth quarter

[485] *Ivi*, p. 183.
[486] According to a report by the U.S. General Accounting Office, the majors lost access to about 3 mb/d of contract crude in 1979, with a corresponding decline in their role as international oil traders from 55% in 1978 to around 45% in 1979.
[487] *Ivi*, p. 222.
[488] *Ivi*, p. 230.
[489] *Ivi*, p. 231.
[490] *Ivi*, p. 229.

of 1979. Notwithstanding such impressive and sharp expansion, the trade press constantly remarked that the open market still resulted very thin, compared to a total traded volume for crude of about 30 mb/d. In addition, buyers, for the most part U.S. independents and Japanese refiners, used to go in and out of the spot depending on their monthly requirements, inducing sharp short term fluctuations in the amount and size of the transactions.[491]

Nevertheless, it is possible to claim that, since 1979-1980, oil started to flow massively from long-term contracts to the spot, and, from then on, it did not stop: little by little, the open market became more supplied, above all by North Sea crude, and more structured, as one-off deals were gradually replaced by serial transactions based on standardized contract terms, such as in the case of the Dated Brent contract, providing for the delivery of a cargo within an agreed time period and at a specified price, declared in $/b.[492] Soon, the Brent, along with other increasingly traded crudes on the spot, such as the Western Texas Intermediate and the Dubai crude, started to act as benchmark, in a role similar to the one played by the Arabian Light with reference to the OPEC's governments' OSP, with the only and significant difference that price of the new markers was the direct result of demand and supply interaction on the international market.[493]

Side by side with the spot market, also a forward market emerged, where transactions occurred on the basis of contracts such as the 15-day Brent, that allowed the delivery of oil at least fifteen days after the date of the deal, up to three months later. In turn, the forward market became interrelated with a futures market: at first, futures were introduced for oil products, specifically for gasoil by the New York Mercantile Exchange (NYMEX) in 1978, followed by the International Petroleum Exchange (ICE) of London in 1981; then, crude futures followed, with the WTI contract launched by the NYMEX in 1983, and the Brent contract created by the IPE since 1988.[494]

Therefore, at the beginning of the 1980s, the spot market finally developed the structured form it had lacked in the previous decade, without any (at least official) contribution by the OPEC, whose administered oil pricing system was in the meantime having its swan song. When prices started to collapse in 1985, spot prices were promptly discounted (also by OPEC members cheating on their quotas and selling their crude well below the postings), whereas the official price was still held up by Saudi Arabia, Kuwait and Abu Dhabi. As mentioned above, the staggering drop in the Organization's, and above all in Saudi Arabia's, market share, and the failed attempt to reestablish some sort of fixed-price regime in

[491] *Ibidem.*
[492] *Ivi*, p. 319.
[493] *Ibidem.*
[494] *Ivi*, p. 320.

1987, sanctioned the ultimate supremacy of the market-related system for oil pricing, the only one able to manage the new characteristics of the international trade of crude.[495]

If reported historical series of crude oil prices are observed[496], the contrast between the first long phase of posted prices, from the 1920s to the end of the 1960s, with the following OPEC administered pricing system and the final emergence of the open market is quite outstanding: prices rose slightly in the first two years of the 1970s, after the signing of the Teheran and Tripoli agreement; however, the first real jump can be observed in 1973, when the first oil shock took place. After OPEC took the lead, posted prices never reverted to their previous levels; instead they stabilized on a plateau for the rest of the decade, and that higher level was the starting point for the second oil shock in 1979-1980. Afterwards, they experienced the long decline that ended with the price collapse of 1985-1986, and with the emergence of the market-related pricing system. From then on, volatility became the rule, with alternate cycles of prices, marked by different events exerting their influence on the market, such in the case of the economic recession associated with the Asian crisis of 1997-1998, or the joint effect of speculation, buoyant demand from new emerging economies (such as China and India) and decreasing spare capacity that triggered the spectacular rise in crude prices at the end of the last decade. (Figure 3.1)

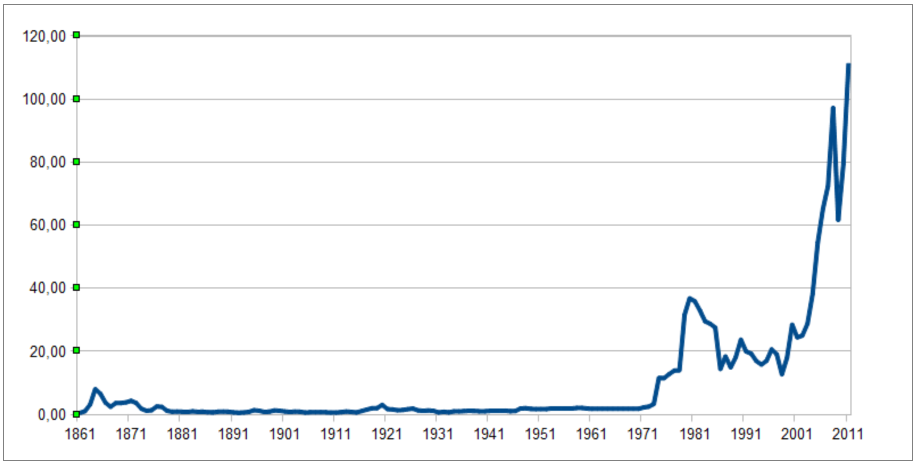

Figure 3.1. Crude oil prices 1861-2011 ($/b)
Source: BP

[495] Of course, the size of the OPEC's reserves and of its spare capacity implied that the Organization still retained some kind of influence on the ultimate level of the price, or at least some influence on the expectations and behaviour of the market players, as will be outlined in paragraph 3.6.

[496] Paradoxically, it is the non-uniformity of the data reported by all the major publications that allows such comparison: almost conventionally, for the period between 1861 and 1944 the U.S. average price is reported; between 1945 and 1983, data refers to Arabian Light posted at Ras Tanura; finally, from 1984 on, the Brent Dated price is taken into account. For further considerations on the issue, see paragraph 3.5

3.3. The current crude oil pricing system

The current oil pricing system revolves around the so-called formula pricing: the price for a certain variety of crude is set as a differential (discount or premium) to the price of a marker or benchmark crude, according to an assortment of relevant characteristics, such as quality, location, and refinery yield. Notably, the first actor to adopt this framework for oil pricing was Pemex, the Mexican NOC, in 1986, after its officials refused to adopt the then in vogue net-back pricing system[497]. At the time, the rationale at the basis of the new system suited well the market for Mexican crude oil exports: first, its main importer was the U.S., therefore Pemex did not need to design a "one-fit-for-all" system; second, Mexican exports were mainly short-haul, considerably reducing approximation in the assumptions about time lag; finally, the U.S. market did not present an high level of concentration[498], and the new market-related framework greatly fit a competitive environment.[499]

Formula pricing has several advantages: it allows to choose what will be the reference point for pricing a particular crude; it can link the price of an oil shipment to the price at the time of delivery, therefore reflecting the prevailing market conditions; finally, the same exporter can diversify its pricing policies by adopting different formulas for different destinations.[500] In addition, prices determined through formula pricing can act as a basis of practically any kind of transaction, both in physical and financial markets. The regime requires the identification of two elements: the benchmark price and the differentials to be applied. The formula can be simply described as:

$P_X = P_R \pm D$

where P_X is the price to be determined, P_R is the reference price, and D the differential.

