The Prospects for Petroleum Output and Investment in MENA Oil Exporting Countries, 2005-2030

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Intro: Is it likely that the output of petroleum will expand sufficiently during the next quarter century, that its inflation adjusted price will stay relatively constant? How much investment funds will be necessary for the corresponding expansion in capacity? The demand side of this question is well understood, although recently practitioners had underestimated the expansion of consumption in China, India, and the U.S. However, there are several aspects of the supply side that are less understood, such as the impact of new technology, the potential for discoveries of new reserves, and the control over output exercised by OPEC. The reader frequently encounters predictions that non-OPEC will reach its maximum output within a decade, but there is rather less agreement on what to expect from the OPEC countries.

Current Projections

There are several efforts at predicting the future of the oil industry, in terms of identifying various scenarios: by governmental agencies, oil companies, and consultants, and in fact an appreciable amount is available on the web--both the projections themselves, and conferences dedicated to the subject.[1] The two most widely cited sets of annual studies and projections concerning petroleum output are the International Energy Agency's *World Energy Outlook* [IEA/WEO], and the US Department of Energy's *International Energy Outlook* [DoE/IEO]. Highlights of their summaries are presented in **Table 1** --it considerably simplifies our work that their numbers are relative consistent. World production and consumption is to rise from the 80 to 120 million barrels per day [mbd] by 2030. The projection for OPEC's production is an increase from its current level in the

[1] For the DoE/IEO go to http://www.eia.doe.gov/oiaf/ieo/index.html; for the IEA/WEO go to http://www.worldenergyoutlook.com/ . A workshop in Washington D.C. in April, 2006, sponsored by DoE/EPA/Resources for the Future, on the Economic and Environmental Implications of Global Energy Transitions, involved some of the most experienced and numerically powered modeling groups, such as IIASA, REMI, JGCRI, Stanford's Energy Modeling Forum, and other groups working with US DoE and EIA. Papers or powerpoints can be accessed at: http://cta.ornl.gov/oilTransitions/. The proceedings of an October, 2005 conference, sponsored by the National Academy of Sciences, are available as an electronic product at: see http://darwin.nap.edu/books/0309101433/html/. Recordings of the presentations can heard at: http://www.globalpublicmedia.com/lectures/542, while the corresponding power point slides are at http://www7.nationalacademies.org/bees/trends_in_oil_supply.html . The OPEC Secretariat, USGS, Exxon/Mobil, and Chevron are represented, as are PFC, CERA, Centre for Global Economic Studies, and several producers of "non-traditional" fuels. OPEC's presence at that conference is an example of greater collaboration between producer and consumer groups; others being the OPEC-EU Energy Dialogue, the joint Oil Data Initiative, and the International Energy Dialogue. The IEA has recently provided on their web-site a "Medium-Term Oil Market Report," that takes a five year time span.

Table 1. World Oil Production Capacity by Region and Country, Standard Cases of *IEO* and *WEO*. (Data in mb/d)

	International Energy Outlook 2006						*World Energy Outlook 2005*			
	Actual		Projections				Actual	Reference Scenario		
	1990	2003	2010	2020	2025	2030	2004	2010	2020	2030
OPEC	27.1	33.0	39.9	43.9	46.7	50.7	32.3	36.9	47.4	57.2
Iran	3.2	4.2	3.8	3.9	4.0	4.3	4.1	4.5	5.5	6.8
Iraq	2.2	2.3	3.3	4.3	5.1	5.5	2.0	3.2	5.4	7.9
Kuwait	1.7	2.4	2.8	3.8	4.2	4.5	2.5	2.9	3.8	4.9
Qatar	0.5	0.9	0.7	0.7	0.7	0.8	1.0	1.1	1.2	1.2
Saudi A	8.6	10.6	14.4	14.5	15.1	17.1	10.4	11.9	15.4	18.2
U.A.E.	2.5	3.3	3.3	3.9	4.4	4.6	2.7	3.2	4.0	5.1
Indon.	1.5	1.4	1.5	1.3	1.2	1.1	1.9	2.2	1.9	1.6
Algeria	1.3	1.5	1.8	1.9	1.8	1.8				
Libya	1.5	1.5	1.8	1.9	1.9	1.8	1.6	1.9	2.5	3.1
Nigeria	1.8	2.0	2.4	2.7	2.9	3.2				
Venez.	2.4	3.0	4.1	5.0	5.5	5.9				
Non-OPEC	42.4	49.3	54.4	63.7	68.2	72.6	46.7	51.4	49.4	46.1
OECD	20.1	23.2	24.3	25.5	26.0	26.1	20.2	19.2	16.1	13.5
USA	9.7	8.8	9.9	10.4	10.4	10.4	9.7	10.5	8.8	7.4
Canada	2.0	3.1	3.6	4.2	4.7	5.0	^	^	^	^
Mexico	3.0	3.8	4.0	4.5	4.8	5.1	3.8	3.9	3.7	3.4
N. Sea	4.0	6.3	5.5	5.1	4.7	4.3				
Non-OECD	22.2	26.0	30.0	38.2	42.2	46.5	26.5	32.2	33.3	32.6
Russia	11.4	8.5	9.6	10.9	11.3	11.6	9.2	10.7	10.9	11.1
Caspian	0.0	1.9	3.0	5.2	6.3	7.5				
China	2.8	3.4	3.8	3.8	4.0	4.2	3.5	3.5	3.0	2.4
India	0.7	0.9	1.1	1.4	1.5	1.6				
M. East	1.4	1.9	2.0	2.4	2.7	2.9				
Africa	2.2	3.2	3.8	5.8	7.2	8.6				
Brazil	0.8	1.8	2.7	3.9	4.2	4.5				
World	69.5	82.3	94.3	107.6	114.9	123.3	82.1	92.5	104.9	115.4

Sources: *IEO* 2006 Table E1, and *WEO* 2005 Table 2.4 and country tables.
Notes: The data for Canada are included in that for the USA in the *WEO* projections. The standard case is named the Reference Scenario in the *WEO*.

Table 2. World Oil Production Outlook, OPEC Projections (mbd)

	2002	2005	2010	2015	2020	2025
OPEC	29.2	29.7	34.1	40.6	48.9	58.3
Non-OPEC	47.8	51.3	54.6	56.5	56.9	56.3
OECD	21.9	22.1	21.4	20.8	20.1	19.2
US & Canada	10.9	11.1	10.9	10.9	10.8	10.7
Mexico	3.6	3.8	3.9	4.0	4.0	3.8
Russia	7.6	9.3	10.4	10.9	11.1	11.1
Caspian Area	1.7	2.0	2.9	3.7	4.1	4.5
China	2.3	2.5	2.5	2.4	2.2	2.0
World	77.0	81.0	88.7	97.1	105.8	114.6

Source: Shihab-Eldin, Hamel, and Brennand (2004) "Oil outlook to 2025," *OPEC Review* September 2004
Notes: The OPEC total includes NGLs. “Caspian” denotes all FSU states, except Russia. Referred to as “World oil production, reference case.”
No dis-aggregation of OPEC output is provided.

low 30s to 50 or 57 mbd in 2030.[2] Both sets of projections in that Table correspond to what can be called a constant price case (discussed further below).

Because the International Energy Agency is part of the OECD, and the Department of Energy is obviously a US organization, both these sets of predictions can be described as representing consumer nations.[3] Therefore, it is quite intriguing to note that recently the Research Division of the OPEC Secretariat has published an outlook (Shihab-Eldin et al. 2004) for future oil production[4], which is quite similar to that of the previously mentioned two major studies. The OPEC numbers are summarized in **Table 2.** By 2025, world production and consumption will reach 115, while OPEC's output would be 58 mbd, slightly higher than the other studies. While neither the IEA/WEO nor the DoE/IEO presents detailed information on methodology, they have presented book length manuscripts for several years, and those projects' leaders have long been engaged with the academic and policy communities. In contrast, the published OPEC work is quite sketchy, and one has the impression that the major product is not yet available to the public. Unavoidably then, this paper will concentrate on the first two studies.

Some important background facts set the stage. Petroleum supplies a third of the world's total energy, down from 43% in 1971 (*WEO 2005*, Table 2.1). The OPEC countries, especially those bordering the Gulf (along with non-member Oman), produce forty percent of the world's oil, and have more than seventy percent of world petroleum reserves. Thus most commentators presume that they will be the major growth area of future supplies of this key raw material. Moreover, oil output and exports from these countries have been affected by wars and politically motivated production decisions, and have fluctuated enormously since 1970. As it turned out, the dramatic increase in the price of oil during the 1970s was partially ameliorated by expansion of non-OPEC production in the North Sea, Latin America, and eventually the former Soviet Union. The country with the largest production is Saudi Arabia, which for some time acted as the "swing producer," but was unable or unwilling to enforce production decisions in OPEC. Both the DoE/IEO and IEA/WEO project its share to fall slightly in the next quarter century, as gas and renewable sources grow in importance.

To further underline the importance of the these studies' prediction of an increase of production of the OPEC countries, of an amount varying between one half (*IEO*), three quarters (*WEO*), and virtually doubling (OPEC Secretariat) in a period of a quarter of a

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[2] To be more precise, the DoE/IEO data in Table 1 refers to production capacity (Table E1 in *IEO 2006*); there is also a table of output (Table E4 in *IEO 2006*), which does not indicate amounts by country.

[3] In Robinson (1988, 110), reference is made to "Kissinger's International Energy Agency," although it is not clear if that phrase is attributable to the subject of the book, or its author.

[4] An article in *Oil & Gas Journal* June 12, 2006 referring to these OPEC estimates contains some graphs of investment outlay that do not appear in the Shihab-Eldin et al. paper. However, they are contained in an unpublished version, as OPEC Secretariat (2006). In addition, from the OPEC web-page at http://www.opec.org/opecna/Speeches/2006/attachments/IEFBarkindo.pdf one can find a set of power point slides that partially fill this gap. Certainly the publication of an extended version of the OPEC study will be widely awaited; the study may be the Long Term Strategy, a brief description of which has been placed on the OPEC web-page. Dr. Adnan Shihab-Eldin, a Kuwaiti, has served as OPEC's acting secretary general as well as head of research.

century, we note that only a few of the OPEC countries (Algeria, Nigeria, Qatar, UAE) had by 2004 surpassed their maximum level of production achieved before 1980, a quarter century ago. A skeptical attitude on future growth is a natural response to a history of stagnation. The failure of production to grow as fast as demand would entail significant price increases.

The common vision represented by these studies has been criticized on a technical or geological level, according to which the corresponding amounts of oil simply do not exist, and at an economic level, by critics who assert that the economic incentive will not arise with constant prices, and that the studies are ill-designed to handle significant increases in prices. We will now discuss these two considerations, before addressing issues of price responsiveness of output. Then we turn to investment required for this production. Of particular interest will be the concern expressed that the several OPEC countries cannot afford the necessary investments.[5]

Geology Pessimism Pessimists on the supply side currently rally to the call of "peak oil," and frame their arguments in terms of a "Hubbert Curve" of production over time; an inverted and asymmetrical U-shaped curve indicating a rapid increase to a peak, followed by a production plateau, and, typically after more than half of total output from the site, a rather constant proportional decline.[6] Although this model is most appropriately posited of an individual oil field, extrapolation of the central idea leads to parallel predictions for countries or regions, important examples of which are the cases of Indonesia, Mexico, and the North Sea.[7] United States production peaked around 1970, as had been predicted by Hubbert. This peaking of oil output can be seen in some of the mentioned areas in **Table 1**.[8] Equally as important, it does not characterize either set of predictions for the OPEC countries. Two justifications for this would be the large size of the reserves in the Gulf countries, and optimism over the production potential of the less explored regions of Iraq, Saudi Arabia, and parts of northern Africa.

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[5] For example, when writing of an earlier *WEO* report, Alhajji (2001, 23) stated, "Adding 13 million bopd to capacity requires an investment of more that $100 billion, and Gulf states cannot afford such a high level." A set of references to trade journal articles expressing the need for more OPEC investments around 1990 is available in Adelman (1995, 237). Some OECD countries' media often portray as alarmist the pronouncements by Fatih Birol, IEA chief economist, about future production and investment needs. They shouldn't shoot the messenger.

[6] In principle, the height of the plateau, and the rate of decline, are primarily determined by technical or geological conditions. It may also be the case that they are affected by prices. In addition, note that the amount of petroleum extracted from a reservoir is much less than the total amount present there, so that technological change leading to improvements in the recovery rate from, say, twenty five percent to fifty percent are equivalent to finding a new field.

[7] The authoritative best opinion about world-wide potential of discoverable reservoirs is the USGS, whose *World Petroleum Assessment 2000* is available at http://pubs.usgs.gov/dds/dds-060/ A short summary is included in the National Academies presentations in the first footnote. Although there is plenty of oil out there, the new frontiers are deep underwater, and/or in the Artic region, which will increase the stress on global environment.

[8] Cavallo (2006, 110) states that the consensus of the participants at the NAS workshop was that non-OPEC production would peak by about 2010.

A well-known corollary of the geologist's skepticism about new discoveries is Hotelling's rule, according to which the price of a non-renewable resource in fixed supply should rise over time, relative to costs, at the prevailing rate of interest. Not surprisingly, this prediction is frequently mentioned in times of rising oil prices.

An important application of geological skepticism is the questioning of the future capacity of Saudi production by Simmons (2005). Several Gulf producers, like other private or publicly owned firms around the world, are reluctant to reveal data about their operations, and Simmons used published papers by Saudi ARAMCO geologists to argue that Saudi Arabia's major giant fields have also passed their peak.[9] If this turns out to be true, then the scenarios in the Tables above are in need of drastic revision.

Increased attention has also been directed to the specific issue of the quantity of reserves. In 2004, Royal Dutch Shell was forced to lower its stated amount of proven hydrocarbon reserves by one fourth, with direct impact on its share price and executive compensation.[10] The January 23, 2006 issue of *Petroleum Intelligence Weekly* carried an article about an internal Kuwait Oil Company memo, written in 2001, which stated that the country's remaining reserves amounted to 48 billion barrels, instead of the 100 billion that were publicly claimed at that time.[11] There have also been unexplained increases, mentioned in that article: in 1983, Kuwait increased its proven reserves from 67 billion to 92 billion barrels; in 1985, reserves of the UAE jumped from 33 billion to 97 billion barrels. Iran raised its reported level of proven reserves by 30% in 2001 (*PIW* p. 6). Saudi Arabia raised its estimated reserves by 50% in 1990.[12] The controversy in Venezuela is discussed in Boué (1993, section 3.2), and the impact on the measurement of Mexico's reserves of adhering to tighter standards is illustrated in Stark and Chew (2005, 163). Evidently there is an issue of transparency that is being addressed by representatives of the IEA, OPEC, and others.

Market Optimism

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[9] "I am convinced that Saudi Arabia is either nearing its peak oil output, or even could have passed its old peak supply record, set in 1980-81. Once Saudi Arabia's oil goes into decline, the world will also have passed peak oil." Simmons (2006, 33). These widely circulated claims have generated responses from Saudi Aramco: see *Oil and Gas Journal* July 11, 2005 p. 22. For a February, 2004 conference at CSIS go to http://www.evworld.com/view.cfm?section=article&storyid=659 which includes presentations by Simmons, and a response by Aramco officials, also at: http://www.saudiaramco.com/sa/webServer/general/Presentation_Fifty_Year_Crude_oil_Supply.pdf with audio at: http://www.evworld.com/view.cfm?section=article&storyid=659 . Michael Lynch , a prominent industry analyst, critically analyzes Simmons's position in *PIW* June 5 2006. Believers that actions speak louder than words should read O'Sullivan (2006).

[10] This corporate scandal was embedded in a larger scandal involving Enron Corporation. Part of the problem with published data on reserves is that they rely on concepts generated by the US SEC, which are said to be out of date. The Society of Petroleum Engineers is involved in an updating of those standards.

[11] *PIW* May 1, 2006 includes a notice that implicitly says the KOC will explain this satisfactorily.

[12] The presentation to the National Academy of Sciences of the then acting Director General of OPEC, Adnan Shihab-Eldin, addressed this issue, attributing the jump in reported reserves during 1987-90 to: 1) change in motivation of member countries to publish reserves; 2) reserve growth in old fields –by applying best practice; 3) adjustments of the technical and economic conditions; 4) conservative initial estimates of field reserves. See slide 22 of: http://www7.nationalacademies.org/bees/Adnan_Shihab_Eldin_OPEC.pdf

What might simplistically be called the supply side, or optimists' position on the prospects for future oil production invokes two familiar, key economic processes associated with the market incentives of higher prices; technological change and discoveries of new fields. This position has been frequently and forcefully emphasized by Morris Adelman throughout his long career, in his assertions that there is no relevant limitation on oil reserves, that oil price increases are not due to capacity shortages, and that new discoveries and technological changes have led to increases in remaining reserves, even while consumption has accelerated. North Sea oil and Canadian tar sands are handy examples.[13] With regard to traditional production, examples of the positive effects of technological change on reversing oil depletion are reported in Managi et al. (2004), and a presentation by Scott Nauman of Exxon/Mobil, with its graph illustrating an improvement of the recovery rate in a specific Texas oilfield, from 28 to 40%, during the period 1982-2003.[14] Market optimists note that North Sea production substituted for a significant part of the OPEC shortfall in the period of politically motivated output reductions, while the volume of tar sands is judged by some geologists to provide the second largest supply of petroleum, after that of Saudi Arabia.[15] In this perspective, the function of oil price is to stimulate efforts at expanding reserves. It goes without saying that the two processes--new discoveries and improved technology--are difficult to model. Beyond that is a key question, what will be the price responsiveness of petroleum output? There are some characteristics of petroleum production that might lead us to believe it to be small. There is also the issue of whether or not OPEC has affected the responsiveness of its members.

Does OPEC Affect Prices and Output?

One of the major strands of the analysis about OPEC affirms that it currently has little impact on prices or outputs. The structural problems of OPEC are well-known. While petroleum lies in its purview, natural gas—which is often jointly produced, and is an important substitute--does not. There is no mechanism to force members to abide by decisions. Production conditions vary widely, as well as such important variables as debtor/creditor status, and oil output/person and indeed *per capita* income. The social and historical situations of the various countries are quite distinct. Adelman has described OPEC as a "clumsy cartel." An article in *Petroleum Intelligence Weekly* (April 10, 2000)

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[13] An example illustrating the vision of the technological optimists appears in the *Oil and Gas Journal* October 17, 2005 "An estimate for the impact of technology can be gleaned from a study … showing that during the period 1995-2003 new discoveries in the world amounted to about 144 billion barrels, while 'resource growth' and 'knowledge growth' in the pre-1995 discoveries was about 457 million bbl, due in large part to improved technology." One might have expected that such growth processes would be better documented and studied, but apparently this is not the case, perhaps due to the data problems indicated earlier.