Currently, the main international benchmarks include the Brent-Forties-Oseberg-Ekofisk (BFOE, also referred to as Dated Brent)[501], the WTI, the Argus Sour Crude Index (ASCI)[502], the Forties, the Dubai, and the Oman.[503] Notably, the underlying physical base of these marker crudes is very narrow, amounting to about 3.5% of global oil production (slightly more than 3 mb/d). In addition, some of them are characterized by rather illiquid spot markets: for instance, as reported in Table 3.1, Forties, Dubai and Oman are not even

497 Mabro, *The international oil pricing regime*, cit., p. 8. Their refusal was mainly based on concerns about possible corruption in the long negotiations with the buyers required by a net-back deal.

498 That is to say, the U.S. market was characterized by a large number of sellers and few buyers.

499 *Ibidem.*

500 Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 23.

501 Dated Brent acts as a trade classification for the group of sweet light crude comprising Brent, Forties, Oseberg, and Ekofisk crudes.

502 The index comprises three crude oils, namely Mars, Poseidon and Southern Green Canyon.

503 *Ivi*, p. 28.

transacted on a daily basis; the difference between the U.S. market (where both WTI and ASCI are traded) and the Dubai market is quite staggering, with the former characterized by around 600 spot trades per calendar month and the latter not exceeding 3 per month.[504] However, it has to be specified that such difference is partly related to the characteristics of each benchmark, namely its physical base and whether it is a pipeline or a waterborne crude.[505]

First-quarter 2010 averages by Argus	ASCI	WTI CMA + WTI P-Plus	Forties	BFOE	Dubai	Oman
Production (MBPD)	736	300-400	562	1,220	70-80	710
Volume Spot Traded (MBPD)	579	939	514	635	86	246
Number of Spot Trades per Cal Month	260	330	18	98	3.5	10
Number of Spot Trades Per Day	13	16	<1	5	<1	<1
Number of Different Spot Buyers per Cal Month	26	27	7	10	3	5
Number of Different Spot Sellers per Cal Month	24	36	6	9	3	6
Largest 3 Buyers % of Total Spot Volume	43%	38%	63%	72%	100%	50%
Largest 3 Sellers % of Total Spot Volume	38%	51%	76%	56%	100%	80%

Table 3.1. Some features of the main benchmark crudes
Source: Fattouh, 2011

The first issue raised by formula pricing is the determination of the price for the benchmark crude: theoretically, such price needs to be generated in a physical market where barrels of oil are sold and purchased, since, according to the economic theory, prices arise at the margins of the physical market[506]. However, the last two decades have witnessed an increasing relevance of the financial layers in the determination of crude oil prices, as the forward markets for crude oil, namely the futures exchanges and the OTC market, attracted more and more transactions and actors. As a consequence, the price of the key benchmarks taken into account by formula pricing can be based either on physical oil trading, such as in the case of the Dated Brent, or on the financial layers surrounding a particular benchmark, as in the case of the Brent Weighted Average (BWAVE)[507]. Therefore, it is necessary to make a

504 *Ivi*, p. 28.
505 U.S. benchmarks are pipeline crudes, with small trading lots, whereas other markers, such as Brent and Dubai, are transported by cargoes, thus implying large trading lots.
506 *Ivi*, p. 9.
507 The BWAVE is an index calculated as the volume weighted average of all the futures price quotations for the Brent contract obtained on the futures market during a given trading day.

first distinction between the spot markets and the forward markets for crude oil.

The physical delivery of crude oil can be organized either through term contracts or through spot supply contracts. Term contracts are negotiated bilaterally, and dispose the delivery by a seller of specific quantities of oil to a buyer at scheduled dates in the future.[508] Conversely, spot contracts dispose the delivery of a specified quantity of oil at an agreed location as soon as possible. Due to the logistics of crude oil transportation[509], it is possible to differentiate between a spot price, i.e. the price of oil for immediate delivery, and a forward price, i.e. the price of oil for delivery at a specified date in the future. Prices are usually agreed through formula pricing[510].

The element of forwardness has gained through time increasing relevance, leading to a staggering expansion of futures and forward markets for crude oil, which today play an essential role in the process of price determination. Such markets perform two relevant functions: they allow traders to hedge against price risk, and they can be used as means to speculate on future price movements. Oil for future delivery is mainly traded using futures contracts or over-the-counter (OTC) forward contracts.

A futures contract gives to its owner the right to buy a standardized quantity of oil for delivery at an agreed date in the future[511]. The peculiarity of the futures contracts is that they allow to never actually take or make delivery of physical oil, since trading can simply consist in buying and selling the future itself, making a profit if the price of the contract falls or increase respectively. Therefore, futures for crude oil are said to deal with paper barrels, as opposed to physical "wet" barrels. Of course, if a buyer of a futures contract holds it past its expiry date, it can potentially take or make delivery of physical crude: less than 1% of such deals are eventually converted in wet barrels, but what actually matters is that the link with a physical quantity of crude still exists, since, when the contract expires, the paper contract value converges to physical oil prices.[512] Futures contract are traded exclusively on regulated exchange markets, which provide three important advantages: they are extremely liquid, almost completely removing the risk of squeezes and distortions; they provide instantaneous and reliable information on the current price for futures contract, since prices are posted by the Exchanges as soon as the relative deals, bids, and offers are recorded; at the same time, also the volumes of daily transactions are reported, providing transparent and accurate

508 Downey, *Oil 101*, cit., p. 318.
509 A cargo can require up to 45-60 days to be delivered.
510 Notably, some countries, among which Abu Dhabi and Qatar, still use an OSP; however, their level is usually strongly linked to the Dubai and Oman benchmark prices.
511 *Ivi*, p. 331.
512 *Ivi*, p. 325.

information readily available to all traders.[513]

The two most important futures contract are the WTI crude oil contract, traded by the Chicago Mercantile Exchange Group (which in 2008 acquired the NYMEX, original trader of the WTI future), and the Brent crude oil contract, traded by the ICE based in London. One WTI contract refers to 1,000 barrels, and its price is quoted in dollars; past its expiry date, the owner must take or make delivery of such quantity of crude at Cushion, Oklahoma. Likewise, a Brent contract is quoted in dollars and equal to 1,000 barrels; if held past its expiry date, it obliges to take or make delivery of the crude at the Sullom Voe terminal, Scotland. However, differently than in the case of the WTI contract, the trader has a choice between cash or physical settlement. If he opts for the former, the reference will be the ICE futures Brent Index, as published at noon the day after the expiry. Both the WTI and the Brent contract are traded electronically, the first on the Globex platform, whereas the second on the Intercontinental Exchange platform.[514]