[14] See slide 17 of http://www7.nationalacademies.org/bees/Scott_Nauman_Energy_Outlook.pdf . Nevertheless, there is not much formal analysis of technological change in the petroleum industry.

[15] In an insincere attempt at avoiding a very political issue by hiding it in a footnote, we will note that it is often commented that Iraq's oil potential is not fully known, and that many believe that the current military intervention there was motivated by the pursuit of what is alternatively referred to as black gold or the devil's excrement. The title of a recent book, *Addicted to Oil,* [Rutledge (2005)] had its fifteen minutes of fame in the discourse used by President Bush, even if some of its contents, e.g. Chapter 12, "A War for Oil" did not.

was titled "Herding cats: Opec's Management of Oil Markets." The recent OPEC meeting in Venezuela (mid-2006) is described as having rejected the host country's calls for production restraint. Commentators have pointed to the organization's inability to hold prices **down** as an indicator of its loss of control of the market.

Perhaps more familiar in the mass media is the counter-position, which asserts that OPEC is a cartel that effectively influences oil prices and/or outputs to the advantage of its member states. This second version is the international trade textbook's optimal tariff case, applied by the producing countries.[16] Many of the corresponding considerations in those textbooks are relevant in the OPEC context, such as the difficulties of enforcement of market controls, either on prices or quantities sold. My judgment would be that few economists writing today would accept the notion that OPEC is an effective cartel. However, there would be more support for the related position that would identify a core of OPEC—Saudi Arabia and perhaps its immediate neighbors—which can act as an oligopolist, even while the others are part of a competitive fringe. Mabro (1998, 18) reminds us of the aphorism that "OPEC is Saudi Arabia," while .?. comments on the U.S. being an unofficial member.

A useful review of both anecdotal and empirical analyses of OPEC's decisions is presented by Mabro (1998); that survey is updated by Smith (2005).[17] Both treat OPEC's modus operandi as having varied over time, thus discouraging broad encompassing labels. They emphasize the difficulty in distinguishing empirically between price increases caused by an increase in demand in a competitive situation, and increases when there is a cartel, because in both cases, an increase in demand will lead to an increase in price, with the major difference being the elasticity of output. This theoretical point flies in the face of much journalistic commentary, which seems to think that OPEC's oligopolistic tendencies will be turned off and on according to circumstance.[18] There is a predilection for describing OPEC's behavior by reference to Saudi Arabia playing the role of a dominant firm, or the swing producer.[19] This is important because of the issue of strategic considerations blocking a standard theoretically approved response of increased output and increased prices.

One of the frequently used visions is that OPEC has maintained a band for the price of oil. An early proponent of this strategy was the Saudi Minister of Petroleum, Sheik Ahmed Z. Yamani. While the logic behind the desire for an exporter of maintaining a price floor is evident, Yamani also warned against prices that were too high, because the development of alternative sources would be motivated by high prices—traditional oil

[16] Gately's calculations raise the question of OPEC's actions in a situation where oligopolistic actions may be beneficial.
[17] An earlier review of OPEC and the world oil market is Gately (1984). A short book that has been influential is Crémer and Salehi-Isfahani (1991).
[18] While the formation-or dissolution-of a monopolistic cartel could theoretically lead to a negative sloped supply to the rest of the world, any assumed continued operation of such a cartel would not.
[19] See Salehi-Isfahani (1995, 17) for insightful comments suggesting that the Saudi strategy evolved over the 1980s.

such as in Russia or Mexico, non-traditional sources such as tar sands and shale oil.[20] Long after Yamani's departure from the Saudi Ministry, OPEC continued to maintain a band, so that in 2000 the range for a barrel of oil was set at US$22 to $28. However, action to implement that decision was only taken once, and the band was suspended in early 2005—when the price was about $50/bbl--amid talk that it would be re-instated, at levels double the previous ones.[21] This gap between policy and action, important in itself for our discussion, illustrates the difficulty of analyzing the impact of the organization.

OPEC's Quotas and Production Capacity

During the early 1970s the price of oil skyrocketed, aided in part by an OPEC-induced reduction in output. These constraints subsequently became more formal, and for the period after 1982--when the oil price was falling—specific quotas were announced. Our attention naturally turns to the quantitative dimensions of that process; both the quotas and the actual reduction in output. On the OPEC web-site, and in OPEC Secretariat (2003), there is a detailed listing of output decisions--another name for ceilings or quotas. The analysis is made more difficult by the listing of quotas in the CIA publications, in terms of amounts that were significantly less restrictive than those reported by the OPEC Secretariat.

After the initial experience of the embargo during the 1973 Arab-Israeli War, there have few cases of OPEC having raised the price of oil, due to production tightening. Of course prices rose during the wars (Iran-Iraq, Kuwait-Iraq, US-Iraq), but that is not cartel action. When prices were falling in the 1980s, OPEC engineered output declines, but this is also a different story. There does not seem to be much written on the determination of the levels of quotas. One of the better treatments of quota allocations is Gault et al. (1999). A key concern is the issue of compliance with the quota restrictions, for which the best treatment is Mazraati and Tayyebi Jazajeri (2004), although they avoid country level details. Some available data on individual countries indicate the difficulties of countries like Indonesia in filling its quotas for many years, the growing gap between quota and production in countries like Iran and Venezuela, and the recent "oversupply" in countries like Algeria, Kuwait and Libya, that has been of the order of ten to twenty percent. Finally Ecuador and Gabon decided to withdraw from OPEC, presumably because of their unwillingness to stay within their assigned quotas.

There are several interesting considerations with regard to estimated production levels corresponding to full capacity.[22] During the mid-1970s, excess capacity[23] for OPEC as a

[20] His biographer quotes a speech in 1981 "If we force western countries to invest heavily in finding alternative sources of energy, they will. This will take them no more than seven to ten years and will result in their reduced dependence on oil as a source of energy to a point which will jeopardize Saudi Arabia's interests." Robinson (1988, 238) Sheik Yamani has maintained this belief—see his talk reproduced in September 20, 1999 *Oil & Gas Journal*. His current position as head of the London-based CGES allows him to state his views to a world-wide audience.

[21] See the discussion in see DoE http://www.eia.doe.gov/cabs/opec.html, or in the *OPEC Bulleti*n of February, 2005.

[22] One un-interesting but unavoidable aspect is the difficulty with data. For a long time, the major source of estimates on capacity was the U.S. Central Intelligence Agency, but they ceased publishing their series in

group was ten or fifteen percent. Subsequently, available estimates suggest that capacity utilization fell by one third or one half during the first half of the 1980s, during the period of falling prices; see **Graph 1**. For 1985, our sources estimate excess capacity in OPEC to have been ten million barrels per day; over half of capacity was idle. The country-specific estimates of capacity utilization during the 1980s indicate that the decline in this variable was widespread across the OPEC countries-see **Graph 2**. However, the decline in capacity occurred for various reasons—most obviously in countries affected by war, such as Iran and Iraq, registered in our source only for the latter 1980s. In fact, the CIA indicates a significant decline in Iran (one million barrels/day) which began before the overthrow of the Shah. Note, furthermore, the fall in Kuwait (before the 1990 invasion), that has been blamed on bad management and low investment. The largest absolute decline occurred in Saudi Arabia, and is said to have been done in an orderly way, so that during the next decade production could be recovered easily.[24]

The more recent situation is somewhat different. The petroleum sector in Iraq has been affected by UN sanctions and war. The so-called OPEC-10 (current members excluding Iraq) had an excess capacity of over five million barrels per day, or twenty percent, in 1999. Estimates of excess capacity for 2005 suggest that only Saudi Arabia had excess capacity, amounting to perhaps five percent of OPEC-10 aggregate output. (EIA…).

A depiction of quotas, production, and prices in **Graph 4** is suggestive of the proposition that quotas are not important. First of all, for OPEC as a group, production was typically greater than the accumulated quota. Note also the significant increase in output and quota during the period 1988-1994, during which price stayed relative constant. There was a decline in price from late 1996 through early 1999, when production and quotas were increasing. The turn-of-century rise in price was certainly not caused by a reduction in quota, nor is that true of the experience during 2005-06.

A brief summary of our conclusions about OPEC will place these in the broader interests in this paper. First of all, the projected future "call" (net demand) on OPEC output is of a

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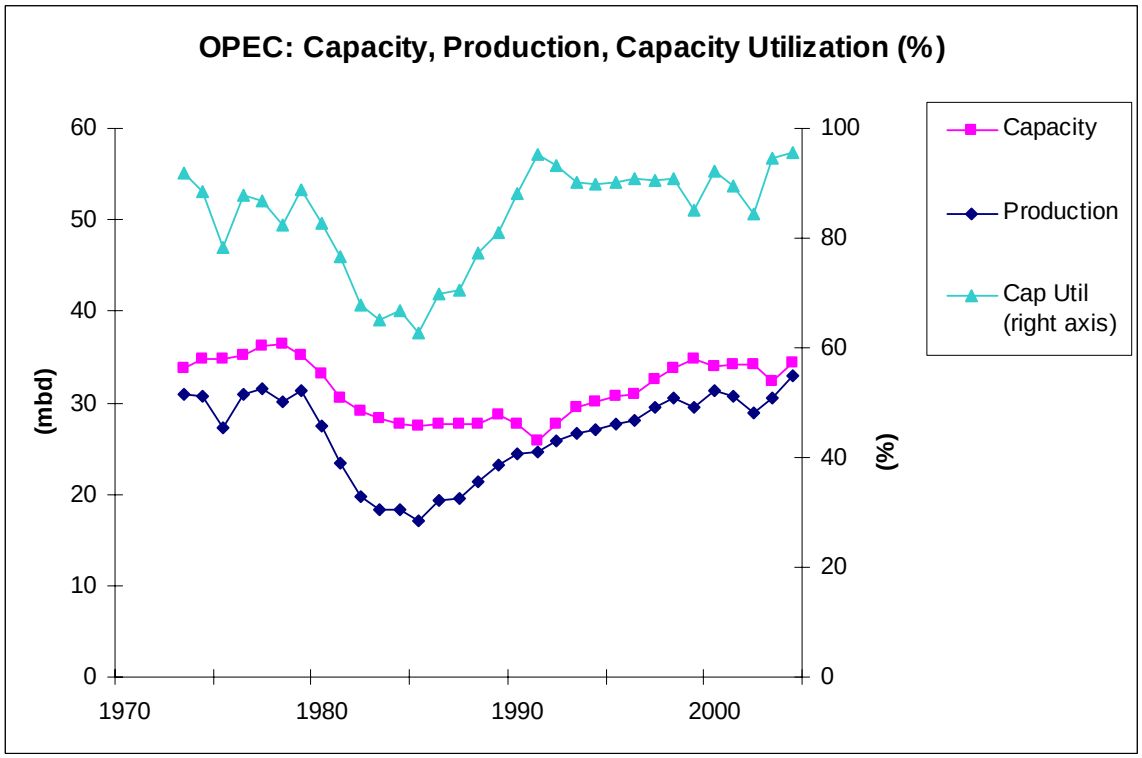
1992. For about the last five years the U.S. EIA/DoE has published this data, by country, in its *Short Term Energy Outlook*, (http://www.eia.doe.gov/emeu/steo/pub/contents.html), and predecessor bulletins. The International Energy Agency has published this relatively consistently since 2000, and sporadically during the previous decade. OPEC is now presenting estimates in its *Monthly Oil Market Report*, although this author has not seen these numbers broken down by country. Special thanks are due to Mr. Curley Andrews of IEA/DoE for providing a set of estimates for the OPEC total, covering the period 1973-2004.

[23] Although our sources give encouragingly close estimates of capacity – see **Graph 3 --** there is no guarantee that they are measuring the same thing. The US-CIA distinguished between "installed" capacity, - design or nameplate - and "maximum sustainable", which is "the maximum production rate that can be sustained for several months. …It is generally some 90-95 percent of installed capacity." (US-CIA January 1979, p. 3). The recent IEA source, *Monthly Oil Market Report* more succinctly defines "Sustainable Production Capacity" as "Capacity levels can be reached within 30 days and sustained for 90 days." (*OMR* June 13, 2006 p. 16) The US DoE's *STEO* uses identical criteria (*STEO* Table 3, April 2006). The OPEC Secretariat does not broach the subject of criteria. None of the sources specifies their ultimate source of data, although some early DoE tables cite the US-CIA.

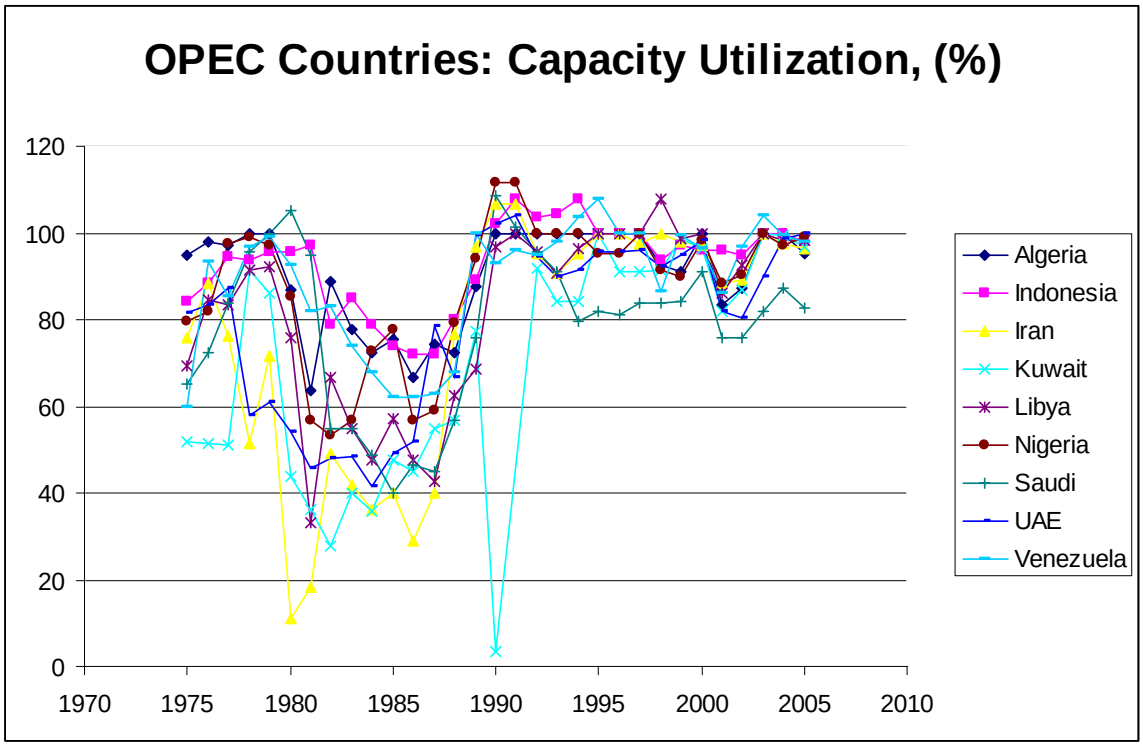
[24] Any discussion of management decisions would have to recognize that most of the MENA countries assumed control of the international oil companies in the 1970s.

Graph 1. OPEC: Total Capacity, Production, and Capacity Utilization



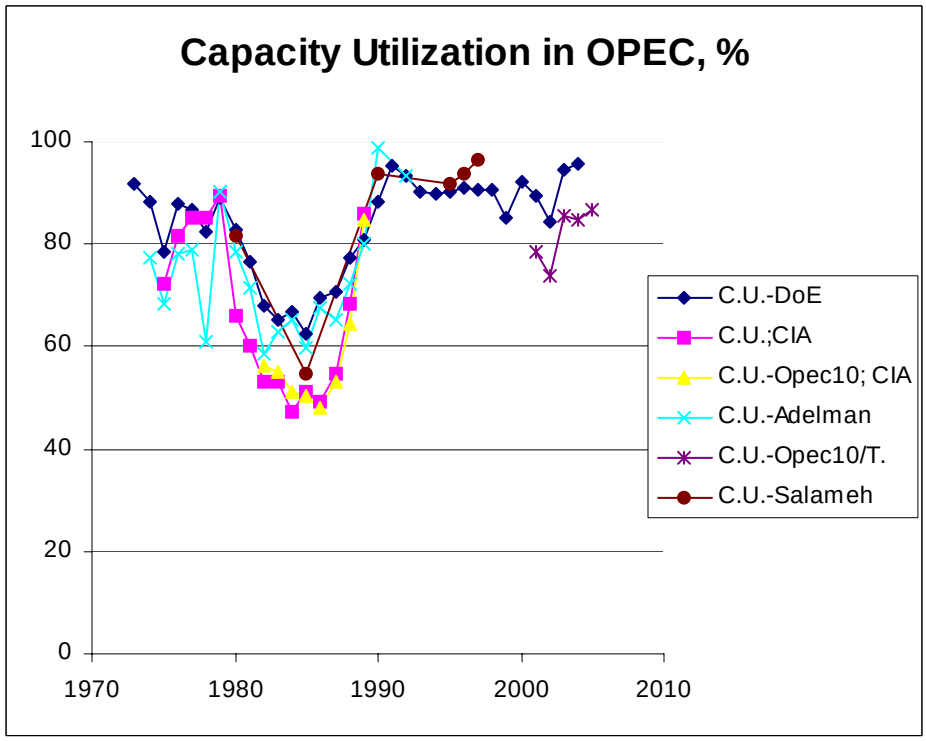
Sources: see data appendix.
[OPEC_Capacity.xls]

Graph 2. OPEC: Capacity Utilization by Countries.