On the other hand, OTC forward contracts are completely customizable, and traded between two counterparties on informal markets.[515] In the majority of cases, an OTC arrangement is cash settled, and does not involve any physical oil component.[516] A particular type of OTC contract is the swap, which allows to shift price movement risk from one trader to another: for instance, an airline can swap the risk of rising fuel prices to a bank, with the result that, if prices effectively rise, the bank will pay to the airline the price increase multiplied by the quantity of barrels specified in the contract. Contrariwise, if prices fell, the airline will pay to the bank the benefit of the lower price level.[517]

Physical, OTC and futures markets for crude oil imply different price discovery processes. As aforementioned, in the case of the futures market, prices are observable in real time; conversely, in the case of OTC and spot transactions, prices are object of calculation and assessment by the so-called Price Reporting Agencies (PRAs), such as Platt's Oilgram and Argus, which act as “a mirror to the trade, and provide transparency on what would otherwise be a collection of bilateral deals”.[518] It has to be noticed that market participants are not legally obliged to report their deals to the PRAs or to any other body: information can be shared on a voluntary basis, or in compliance to companies' reporting policies. In order to ensure a sufficiently wide basis for the assessment process, confidentiality agreements are

513 Mabro, *The international oil price regime*, cit., p. 11.
514 Downey, *Oil 101*, cit., pp. 355-357.
515 However, there are some industry standards for the most common OTC transaction types.
516 *Ivi*, p. 335.
517 *Ibidem.*
518 Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 30.

often signed between the PRA and the counterparties.[519]

The role played by the Agencies is essential in the case of physical benchmark prices, since they emerge in markets often illiquid, i.e. where a sufficient number of representative deals or transactions does not take place, or opaque, i.e. where the transactions concluded between the parties are not directly observed by the other participants.[520]

Agencies use several methods to identify the oil price for the various benchmarks, and the result can be a price expressed as an index or as an assessment. Indexes are prices identified through the application of a direct mathematical formula, as in the case of the volume weighted average system, used to identify the BWAVE: all futures price quotations obtained for a specific contract are used to construct an average, where the weights are the shares of the relevant volume of transactions on the considered trading day.[521] Otherwise, prices can be identified through an assessment, that is to say through the interpretation of relevant data collected by reporters: an example is provided by the market-on-close methodology (MOC). The MOC, which Platt's started using in January 2001, replacing the previously applied volume weighted average, requires the establishment of a time window: only deals, bids and offers observed within such time span (usually 30 minutes at the end of each trading day) are used to assess prices; the result will also be adjusted according to information derived from the financial layers, thus allowing an accurate assessment also of time and inter-crude spreads.[522] Notably, the methodology and hierarchy of information applied by the PRAs differ from market to market, depending on the relevant characteristics.

As previously alluded to, both exporting countries and individual traders more and more frequently choose to base formula pricing in their contracts on the benchmark price as determined in the futures market, for example by replacing Dated Brent with the IPE's BWAVE. Such shift is related to some problems presented by the physical markets for the reference crudes. The crucial issue is that such markets are becoming thinner and thinner, since most of the markers is characterized by declining production rates; accordingly, the number of spot transactions has decreased significantly, making the physical markets increasingly illiquid, and therefore more easily subject to squeezes and distortions, since a small number of reported deals can heavily influence the price assessment process.[523] In addition, the fact that price discovery is carried out by institutions “external” to the market,

[519] *Ivi*, p. 33.
[520] *Ivi*, p. 26.
[521] *Ivi*, p. 25.
[522] *Ivi*, p. 31.
[523] Mabro, *The international oil price regime*, cit., p. 15. Squeezes are however becoming less frequent as laws against the abuse of market power are implemented by the regulators, and as the spot markets are more and more structured, also thanks to the collaboration between PRAs and market participants.

the PRAs, implies that their decision making processes can influence the assessments, and even lead to the delivery of different prices for the same marker.[524] By contrast, futures market are characterized by a large volume of transactions and transparent reporting of information, implying less room for manipulations and interferences.

Nevertheless, one of the most peculiar features of the current pricing system is that crudes with relatively low produced and traded volumes still set the oil price for far larger markets, such as that for Gulf oil: the main problem is that, despite the massive output, these crudes (with the exception of the Dubai) lack both a liquid futures market and a sufficiently developed spot market to act as benchmarks.[525]

The second element related to formula pricing are differentials, which can be either set by the same exporting country or assessed by the PRAs. In the first case, the differential is usually set in the month preceding the loading month, and is adjusted by the exporter on regular basis, monthly or quarterly, in order to compensate for eventual imbalances due to the time lag between the setting and the time of loading, since the market can present different conditions. Movements in differentials are related to various features of the considered crude, such as quality, refinery yield, and changes in the physical base of the marker through time.[526] In addition, when establishing the level for the differential, the exporting country has to take into account also how its closest competitors are pricing their crude with respect to the marker: competition implies that crude oils of the same quality and destined to the same region tend to trade at very narrow differentials, as in the case of the Saudi Arabia Light (33.0° API) and the Iranian Light (33.4° API): differentials do not exceed \$0.30 most of the time.[527]

Notably, absolute price levels are rarely the object of trading in financial markets, since taking a position against an absolute price rise or increase is far too risky for almost all participants; conversely, financial markets are characterized by trading in differentials, which allow participants to hedge against risks of time, location, grade and volume.[528]

At this point, the situation can appear rather confusing, and the spontaneous question is: where, in the last instance, is the price for benchmark crudes determined? In the financial or in the physical layer? Actually, as observed by Fattouh, the most plausible answer is that the two layers are inextricably interconnected, and they jointly contribute to the process of price identification for the physical benchmark, as clearly reflected by the assessment

524 See paragraph 3.5.
525 Fattouh, *An anatomy of the oil pricing system*, cit., p. 70.
526 *Ivi*, pp. 21-22.
527 *Ibidem.*
528 *Ivi*, pp. 74-75.

procedures undertaken by the PRAs.[529] More specifically, the author argues that the absolute level of the benchmark price is set in the futures market, whereas the financial layers set the differentials, which in turn are used by the PRAs to adjust their price level assessments. Therefore, to say that the price for the physical benchmarks drives the price of the derived financial instruments, or vice versa, risks to be a gross oversimplification.[530]