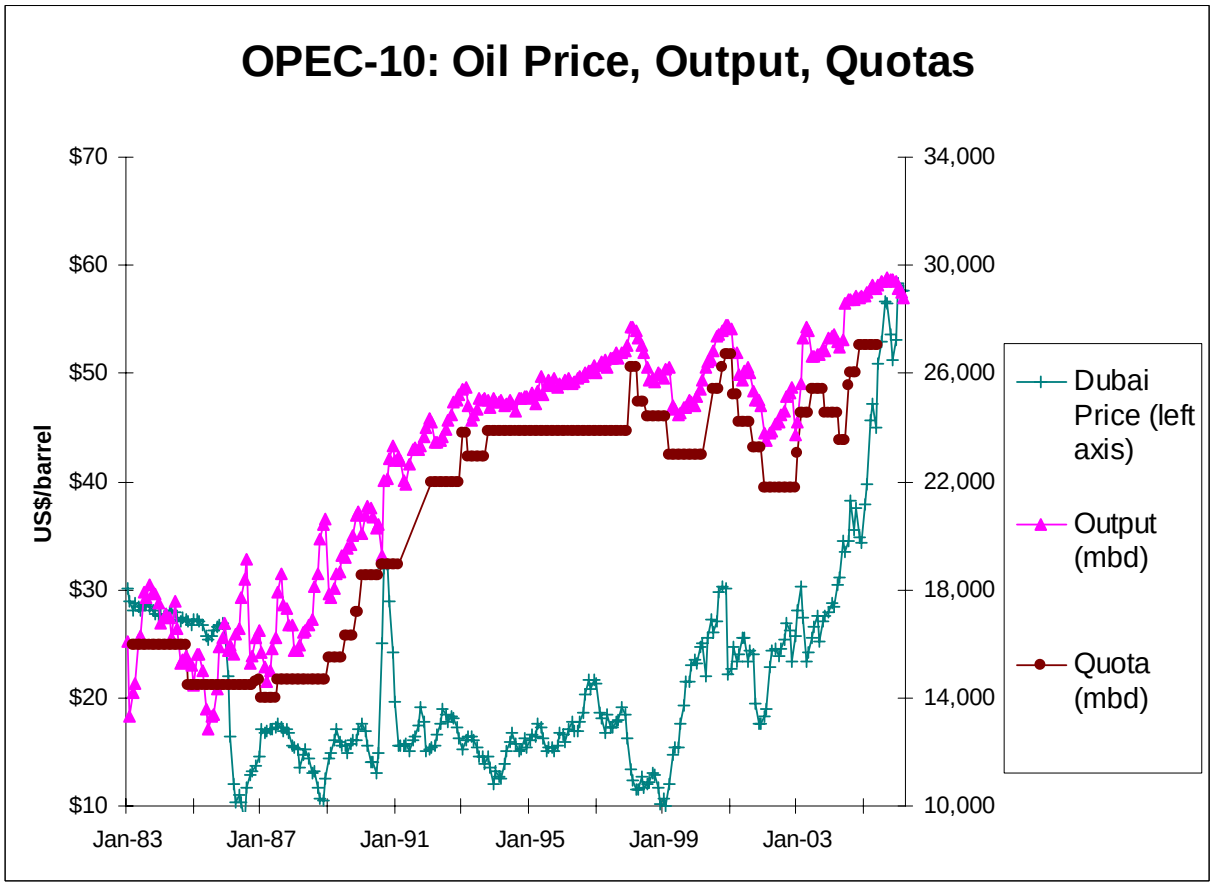


OPEC_capacity/various

Graph 3. Comparison of Various Sources on OPEC Capacity Utilization



Graph 4 Price vs. Output and Quotas



The spike in oil prices in late 1990 is the result of the Iraqi invasion of Kuwait. MonthlySupply.xls

much larger order of magnitude than excess capacity has been. Spare capacity rose when prices were falling during the early 1980s, but there is little evidence for the period after 1985 of spare capacity rising when prices were rising. There is no systematic treatment in the literature supporting the vision that tightening OPEC's quotas have increased prices. The current tight situation of excess capacity implies that increased demand should translate more directly into higher prices, compared to the case for several pervious years. Finally, currently available information cannot answer the question of whether countries are fully utilizing their known reservoirs.

An Economic Criticism of IEA/WEO and DoE/IEO Methodology.

Let us first consider the treatment of production in the large models, specifically production by OPEC. Formulas are not given in any of these modeling exercises, although vague references are made to country specific considerations of new fields. Overall one has the sense that production from OPEC is essentially treated as the residual necessary to fill the gap between rest of the world's production and consumption. This is evidently unsatisfactory, and Gately (2001) represents a good start at providing a better understanding of the implications of different supply and demand price elasticities.

In the baseline scenarios, prices are treated as remaining relatively constant, so that price induced substitutions have a minimal role, compared to the effects of income growth and technological change. Any effort at taking into account elasticities of substitution between products, as relative prices change, quickly becomes un-surmountable in a study encompassing many countries and products, as recognized by the organizers and participants of the symposia mentioned in this paper's first footnote. One fact that mitigates this criticism is that those modeling efforts incorporate several kinds of energy beyond oil and natural gas, including coal and renewable energy. Secondly, the models might fairly be described as reflecting the interests in the demand effects on the part of their sponsoring countries, while paying less attention to the production side. Thirdly, as we will see, the modeling of OPEC's supply is quite difficult. [25]

A telling example of the danger of a lack of a model of production in the OPEC countries arises when addressing the question of what happens if their output is insufficient, and prices rise. The DoE/IEO pays more attention to price changes; considering two alternative scenarios of an oil price in 2030 of $96/bbbl and $34/bbl, **Table 3** lists their projected values of oil output for the year 2030, contrasting the high and low price variants with the reference case. With high prices, one expects that the OPEC countries would have higher output, but the opposite happens. Apparently this occurs because the

[25] To illustrate the important potential of price increases, let us take the simplest of examples, supposing the elasticity of OPECs supply is 0.13, and the elasticity of the rest of the world's demand for oil is 0.2, with an initial situation of a price of $40/barrel, and exports of 30 mbd. Then a few lines of algebra leads to the formula that the increase in the price of oil is four times the difference in the amount of growth of demand and supply. For example, if after ten years world demand has grown by 15 mbd, and OPEC's supply by 5 mbd, then the equilibrium price would increase by four times the 10 mbd difference, or by $40/barrel, thereby doubling its hypothetical initial price. Compare the US DoE rule of thumb that a shortfall/supply disruption of one mbd leads to an increase of price of 4-6 $/b.
(http://www.eia.doe.gov/emeu/security/rule.html; accessed August 2006.)

Table 3. Comparisons of Output Predictions for 2030 in the EIA model.

	2003 Actual Price	Predictions for 2030			Ratio of 2030 Output: High price to Low Price (%)
		Reference Price	High Price	Low Price	
	$41/b	$57/b	$96/b	$34/b	
Output, (mbd)					
Total OPEC	33.0	50.7	36.7	55.4	66
Iran	4.2	4.3	2.9	4.8	60
Iraq	2.3	5.5	3.6	6.1	59
Kuwait	2.4	4.5	3.0	5.0	60
Qatar	0.9	0.8	0.5	0.8	63
Saudi Arabia	10.6	17.1	12.4	18.6	67
U.A.E.	3.3	4.6	3.2	5.2	62
Indonesia	1.4	1.1	0.7	1.3	54
Algeria	1.5	1.8	1.1	2.0	55
Libya	1.5	1.8	1.2	2.1	57
Nigeria	2.0	3.2	2.1	3.5	60
Venezuela	3.0	5.9	6.1	6.0	102
Total Non-OPEC	49.3	72.6	71.0	77.4	92
OECD					
United States	8.8	10.4	11.9	9.5	125
Canada	3.1	5	5.9	4.5	131
Mexico	3.8	5.1	4.2	5.8	72
North Sea	6.3	4.3	3.7	5.2	71
Non-OECD					
Russia	8.5	11.6	10.2	13.0	78
Caspian Area	1.9	7.5	6.4	8.4	76
China	3.4	4.2	5.4	4.2	129
India	0.9	1.6	1.8	1.6	113
Brazil	1.8	4.5	4.0	5.0	80
Total World	82.3	123.3	107.7	132.8	81

Source: U.S. DoE EIA, *International Energy Outlook 2006*, and author's calculations.

model privileges higher output for the importing countries, and then proceeds to calculate OPEC production as filling the remaining gap. This approach, treating OPEC as a residual, reflects thinking of a generation ago, but it is less convincing today, as these countries' national oil companies have improved in technical achievements, and the national governments are putting increasing pressure on them to produce funds. Given the difficulties discussed below in modeling OPEC behavior, this methodology may well be the least objectionable.[26] Recall that it is common to describe OPEC as at least attempting to vary its level of output, in order to achieve certain income goals. In this context, a straightforward supply function is certainly not appropriate.

Overview of the Data

Before presenting sets of regressions, let us look at graphs of some relevant data. **Graph 5**. The pattern of the real price of oil is: jumps in prices in the 1970s, followed by decline until 1986, oscillations for a few years and then further declines until 1998, after which it has been increasing. So where price does affect output, we should see increases in the 1970s, declines during most of the 1980s and 1990s, and a recent recovery.

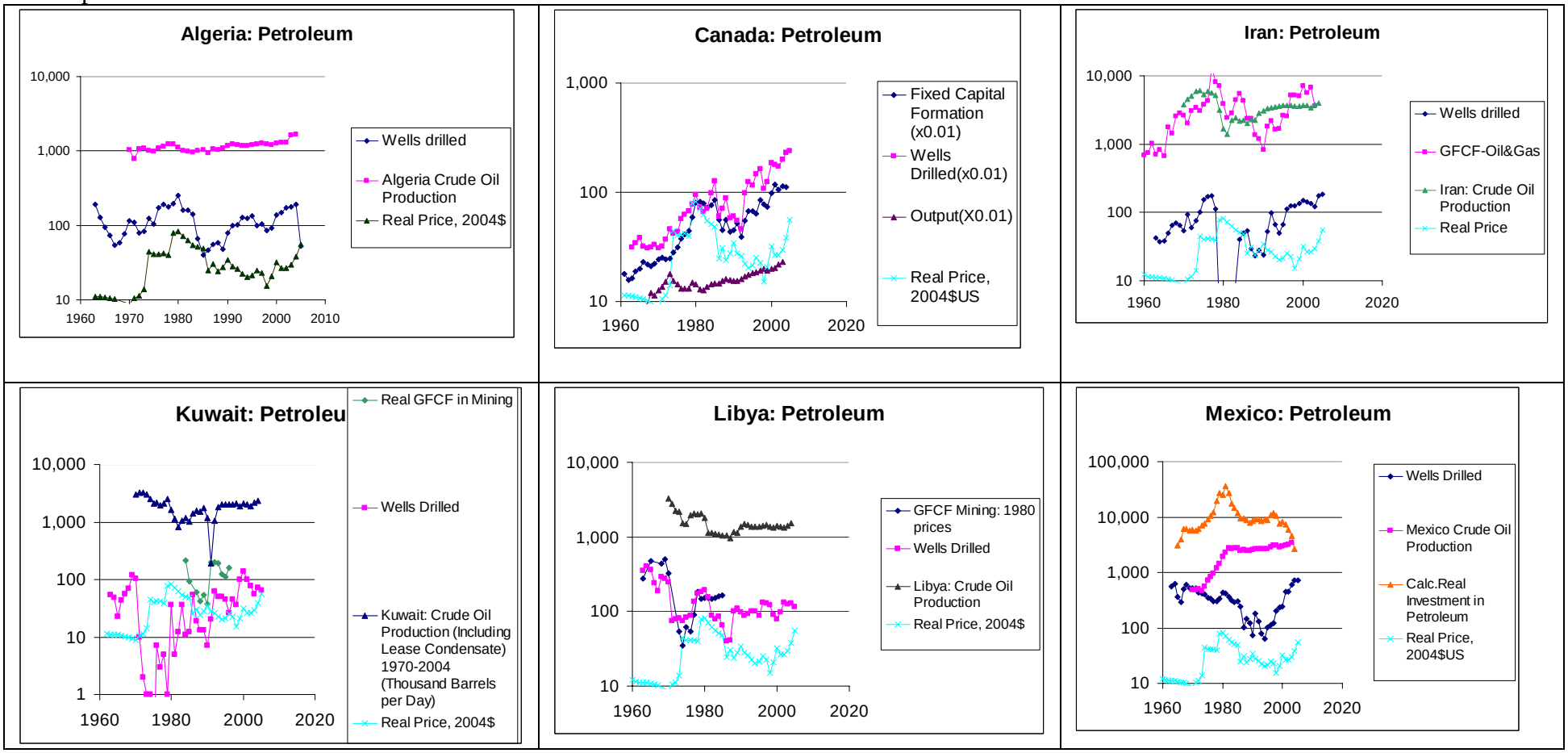
There is something of this pattern for: Algeria, Kuwait, Libya, Qatar, Saudi Arabia and Venezuela, and not much for Canada, Iran, Iraq, Nigeria, Mexico, Norway, Oman, and the UAE. A brief listing of non-price factors would include new discoveries, increased productivity in existing fields, wars, domestic political problems, and exhaustion of existing wells.

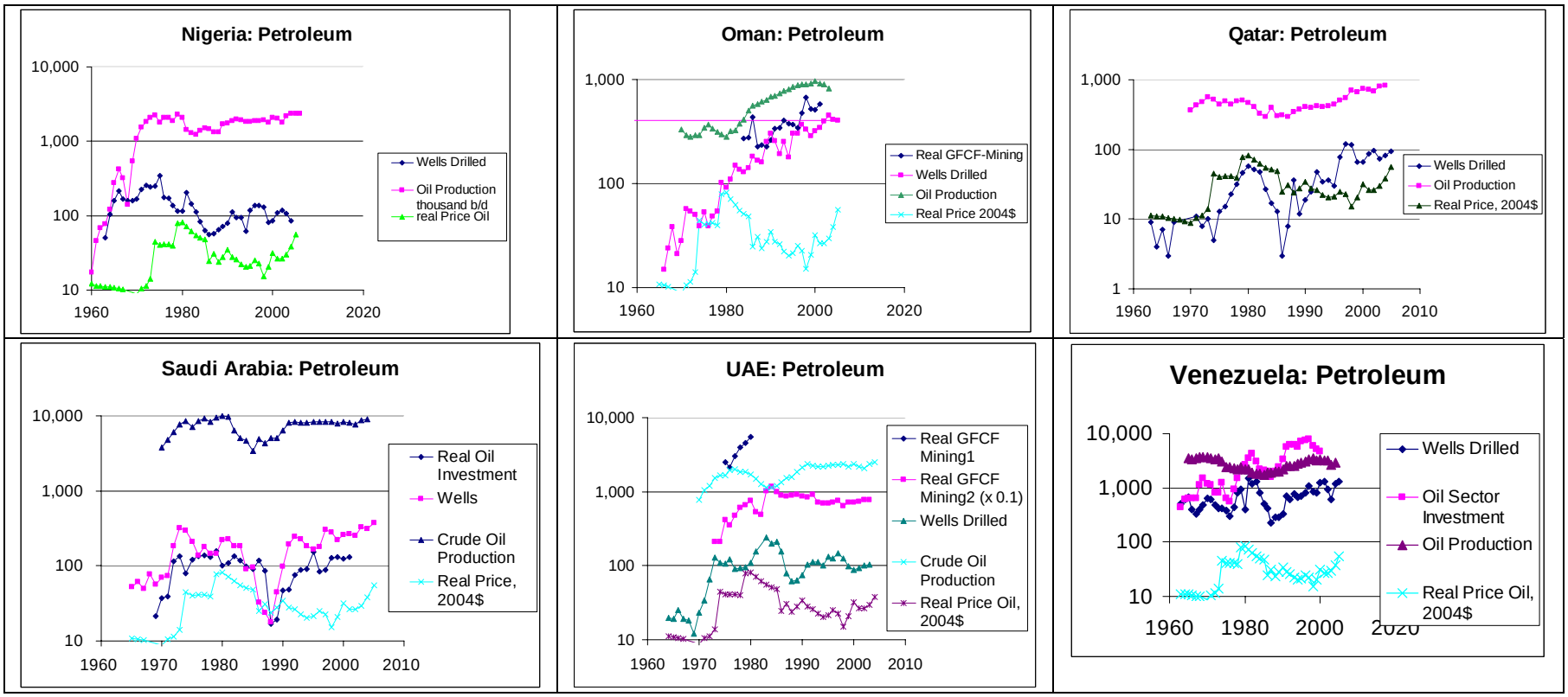
Given that the short run level of output may be determined by technical and geological factors, can we find a link between oil prices and investment in this sector? We will again look at our set of graphs. There are two indicators of investment; the number of wells drilled-which is a non-monetary measure, evidently related to the factor at hand, and the level of sectoral investment reported in the national accounts data-a monetary variable in need of price correction, possibly contaminated by inclusion of other activities (mining of minerals, oil refining), and probably not uniformly measured across countries. For the countries for which both measures of investment are available, only for the case of Mexico does there appear to be gross inconsistency between these two indicators. Our data suggest clearly positive correlations in Iran, Mexico, Saudi Arabia and the UAE, probably negative correlations in Canada, Kuwait, Oman, Qatar and Venezuela, and an arguable case for positive correlations, after an initial "growth spurt" in Libya, Algeria and Nigeria.

Supply Functions

[26] One of the inherent limitations to exercises such as those of the DoE or the IEA is that must serve diverse audiences, predominantly in the consuming countries. It is useful to think of these products as being scenarios, rather than predictions. Furthermore, the successive publications modify the scenarios from the previous years, highlighting the importance of several factors treated differently. One laudable aspect that is not treated in this paper is the increasing attention paid to the environmental effects of petroleum use.

Graph 5. Basic Data




Nigeria: Petroleum
10,000
1,000
100
10
1960
1980
2000
2020
Wells Drilled
Oil Production thousand b/d
real Price Oil
Oman: Petroleum
1,000
100
10
1960
1980
2000
2020
Real GFCF-Mining
Wells Drilled
Oil Production
Real Price 2004$
Qatar: Petroleum
1,000
100
10
1
1960
1970
1980
1990
2000
2010
Wells Drilled
Oil Production
Real Price, 2004$
Saudi Arabia: Petroleum
10,000
1,000
100
10
1960
1970
1980
1990
2000
2010
Real Oil Investment
Wells
Crude Oil Production
Real Price, 2004$
UAE: Petroleum
10,000
1,000
100
10
1960
1970
1980
1990
2000
2010
Real GFCF Mining1
Real GFCF Mining2 (x 0.1)
Wells Drilled
Crude Oil Production
Real Price Oil, 2004$
Venezuela: Petroleum
10,000
1,000
100
10
1960
1980
2000
Wells Drilled
Oil Sector Investment
Oil Production
Real Price Oil, 2004$

Introductory microeconomics describes supply as a function of price. In the case of petroleum, several extensions are suggested. Price expectations should be considered, especially because certain aspects of production involve sizeable investments that need several years. Secondly, in the short run—given the number of fields—the possibilities of increasing output are small, as geological considerations determine the optimum rate of extraction, and indeed one expects something like a classic backward L for the short run supply of oil.[27] Thirdly, and as an extension of that idea, one looks to re-phrase the issue as one of exploration activity, and ultimately the supply of funds for exploration. Finally, we note that in this sector there is much interest in ascertaining the actions of monopolists, for which a standard methodological route is to investigate the difference between price and marginal cost. Unfortunately, the cost data are very scarce in the MENA region.