Finally, the phenomenon of the "financialization" of the crude oil markets requires a brief remark. When the current pricing system was born, the fact that prices used in the formula were anchored to the price of a specific physical base undoubtedly made traders comfortable. Conversely, even after more than two decades, price derived from paper markets still rise some suspicion: the main argument advanced by skeptics is that such prices are not determined by physical barrels, but instead refer to the real object of trading, namely the financial contract. In addition, a further problem has emerged: in recent times, the futures market have attracted an increasing number of financial players, such as pension and hedge funds, investors, technical traders, and high net worth individuals; such actors have entered the scene mainly for portfolio diversification and speculation purposes. The following question arises: in what measure such "financialization" of the market affects the oil price? Different authors express different positions. According to Fattouh, the impact of this process on actual price levels is limited: shifts in the expectations regarding the financial layer have only small effects on the basis. On the contrary, Engdahl express a completely different point of view, by claiming that "60% of today's oil price is pure speculation", driven by trader banks and hedge funds, and favoured by gaps in the regulation of derivative trading.[531] However, oil prices in the past proved to be definitely more sensitive to shifts in the expectations about physical oil supplies, rather than to shifts occurring in the financial layer.[532] In addition, the most part of the participants in the forward markets is still "physical", including players such as refiners, oil companies, and other physical traders.[533] Therefore, it is possible to assume that oil prices are still mainly linked to more or less bleak prospects about future production, and that pure financial speculation still plays a minor role, being relegated to unregulated markets.

529 *Ivi*, p. 74.

530 *Ivi*, p. 75. However, Fattouh notice how the issue still remains quite under-researched, probably due to the fact that it is both "difficult to construct theoretically, and to test empirically".

531 F.W. Engdahl, Perhaps 60% of today's oil price is pure speculation, http://www.globalresearch.ca/perhaps-60-of-today-s-oil-price-is-pure-speculation/8878, accessed March 28, 2013.

532 B. Fattouh, L. Mahadeva, Financialization in oil markets: lessons for policy, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2012/12/Financialization-in-oil-markets.pdf, accessed March 28, 2013, p. 5.

533 Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 74.

3.4. On oil price talking and oil price reporting

Nowadays, it is not unusual for crude oil prices to hit the headlines, or to be object of major and in-depth studies trying to talk out every side of the issue; books and articles that focus on their historical evolution are almost innumerable, and whoever is looking for historical series and indexes can easily come into their possession simply by accessing online databases, by consulting statistical reviews or trade journals archives. However, two remarks are needed. The first one points out how oil prices talks had not always characterized the public domain: on the contrary, they were at first discouraged by the main actors involved, but then fueled by the events that shook the industry and the market in the 1970s and 1980s. The second remark concerns historical data series for oil prices: on the one hand, they are conceived to provide a comprehensive look on the evolution of oil price levels since the very beginning of the industry; on the other hand, such result requires some kind of inconsistency that sometimes risks not to be fully understood.

Until the mid-1950s, virtually nothing was published on the topic of oil prices. Of course, such statement does not refer to the price level: as aforementioned, first in the U.S. oil industry and then also for Middle East crudes, prices were posted, that is to say publicly available by definition. A simple and quick research run through the New York Times historical archive allows to find a considerable number of entries for "crude oil price" during the period 1900-1945, almost all related to articles that reported cuts and increases in the U.S. posted prices for crude and refined products[534]. Conversely, the majors discouraged any publication about the economics of an industry in which "competition was nil, demand was booming"[535]. Public discussion about how oil prices were actually determined was taboo: the industry made sure to be perceived as highly competitive, and to classify the subject of oil prices as too complex to be fully understood by the public[536]. Parra reports two interesting examples. The first one is a paper presented by Walter J. Levy, a famous U.S. oil expert, at the World Petroleum Congress held in Le Hague in 1951. The initial sentence of the paper, titled "The past, present, and likely future price structure for the international oil trade", reads: "The structure of world oil prices is intimately related to the pattern of competitive oil world supplies and demand, and any basic changes in the supply pattern are sooner or later reflected

[534] ProQuest, The New York Times (1851-2009), http://search.proquest.com/hnpnewyorktimesindex?accountid=17274, accessed 15 May, 2013.
[535] Parra, *Oil politics*, cit., p. 64.
[536] *Ivi*, p. 67. Indeed, after the publication of the famous report by the Federal Trade Commission titled "The international petroleum cartel" in 1952, the oil industry started to be literally demonized (and blamed for every price rise) by the public opinion for its oligopolistic nature.

in the price structure"[537]. As previously stated, the pricing system at the time was not based on competition at all, but was carefully devised to protect as much as possible U.S. crudes from the cheaper Middle East oil.[538] In addition, Parra highlights how "the whole piece can be read without discovering whether there were two, twenty or 200 companies of any significance in the international trade" at the time[539].

The second example, which somehow marks the changing public attitude towards the oil majors, is the study titled "The price of oil in Western Europe", published by the UN Economic Commission for Europe in 1955. Basically, the study claimed that the current oil price could not be explained in terms of competition, concluding that "the wide divorce which persists between prices and production costs in the Middle East suggests that, if this link were severed, the price charged on sales to European countries by the Middle East could be significantly lowered without adverse effects on the further development of its crude oil production"[540]. Actually, the overall report was quite cautious, but it triggered sharp reactions by the majors, as illustrated by the words of Shell's chairman Sir Frederick Godber, who described its conclusions as based on incomplete knowledge, in addition to erroneous and academic.[541]

The situation definitely changed as power over the management of Middle East oil resources started to slip away from the hands of the majors, and was completely reverted by the events of October-December 1973, which threw oil prices at the very center of the public debate. From then on, academic publications on the subject have been practically countless; simultaneously, oil and its price have increasingly become an usual topic for the media. Since newspapers mirror in some measure public concerns and questions on a particular issue, the increasing number of articles about oil price levels, and on the reasons of their cuts and increases, either promoted by the OPEC or triggered by political turmoil, undoubtedly let out the mounting importance of the debate on oil pricing. If the New York Times historical archive is consulted, 12,647 entries related to "crude oil prices" can be found for the period comprised between 1940 and 1969; conversely, the result nearly doubles for the period between 1970 and 1999, where 22,699 entries are found. The decade 1960-1969 is characterized by "only" 3,505 entries related to the query, compared to 6,418 for the 1970s, and to 9,303 for the 1980s. Notably, the years with the highest numbers of entries are 1974

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537 Levi W.J., *The past, present, and likely future price structure for the international oil trade*, Leiden, E.J. Brill, 1951, p. 6.
538 See paragraph 3.1.
539 Parra, *Oil politics*, cit., p. 65.
540 United Nations Economic Commission for Europe, *The price of oil in Western Europe*, Geneva, 1955, p. 47.
541 Parra, *Oil politics*, cit., p. 66.

(1,179 results), 1979 (1,200), 1986 (1,225), and 1990 (1,232).[542] Paradoxically, talking about crude oil prices became more and more frequent right at the time in which oil prices themselves were becoming increasingly complex to understand.

The second issue that needs to be highlighted concerns price reporting, in particular the reporting of historical series for crude oil prices. As aforementioned, when data pertaining the historical evolution of crude oil prices are reported, it is not unusual at all to come across a statistical inconsistency. Usually, reported data follow this kind of pattern: for the period between 1861 and 1944 the average for U.S. posted prices is reported; then, between 1945 and 1983, data switch to Arabian Light posted at Ras Tanura; finally, from 1983-1984, the price of one of the main benchmarks, namely WTI or Brent Dated, is taken into account (Figure 3.2).[543] Obviously, the result is a series that patches together price concepts that differ greatly between each other[544]; in addition, if for example the 1945-1983 period is considered, data will indeed refer to posted prices, but it is possible to claim with a certain degree of confidence that prices posted in 1950 were guided by a logic differing completely from the one influencing the level of the postings in 1974, since both the decision makers and the interests involved had changed through time. Similarly, the influence of the financial layers in determining the level of crude spot prices in the mid-1980s is nowhere nearly comparable to the weight that such layers acquire today in the process of price discovery.[545] Therefore, there must be a criterion other than consistency, which guides the selection of the reported data, and such criterion is relevance, both economic and political. Without sacrificing consistency to the advantage of relevance, it is not possible to assemble a meaningful trend able to cover the considered time period. By way of illustration, it suffices to take into account spot prices: until the late 1970s, there was no systematic, and above all no consistent reporting of their level, due to the lack of both a suitably developed and structured open market for crude oil, and of an adequate number of transactions, the necessary premise for an assessment able to deliver representative results. In a similar fashion, the choice to report the Arabian Light posted price since the mid-1940s, instead of keeping the U.S. average as the main reference until the 1960s, clearly expresses where the focal point of the market had shifted, namely away from the U.S. domestic oil industry and towards the Middle East.

In conclusion, it is certainly possible to consider the evolution of crude oil prices on the whole, even by constructing a “mixed” series, since what eventually matters is the actual

542 ProQuest, *The New York Times (1851-2009)*, cit.

543 See for instance the BP Statistical Review of World Energy, the ENI World Oil and Gas Review, and the OPEC Annual Statistical Bulletin.

544 See paragraph 3.1.

545 See paragraph 3.3.

relevance, both political and economic, of the selected data. At the same time, it is of crucial importance to bear in mind the existence of eventual voluntary inconsistencies, in order to truly read between the lines of the message conveyed by a particular piece of information.

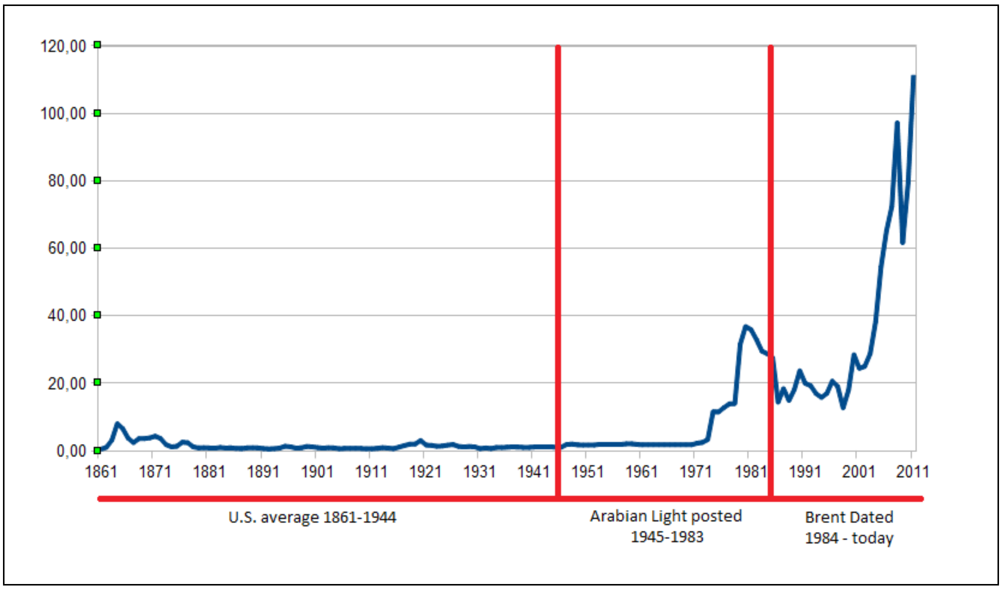

Figure 3.2. Crude oil prices references 1981-2011, ($/b)
Source: BP

3.5. Oil prices and institutional interferences

When considering the overall evolution of the oil pricing systems, it is possible to extrapolate at least one constant feature: until the 1980s, there has been an institution taking over the task of administering oil prices. If at the beginning such role was performed by the Western majors and by the TRC, which was in charge for the control of spare capacity in the U.S. up to the 1970s, after the 1973 oil shock the OPEC took the lead. The Organization held such position at least until the mid-1980s, when it was displaced by the current "administrator" of oil prices, the market. Therefore, any interpretation of oil concepts must be related to the characteristics of the surrounding institutional system. In addition, the transition from one pricing system to another has occurred in correspondence to major shifts in the contemporary economic and political framework, endowing every regime of great specificity and significance[546].

Oil pricing systems then highlight the economic and political imbalances of the surrounding international environment. With reference to the period between the birth of the industry and the 1960s, Al-Chalabi claims that "prices always reflected the overall political strategies of the Western countries in their determination of economic relations with the Third

[546] Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 14.

World"[547]; more specifically, they were expression of the extents to which the host governments were deprived of their sovereignty on natural resources[548]. Indeed, as previously illustrated, the first pricing system had its focal point in the preservation of the dominant position of the U.S. domestic oil industry, a goal that was pursued by envisaging a pricing formula able to lower the competitiveness of the abundant and cheaper Middle East resources, at the complete disposal of the Western majors. However, in the 1950s, a different purpose intrude: the West needed massive supplies of crude oil at stable and low prices, and Middle East oil was the only available option. The system was still managed by the big oil companies, but the means adopted were partially different, being embodied by the posted prices. If, on the one hand, the postings were just another expression of the colonialist-like relationship between consuming and exporting countries, on the other hand they set in motion some unforeseen mechanism, namely the flow of dreamlike revenues in the pockets of the host governments. Undoubtedly, such countries were entirely dependent on this new source of income that at last looked like the perfect opportunity to finance their economic and social development; but it was also true that, no matter how still economically backward, the exporting countries were, and still are, the holders of the bulk of world oil resources. The situation was due to change, and it did: the creation of the OPEC, the cancellation of the concessions, the issues of participation and nationalization, all pointed towards the demise of the pricing system administered by the Seven Sisters, which timely happened when the OPEC members unilaterally decided to increase the level of the postings in 1973, paving the way for the first oil price shock. Notably, the 1973 events meant also the informal expiry of the Teheran and Tripoli agreement, which had represented an important landmark in the assertion of the OPEC as a relevant player on the international oil scene: as in the case of the concessions, such arrangements had no longer reason to exist, since the majors had been practically pushed out.[549]