Price expectations are obviously of great importance to supply in the short run. However, our primary interest here is a time span of five to twenty years. Given the length of time required for the expansion of production potential, an attractive option might be to look at movements in the long term forward market. There has been a long term futures market functioning since the 1980s, and of interest to us is the fact pointed out by Paul Horsnell that the long term future price of oil (more than a year) has stopped pointing back to a price in the $20/bbl range, but has recently jumped up to $60 and more (*BusinessWeek* online February 6, 2006). Overall, one's sense from the literature is that increased price variability is reducing supply, through its effect on investment.

How does price affect the supply of crude oil? One convenient reference and introduction to the literature is the recent article by Ramcharran (2002). In it are presented standard regressions of oil supply functions for over twenty countries, in which the price coefficients for the OPEC countries typically have *negative* coefficients, while similarly estimated regression coefficients for other, non-OPEC countries are generally positive.[28] Ramcharran's regressions included a time trend; the results of other authors –especially Griffin (1985)--reproduced therein, reported regressions without the time trend, with similar findings, and evidently the literature is replete with studies leading to this conclusion. The reader is somewhat taken aback by the widespread, but not universal, lack of modification of the regressions to take into account periods of external war (Iraq, Iran, Kuwait), civil war (Nigeria, Algeria), or change of government (Iran; nearly Venezuela). Nevertheless, the dominant view in the published literature is that the price impact on OPEC's oil supply is minimal, and perhaps negative. The implication is that the OPEC countries are different, and to this subject we now turn.

My regressions initially attempted a straightforward supply relationship, using annual data for each country, of Output = $\alpha + \beta$ Real Price, inserting dummy variables for periods of turmoil. Even when combined with a time variable, these results were not different from those of Ramcharran (2002) et al., in the sense that the estimated

[27] Estimates of an asymmetric effect on demand are presented in Gately and Huntington (2002).
[28] One important consideration is the price threshold at which non-traditional oil (oil sands, oromulsion, etc.) becomes economically feasible. A few years ago, when the price of oil was in the $20s, it was said that this price was in the $30s. It is unclear how this subject is treated in the estimates of the IEA and DoE.

coefficients on the price variables were usually not statistically significant, and often negative. As the Durbin Watson statistics were generally quite low (< 1.0), the lagged dependent variable was inserted on the right hand side, with no improvement in terms of the coefficient on price. Curiously, allowance for an asymmetric supply curve resulted in an upward-sloping negative supply. These regression results are not included here. More sophisticated time series analysis was not attempted, although an important work in this direction is Kaufmann et al. (2004).[29]

Another option was to attempt to incorporate factors causing shifts in the supply curve. Following the example of Youhanna (1994), a variable was inserted representing fixed "capital"--the amount of reserves, or the number of wells, with an expected positive coefficient.[30] Another consideration of shifting of supply curves was to incorporate the impact of the production quotas. These were implemented formally in 1983, although some countries had been supporting the earlier price floors with voluntary constraints.[31] The data suggest that several countries continue to produce over quotas, while some cannot even meet those levels. In order to avoid using oil output in the right hand side of the regression equations, we used the ratio of full capacity to the quota, labeled "pressure," whose expected sign was negative.

These results are shown in **Table 4**, where it can be seen that the price coefficient is not positive. Nevertheless, the estimated coefficients on "pressure" and capital-reserves or wells--are generally of the hypothesized sign, even if often insignificant.

Many narrative histories of OPEC suggest that the period after 1970 should be broken up into sub-periods. One cut-off was 1985, after which Saudi Arabia's policies are said to have changed. Other cut-off points would include the period after the October War (1973), and after 1982, with the acceptance of formal quotas. For this, monthly data on prices and output were necessary, to have sufficient number of observations. Refining the political dummies, it turned out that the price coefficient continued to waver in insignificance.[32]

Target Income Hypothesis

One interpretation of the result of negative price coefficients is that they reflect target income behavior. This paper is not sympathetic to this vision, although no proofs of a

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[29] This article concludes that OPEC capacity utilization, quotas, stocks, etc. "Granger cause" real oil prices, and that the converse is not true.

[30] What is still lacking is a means of capturing the declining productivity of an aging field, as reflected in the Hubbert curve analysis. In addition to the above-mentioned controversial case of Saudi Arabia, the business press suggests this to be important in Kuwait, Venezuela, and Indonesia, among others.

[31] The most well-known action was the short-lived Arab embargo of certain western countries that accompanied the 1973 Arab-Israeli War. Even in this case, the non-Arab countries of OPEC did not support the boycott, nor did Iraq. The narrative histories of OPEC suggest that voluntary restrictions were operational before October, 1973, although of course at that time most of the decisions about the oil was in the hands of the international oil companies. For an analysis of compliance for the period 1995-2002, see Mazraati and Tayyebi Jazayeri (2004).

[32] Claes (2001, 248) presents tables of output/price correlations for different periods, in which the sign of the correlations also do not shift over time in a readily explainable manner.

Table 4. Regression Results on Supply of Crude Oil.

R2	Dep. Var	Constant	Price of Oil	Wells	Reserves	Pressure	Dummy	Degrees Freedom
0.74	Algeria Q	1.06 (1.15)	0.16 (0.63)	0.60 (6.72)	0.19 (1.67)	0.01 (0.42)		34
0.47	Indones Q	3.08 (1.47)	0.12 (2.50)	0.23 (2.12)	0.20 (1.34)	0.05 (1.23)		34
0.69	Iran Q	16.1 (5.59)	0.10 (1.04)	0.07 (0.48)	-0.76 (2.40)	-0.02 (0.27)	0.14 -0.84 (0.43)(5.56)	29
0.62	Kuwait Q	11.3 (3.25)	-0.37 (4.74)	0.33 (3.36)	-0.41 (1.34)	-0.15 (2.04)	n.a.	33
0.46	Libya Q	4.13 (1.50)	-0.19 (2.52)	-0.62 (2.52)	0.80 (2.42)	-0.17 (2.140		34
0.62	Nigeria Q	1.51 (1.29)	-0.07 (1.59)	0.14 (1.75)	0.53 (3.33)	-0.08 (1.63)		34
0.64	Qatar Q	2.30 (3.71)	-0.02 (0.24)	0.12 (1.91)	0.38 (5.12)	0.03 (0.49)		34
0.36	Saudi Q	5.19 (1.85)	0.20 (2.39)	0.42 (1.88)	0.01 (0.03)	-0.09 (1.30)		34
0.72	UAE Q	2.01 (2.10)	0.10 (1.85)	-0.16 (1.32)	0.57 (3.85)	-0.07 (1.35)		34
0.53	Venez Q	5.18 (2.99)	-0.28 (5.26)	0.46 (2.23)	-0.08 (1.53)	-0.05 (0.89)		34
0.74	Canada	4.22 (10.3)	-0.06 (2,24)	0.28 (7.74)	0.06 (2.98)			33
0.98	Oman Q	4.14 (11.8)	-0.20 (8.79)	0.39 (34.7)	0.03 (0.78)			34
0.85	Mexico Q	19.4 (3.57)	-0.16 (1.63)	-2.24 (3.29)	0.68 (12.1)			33
0.46	Norway Q	-20.56 (3.89)	0.27 (0.66)		2.93 (5.11)			33

OLS equations. ‘t’ statistics in parenthesis. Durbin Watson statistics were usually quite low.

Notation: Q is oil output, in million barrels per day. Wells is the number of operational wells, Reserves is the amount of recoverable oil, Pressure is the ratio of Production Capacity to Quota, and the dummies were for the periods of war. All variables except the dummies were entered in logarithms.

The hypothesis was that the estimated signs of the coefficients on Price, Wells, Reserves would be positive, and that for Pressure and Dummy would be negative.

Using NewOutput3, with regressions from OilRegress3…

contrary hypothesis will be offered. First of all, the target income hypothesis is quite distinct from the cartel vision. Secondly, the overwhelming opinion in the literature is that countries in OPEC, as elsewhere, now consider themselves to have sufficient needs that no target income would suffice. Thirdly, this is rejected by Griffin (1985) and others mentioned in Smith (2005, 55-56).

What should be our response to the (present) inability to uncover a price effect on petroleum supply? Will prices equalize supply and demand? The simple part of the answer is to remember that studies of oil demand generally report negative elasticites, even if low. A second part of an answer is simply to forge ahead, trusting basic economic principles taught in the intro classes. For example, lacking good estimates of output elasticity, Houthakker (1976, 19) utilized values termed "optimistic" and "pessimistic" of 50 and 0.1 for the MENA region, whereas his optimistic values for other regions varied from 0.1 to 0.5, and the pessimistic values from 0.05 to 0.15. McAvoy (1982) was similarly unsuccessful in his econometric search for price elasticities, and in his simulations he used alternative parameter values reflecting conventional wisdom, in particular, short term supply elasticities of 0.2 or 0.3.

Investment Functions

Let us broaden our attention from the direct link between price and petroleum output, to a more medium term relationship between output, reserves, investment, and prices. Such a different perspective has been proposed by Morris Adelman and his co-authors, who treat the output of a given oil reserve field as determined by geological conditions relatively insensitive to prices,[33] and prefer to model changes in petroleum supply as a function of expansion of reserves, so that prices become important by affecting the number and extent of new fields. One study in this tradition, Watkins and Streifel (1996), focused on the time trend associated with these supply functions. The data requirements of this work are more stringent than most, especially for OPEC countries, because of the importance they attach to costs of production. Of interest to our broad focus is their finding (Table 5-1) that the following countries have contracting supply functions: Abu Dhabi, Algeria, Iran, Kuwait, Libya, and Nigeria, while Venezuela and Oman had expanding curves.[34] The authors caution against the straightforward application of their model—in which the countries are assumed to be price takers—to the case of OPEC as a cartel.