In 1973 the OPEC became the new administrator of the oil pricing system, which would be based on the linking of all the member countries' OSPs to the posted price of an official marker crude, namely the Saudi Arabia's Arabian Light. However, the task did not prove so easy to manage. Negotiations within the Organization to establish the level for the posted price were difficult, due to the different position and interests of each member. In particular, the marker price, Arabian Light, implied two different concepts of sovereignty: that of the OPEC, in charge of its administration, and that of Saudi Arabia, since the marker price

547 Chalabi, *OPEC and the international oil industry*, cit., p. 61.
548 *Ivi*, p. 57.
549 Parra, *Oil politics*, cit., p. 179. As noted by Parra, the agreements were never formally annulled.

was also the price of its more valuable national resource.[550] In addition, the members of the Organization pursued different price objectives, related to their own peculiar interests: in the 1970s, one of the most notable and endurable confrontations took place between Iran, a price "hawk", always trying to push for an increase in the level of the postings in a never-ending quest for greater and greater revenues, deemed essential to finance the Shah's vision of a Great Civilization for his country, and Saudi Arabia, a "dove", endowed with massive reserves and (at the time) small population, trying relentlessly to hold the price down, in order to preserve its market share. More than once, such situation resulted in a two-tier pricing system, characterized by a lower posted price for the marker and higher postings for the OSPs.[551]

In the late 1970s, a massive flow of non-OPEC oil invaded the market, thus making the task of administering prices even more difficult, above all in the presence of an expanding spot market were the OPEC's OSPs were heavily discounted. Nevertheless, the Organization was able to hold on until the mid-1980s, not only because it was powerful, but more importantly because it was perceived to be powerful. However, in the early 1980s it definitely lost its grip: the adoption of a quota system was not sufficient to sustain prices, provided the fact that most of the member countries were cheating, producing more than allowed by the imposed ceilings, in an attempt of exploiting the situation to expand their own market share. The refusal of Saudi Arabia to continue to perform the role of swing producer, which had greatly damaged its revenues and its share in the market, and the introduction of the net-back deals, were the prelude for the price collapse of 1985-1986, and for the final emergence of a market-related pricing system for crude oil.

The current oil pricing system has now survived for more than 25 years, and apparently all the major players have no intention of "rocking the boat": their main concerns are related to price behaviour and to its impact on the macroeconomic level, not to the pricing structure itself, despite its many flaws.[552] As in the case of the previous oil pricing systems, the current one suits the vested interests of the actors involved. As stated by Mabro: "Banks and hedge funds are wedded to it. Some of the major oil companies have trading arms that operate in these derivative markets like financial institutions. Their trading profits are substantial. OPEC accepted it because they thought that it will protect them from blame. It didn't. And the question always asked is: What is the alternative? I will simply say that no alternative will ever be found if nobody is looking for one".[553]

[550] Mabro, *On oil price concepts*, cit., p. 28.
[551] See paragraph 3.1.
[552] Fattouh, *An anatomy of the crude oil pricing system*, cit., p. 10.
[553] R. Mabro, "The oil price conundrum", Oxford Energy Forum, 74, 2004, p. 14.

Despite the lack of an administrator other than the market itself, it is still possible to make some considerations about two quite different kinds of institutional interferences on the current pricing system: the first one concerns the PRAs and their role in the assessment of price levels, whereas the second suggests the need to analyze the new role of the OPEC and of its signals to the market.

The PRAs play an indispensable role in the oil industry, since the prices they assess for the benchmark crudes will act as the basis for a massive number of transactions. However, they are not mere observers: by setting specific internal standards and choosing to apply a particular assessment methodology to a certain market, they enter the decision making territory. Therefore, they indeed act as "mirrors to the trade", but it is also true that "the reflection in the mirror can affect the image itself".[554] The setting of a specific time window in which the assessment will took place, the way indexes are constructed, the kind of information that will be taken into account in case there is not a sufficient number of concluded observable deals, in a few words, all the assumptions behind the methodologies applied can even lead to the production of different prices for the same benchmark.[555] However, the main aim of a PRA is to provide an "intelligent assessment", since its very existence relies on its reputation. The market participants will thus base their evaluation of the role played by the Agency not only on the methodologies applied, but also on the internal measures adopted to protect integrity and efficiency, and on the accuracy of the assessments.[556]

Finally, the role of the OPEC in the current market-related pricing system undoubtedly requires a brief commentary, since, after losing its role of price administrator, the Organization still continued to exert an indirect, but sometimes important, influence on oil price levels. From the late 1980s, the OPEC has been performing a sort of "residual" supplier role, covering that part of demand which cannot be satisfied by non-OPEC production (the so-called "call on OPEC"): its production quotas are set trying to anticipate the magnitude of such residual demand, and oil prices also fluctuate following the accuracy of this assessment. As a consequence, the OPEC can also try, by cutting or increasing its output rates, to influence price levels towards a desired target zone. However, the actual price will probably differ from the target, and the Organization will have to be content of a second best.

The effectiveness of the signal relies on two circumstances. The first one is external to the Organization, depending on how the conveyed message is received and interpreted by the

554 Fattouh, *An anatomy of crude oil pricing systems*, cit., p. 30.
555 *Ibidem.*
556 *Ibidem.*

market participants. The second one is internal: a positive response of the market to an OPEC signal is more likely if the Organization is perceived as unite in its policy decision, and if the decision itself sounds credible.[557]

The indirect pricing power of the OPEC is not constant over time, since economic and political factors intrude. First of all, the magnitude of the produced effect greatly depends on actual market conditions, i.e. if the market is slack or tight. Secondly, the growing importance of financial markets and non-commercial actors adds a further dimension to the process of price discovery. Third, long-term investment plans by the single member countries will undoubtedly have important consequences on the OPEC's ability to influence price levels, since such ability directly derives from the presence of spare production capacity: some countries may not have the incentive to invest, or incur in bottlenecks[558] preventing the investment to take place.[559] Finally, political factors can deeply affect OPEC internal discipline, and therefore the perception of its policy decisions by the market participants.

The nature of the decision itself can affect the success of OPEC's signals, since the Organization also faces the problem of internal collusion. In particular, if a downward adjustment in output is required to sustain the price level, two issues arise: first, small members usually find it difficult to significantly reduce their production on a pro-rata basis; second, some members can have an incentive to cheat, in order to expand their own market share. It is important to notice that violations are not detected, and that the OPEC does not have the means to enforce its members to abide to the agreed production ceilings. As a consequence, the players in the market can doubt the credibility of the adopted policy, and ignore the signal, above all in presence of known divisions and rivalries within the Organization. On the other hand, also an upward adjustment can prove unsuccessful: the response of member countries to an excessive increase in prices can be not prompt enough, or even delayed, in order to avert the losses related to a false price trend.[560]

Nevertheless, the capacity of the OPEC of conveying the right signal and, above all, to avert or mitigate the impact of major supply disruptions or sudden gluts must not be ignored. A clear example is provided by the events of 1990, when the Organization was able to offset the loss in supplies following the burst of the Iraq-Kuwait conflict.[561] The war produced the

557 B. Fattouh, OPEC pricing power: the need for a new perspective, http://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/WPM31-OPECPricingPowerTheNeedForANewPerspective-BassamFattouh-2007.pdf, accessed March 28, 2013, pp. 6-7.

558 For instance, investment can be prevented by closure to foreign capitals, or by geopolitical factors, such as wars and international sanctions.

559 *Ivi*, p. 2.

560 *Ivi*, p. 7.

561 Another relevant instance testifying the role of the OPEC and of its signals to the market is provided by the Organization's policy decisions following the Asian crisis in 1998. See: W.L. Kohl, "OPEC behavior, 1998 –

immediate ceasing of oil exports from the two belligerent countries, at the time providing around 20% of the OPEC's total output (about 25 mb/d in July 1990). More than the actual shortage (since inventory levels were quite high at the time), it was fear that pushed up oil prices: the spot price for Brent reached in September the level of $36/b, more than a twofold increase from its July level of $17/b. However, the other members of the Organization responded quickly, in particular Saudi Arabia, whose production jumped from 5.7 mb/d in July to 8 mb/d in September, a level that was maintained throughout the following year. By September, the total output of the OPEC, which in August had fallen to 22 mb/d, reached 24 mb/d, and even exceeded the pre-invasion level in November. Prices started to weaken, and spot Brent fell back to $18 by July 1991.[562]

As mentioned above, the influence exerted by the OPEC on oil prices in not constant over time: undoubtedly, the effectiveness of its signals in the future will highly depend on how the Organization will adapt to the new features of the pricing system, on its capacity to maintain the internal cohesion necessary to produce credible policy decisions, and on the investments undertaken by each of its member countries to preserve the necessary flexibility in the output capacity.

2001", *The Quarterly review of economics and finance*, 42, 2002, pp. 209-233.

562 Parra, *Oil politics*, cit., p. 305.

CONCLUSIONS

The aim of the present study was to analyse how data and key concepts concerning oil reserves estimates, production levels, and prices have been constantly shaped by the evolution of power relations and vested interests concerning the main actors in the industry. The analysis has allowed further insights, focused respectively on the implications deriving from the same technical and quantitative nature of oil statistics, and on the inevitable feedback effects experienced by the key players as a consequence of the same frameworks and structures they had contributed to create.

Therefore, it is possible to delineate three groups of considerations, integrated by a final remark concerning the case of the OPEC, which proved to be of particular interest throughout the research.

The first set of conclusions contemplates oil statistics, especially oil reserves estimates, as peculiar pieces of information carrying an intrinsic power, which derives from their quantitative nature. Numbers are usually perceived as objective, they convey fairness, impartiality and, accordingly, credibility. Our society has indeed developed a particular taste for quantification: however, data backed by sufficient institutional support are simply taken at face value, with the paradoxical result of conveying information while at the same time becoming inaccessible black boxes.

When the "technology of trust"[563] combines with the congenital ambiguities of a particular object of estimation, as in the case of oil reserves, the creation and the reporting of data can become precious opportunities for institutional actors pursuing particular goals, or trying to secure their own status. Dennis, through his analysis of two divergent estimates of the U.S. conventional oil reserves published in the 1920s[564], provides a clear example of how quantitative data can be seen not only as a product of scientific knowledge, but also as the direct output of the social processes within an institution, which in turn is inserted in a specific historical context: while the USGS and the AAPG supported a lower estimate of oil resources that secured their status as necessary advising institutions in front of the imminent depletion of the country's oil endowment, the API claimed that "no imminent danger of exhaustion existed", thus dismissing any eventual accusation of mismanagement of oil production directed towards the oil industry, and instead promoting the self regulation of the

[563] See paragraph 1.7.
[564] Dennis, *Drilling for dollars*, cit.

latter.

In addition, the social and political dimension of an institution not only shapes the creation of quantitative data: it also impacts in a substantial way on the construction of validity surrounding a particular piece of information. As the interests of the main actors change and realign through time, influenced by parallel changes in the surrounding environment, also the perception of validity evolves, even leading to the dismissal of data that were previously held as convincing. Bowden[565] extensively illustrate the case of the estimates published by Hubbert in 1950s, which predicted an impending peak in U.S. oil production, due to the increasing depletion of its hydrocarbon resources: the estimates were harshly criticized in the 1960s, since they clashed with the predominant view of never-ending growth that heavily relied on potentially inexhaustible oil reserves. However, an external event, namely the 1973 Arab oil embargo, caused the industry to adopt a new set of goals, which revolved around the concept of conservation of domestic resources, and to reassess Hubbert's estimates as valid, and therefore supportive of those new objectives. Consequently, it is of paramount importance to critically approach reported data. Estimates of proven reserves do not simply provide information about the oil potential of a specific country or institution: they can also serve an operative purpose. Through the adoption of ad hoc estimation methodologies and classification frameworks, and even through reporting escamotages (such as over, under, and non-reporting) reserves estimates become means for the transmission of a specific message, expressing the predictor's political ends, his actual values and circumstances, and the status he wants to consolidate.

We are thus led to the second set of considerations, the central claim being that the message conveyed by past oil statistics can be fully appreciated only if linked to the very concepts and governance regimes that marked the functioning of the hydrocarbon industry through time. In virtue of the multifaceted nature of oil, the analysis of the pricing systems and of the frameworks regulating crude production that followed one another during the decades turned out to mirror with extreme accuracy not only the evolution of the power relations between the main players of the industry, but also some of the major dynamics involving the international scene in the 20th Century. Notably, four relevant shifts of different nature, but deeply interrelated with each other, can be identified in the period between the 1950s and the 1980s.

The first is a geographical shift: if up to the 1940s the bulk of oil production had been

565 Bowden, *The social construction of validity in estimates of U.S. crude oil reserves*, cit.

concentrated mainly in the Western hemisphere, namely in the U.S., Mexico, and Venezuela, the Second World War and its aftermath led to a change of focus, as more and more oil started to flow towards Europe and the U.S. themselves from the vast oil concessions controlled by the majors in the Middle East. Such transition had two main consequences: on the one hand, it inevitably implied a new kind of supply security concept, namely the one concerned with political stability in a distant and culturally different area; on the other, as the majors consolidated their control of Middle Eastern production through the concessionary system, the host governments were literally flooded by revenues.

Royalties, and subsequently income taxes, cast on the exporting countries an "irrevocable spell", and unquestionably contributed to the second shift considered, namely the passage of oil "actual" ownership from the Western majors to the producing countries: the claim and achievement of sovereignty on the disposal of their domestic mineral resources definitely deleted one of the last formal traces of the already demised colonial system. As a consequence, also the widespread concessions were replaced by new and more flexible forms of agreement, characterized by the concept of production sharing, and by the role of the majors, formerly the sole rulers of the industry, as simple service providers or purchasers. The link that was established between oil and the sovereign state implied a new perception of the precious resource, which no longer was the means to assert and secure Western economic and military dominance, but instead became one of the prime devices to gain independence from the control and ascendancy of the West itself.

Accordingly, a third transition took place, which witnessed the replacement of the majors as administrators of oil prices by the OPEC in the 1970s: such shift, along with the increasing implementation of participation and nationalization measures, implied the emergence of a new rationale for oil prices. The pricing system devised by the majors revolved around the main concepts of posted price, tax-paid cost, and transfer price: its aim was at first to protect U.S. domestic production and exports from the competition of the low cost Middle East oil, and in a second moment to guarantee stable and low price crude imports for the West, while at the same time locking the amount of rent due to the host countries under the concessions through the adoption of ad hoc fiscal clauses. Conversely, as the OPEC became the new administrator, following the events of October 1973, the posted price became the means to secure the inflow of revenues, albeit with different time horizons, and therefore pricing preferences, between the members of the Organization.

Finally, the fourth shift, which resulted from the strict interrelation of the previous three, entailed a passage from cooperation and coordination, the two features characterizing the management of international crude oil production and trade by the majors, to confrontation: on the one hand, the governments of the exporting countries started to advance sovereignty claims, obtained the control of their hydrocarbon resources, and the OPEC asserted itself as a new powerful bargaining force, directly challenging and eventually displacing the system ruled by the majors; on the other hand, new actors, such as independents and non-OPEC producers entered a previously not so crowded market, greatly enhancing competition.

When taken into account, such evolution allows to shed new light on oil statistics. Remarkably, the case of historical series for oil prices provides quite an interesting example, since usually such series patch together price concepts that differ greatly between each other[566]. Clearly the selection of the reported data is guided by a criterion other than consistency, and such criterion is relevance, both economic and political. Without sacrificing consistency to the advantage of relevance, it is not possible to assemble a meaningful trend able to cover the considered time period. However, inconsistency, and consequently relevance, can be fully appreciated only if the above mentioned shifts affecting the evolution of power relations and dynamics within the international oil industry are considered. Therefore, there is an inextricable link between "petronumbers" and the concepts and regimes on which these data are embedded; in turn, such structures have been shaped by the leading institutional actors, by their goals and nature, and by their relationship with the other key players in the industry and on the international scene.

The third group of conclusions attempts to dismiss the idea, maybe somewhat conveyed by what asserted above, that the evolution of the main dynamics and frameworks concerning oil reserves, prices and production was exclusively the result of a deliberate and straightforward decision-making process implemented by the industry participants at specific points in time. The study has highlighted the fact that the key players inevitably experienced important "feedback effects" deriving from the vary frameworks and structures they had contributed to create. Notably, some of these feedbacks eventually led to counter-productive developments, and to a complete reversal of the existing conditions: a clear example is constituted by the massive flows of revenues reaching the host governments under the concessionary system that the Seven majors so strived to expand, and which led through time to mounting pressures for the revision of the existing contractual terms, and eventually to the

[566] Usually, reported data follow this kind of pattern: for the period between 1861 and 1944 the average for U.S. posted prices is reported; then, between 1945 and 1983, data switch to Arabian Light posted at Ras Tanura; finally, from 1983-1984, the price of one of the main benchmarks, namely WTI or Brent Dated, is taken into account.

outright nationalization of oil resources and to the demise of the concessionary system itself.

To provide another case in point, the pricing policy adopted by the OPEC at the end of the 1970s, characterized by a two-tier pricing system materializing the divergent opinion of Saudi Arabia with respect to the other members of the Organization, especially Iran, allowed those majors able to purchase the cheaper Saudi oil to make windfall profits on the spot market; in addition, the OPEC itself indirectly contributed to the emergence of the latter, which would eventually displace the Organization as "administrator" of oil prices in the 1980s. In particular, the Iranian crisis of 1978-1979 and the Iran-Iraq war of 1980 proved crucial to the emergence of the spot market, since the oil companies, increasingly lacking access to Middle East oil as contractual arrangements were replaced by outright nationalization, had no other choice than resorting to open trade to satisfy their requirements.

Finally, an additional remark is deserved by the OPEC, which proved an interesting case of study throughout the research. First of all, as it was outlined above, its evolution and its role between the 1960s and the 1980s were essential to the development of the main dynamics and concepts impacting oil pricing and production in those crucial years. Secondly, the Organization's internal dynamics and power relations constantly reverberated on the related oil statistics: for instance, the increase experienced by the reported proven reserves of six OPEC countries in the late 1980s, an overnight addition of about 300 bbls not related to any major discovery or technological breakthrough, can be interpreted as part of an internal struggle between the members to boost their own production quotas, the allocation of which was partly based on the estimated size of oil endowment. Last but not least, the OPEC act as prominent example of an actor that impacts, and at the same time results impacted by, the current developments experienced by the oil market. Specifically, since the late 1980s the OPEC has played a new role as residual supplier and indirect price setter, trying to prevent major price disruptions, and simultaneously to influence through its output decisions the expectations of market participants concerning future oil price movements.

The analysis of the link between oil statistics and changing power relations arises several other questions, which have been necessarily excluded from the present study, but that are undoubtedly worthy of deep and extensive research. It is possible to enumerate at least two of these issues: first of all, the insertion of the changing power relations characterizing the oil industry, above all in the 1970s, in the much broader framework provided by the bipolar confrontation; second, the detailed analysis of the nature of the OPEC, constantly split between collusion and differences of opinion, of its statistics, and, last but not least, of its role as residual supplier and indirect price setter.

The oil industry is currently marked by the emergence of new features: the increasing weight of non-traditional actors, such as financial traders and iNOCs, the more and more frequent performance of the FOCs as service contractors, the opening of additional frontiers in exploration and production thanks to technological progress, and major political developments, above all in the oil-rich Middle East, unquestionably provide fertile ground for future studies. The challenge is trying to assess if such developments will eventually lead to innovative regimes and frameworks for the governance of oil prices and production, and, eventually, how this transition will result in the construction and reporting of new relevant statistical data.

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