There are two major types of data for oil investment: wells drilled, as reported in the trade journals, and sectoral expenditure from the national accounts. There is also scattered information about numbers of teams doing exploratory work. Data on drilling has presumably been produced using a standard methodology for many years, in MENA as elsewhere. Because gas and oil are often produced together, there is good justification

[33] On how the microeconomics of oil recovery is affected by policy-and by implication, prices-see Nystad (1988).

[34] This work continues Adelman and Watkins (1995) which had as a broader theme the in-applicability of the Hotelling model to petroleum. An important input into these studies is data on drilling costs, which are very scarce for MENA countries. The lack of a positive time trend in output complicates long term projections.

for not attempting to separate the data on wells drilled by product. Unfortunately only a fraction of the available data do not separate on-shore from off-shore drilling. An immediate problem with the national accounts data, as published by the UN, is that the sectoral data series include both mining and hydrocarbons. From production data we know that mining is important in Algeria of the OPEC countries, as well as Canada and Mexico among non-OPEC oil exporters. In addition, there is the question of where the dividing line is drawn between raw material production and industry-refining. Statistics Norway data indicate that exploration varied between five and ten percent of total extraction costs in the early 2000s. Finally, we have to confront measurement issues of price deflator, and depreciation.

The question arises as to what fraction of the wells should be considered expansion of output, as contrasted with replacing worn out installations. We have discussed the importance of this issue in Saudi Arabia, where the existing fields, although very large, have been worked for many years, and the ministry's defenders claim that larger amounts of production must come from new fields, for which exploration in areas like Rub al-Khali has intensified. At the present time we have little to go on; most countries throughout the world do not present estimates of depreciation in petroleum production.

A recent article[35] by researchers associated with the OPEC Secretariat goes directly to our interest of studying the empirical determinants of petroleum investment. Aloshban and Sandrea (2006) examine annual global exploration and production capital expenditures (E&P capex) in the petroleum industry. They find that demand is an important factor, in addition to the price. In addition, cash flow for non-OPEC countries was not statistically significant, nor was spare capacity, although the latter variable had the expected negative sign. The price variable was highly significant, although unfortunately the elasticity was not calculated.[36]

We generated two indicators of country level investment in the petroleum exporting sector: fixed capital formation (FCF)--from the national income accounts, and wells drilled--available from the trade journals. Following Aloshban and Sandrea (2006), we include excess capacity along with price. Our own regression results are presented in **Table 5**. The results are encouraging. The coefficients on the price variable had the expected positive sign in almost all of the regressions, although they were seldom statistically significant. The coefficient on the lagged dependent variable was generally over one half, suggesting that the long term impacts of price changes were rather larger than the short term impacts.[37] The variable excess capacity (for OPEC countries) did

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[35] My thanks to Ivan Sandrea for sending me a copy of the paper. A summary is available on the web as: "Global E&P capex and liquid capacity trends, and medium term outlook," paper presented to APPEX London, http://energy.ihs.com/NR/rdonlyres/706E1482-6AA8-4E80-9451-C63C6EDB5F33/0/OPEC_Sandrea_APPEX2006.pdf

[36] In a "reduced form" specification of an equation, where both supply and demand elements appear on the right hand side, it would be inappropriate to make a calculation of a supply elasticity.

[37] When these regressions were run without the lagged dependent variable, the size of the coefficient on the price variables was somewhat larger than those reported here, and more were significant-although more of them were negative-but the long term price impact is larger in the regressions run with the lagged dependent variable. The Durbin-Watson statistic was quite low in the regressions not reported here,

Table 3. Oil Investment Regressions.

R2 adj.	Dependent Variable	Constant	Lagged Dep Var	Price of Oil	% Excess Capacity	Dummy	DoF
OPEC							
0.55	Algeria Drill	1.49 (2.28)	0.69 (4.19)	0.17 (0.09)	-0.01 (1.77)		30
0.70	Indonesia Drill	1.16 (1.40)	0.82 (7.38)	0.40 (0.58)	-0.01 (2.59)		30
0.57	Iran FCF	-0.23 (0.15)	0.90 (5.92)	0.38 (1.38)	-0.10 (1.08)	-0.35 0.07 (0.75) (0.17)	28
0.78	Iran Drill	-0.14 (0.19)	0.86 (7.88)	0.28 (1.25)	-0.01 (0.64)	-0.33 -0.04 (0.71) (0.08)	24
0.79	Kuwait FCF	1.07 (0.71)	0.65 (3.81)	0.29 (0.56)	-0.02 (2.42)	n.a.	7
0.37	Kuwait Drill	3.79 (1.68)	0.47 (2.68)	-0.55 (0.89)	-0.01 (0.63)	n.a.	28
0.63	Libya FCF	2.69 (2.31)	0.79 (3.50)	-0.40 (0.92)	-0.001 (0.19)		10
0.53	Libya Drill	1.79 (2.89)	0.50 (2.97)	0.19 (1.27)	-0.01 (2.09)		30
0.58	Nigeria Drill	1.21 (1.98)	0.69 (5.41)	0.07 (0.47)	-0.002 (0.61)		29
0.65	Qatar Drill	1.81 (2.06)	0.46 (3.16)	0.21 (0.89)	-0.02 (2.71)		30
0.42	Saudi FCF	1.26 (1.54)	0.71 (4.39)	0.05 (0.28)	-0.01 (1.15)		26
0.85	Saudi Drill	1.35 (2.44)	0.78 (10.6)	0.03 (0.22)	-0.16 (5.17)		30
0.55	UAE FCF	2.90 (3.31)	0.58 (5.53)	-0.04 (0.29)	0.002 (0.69)		28
0.54	UAE Drill	0.85 (0.89)	0.71 (4.59)	0.15 (1.13)	-0.001 (0.32)		26
0.91	Venezuela FCF	1.20 (1.39)	0.85 (11.3)	0.06 (0.26)	-0.01 (3.64)	0.06 (0.26)	25
0.44	Venezuela Drill	2.17 (2.13)	0.62 (4.42)	0.13 (0.77)	-0.10 (2.01)		30
Non-OPEC							
0.51	Oman FCF	3.60 (2.21)	0.61 (3.06)	-0.40 (1.62)			16
0.89	Oman Drill	0.60 (1.47)	0.91 (16.9)	-0.02 (0.20)			34
0.87	Canada FCF	0.74 (1.32)	0.88 (13.4)	0.10 (1.74)			33
0.77	Canada Drill	0.97 (1.28)	0.89 (19.7)	0.04 (0.41)			34
0.82	Mexico FCF	0.16 (0.19)	0.97 (8.82)	0.04 (0.37)			33
0.75	Mexico Drill	0.58 (1.09)	0.89 (9.65)	0.10 (0.08)			34
0.89	Norway FCF	2.38 (4.84)	0.76 (16.2)	0.06 (0.82)			34
0.72	Norway Drill	0.88 (1.34)	0.79 (9.05)	0.04 (0.27)			31

FCF – Fixed Capital Formation in the petroleum sector; Drill is number of wells drilled that year, Price of Oil is the "real" price, Excess Capacity is the difference between Full Capacity and actual output, and Dummy variables refer to periods of wars or political unrest. The dependent variable and the Price of Oil were entered as logarithms.
NewOutput8 and 8a using OilRegress7c

quite well, with most of the coefficients having the expected negative sign. Curiously, the political dummies were not particularly significant.

Do these regressions justify optimism that the price mechanism will stimulate investment enough to ensure a significant amount of oil production? Not yet. Being generous and taking the long term elasticity of investment with respect to prices at 0.5, and combining that with a price increase of 50 percent (currently 2004 to mid-2006), leads to a twenty five percent increase in investment. To judge by the data on wells drilled, the ratio of new capital stock to existing stock in the petroleum sector in these countries is usually not more than five percent. Thus a fifty percent price increase would raise the total capital stock in the hydrocarbon sector by less than five percent, which is not much. Of course, for a complete picture one would need to estimate how that capital stock would translate into greater oil supply and price changes, which is beyond our means here.

Traditionally the extraction of crude oil from the Gulf countries has been described as having very low costs. These costs are not constant, as the construction of a new well on a currently producing reservoir should increase short term output while obviously raising prices. The strong emphasis on reliance of technological progress inevitably implies an increase in marginal costs, even in this geographical area.

Investment required for the projected output growth

A related topic is the amount of investment that would be needed to fulfill the projections of the DoE/EIA and the IEA/WEO. The *WEO* 2005 is particularly useful for our purposes, because it provides for the Middle East countries detailed estimates of the total investment costs implied by these expansions of output. Some relevant data are provided in **Table 6**, with, for comparison, estimated totals for other parts of the world, which appeared in the earlier *WEIO* 2003. Two major findings help establish the context: the OECD countries will spend much more on developing energy or petroleum than will OPEC, and in the OECD countries oil and gas are projected to involve less than half of the total expenditures on energy. It was noted earlier that the OPEC Secretariat is now publishing forecasts of output, and that its numbers are basically consistent with the *WEO* and EIA/DoE. In addition, the OPEC web-site contains a graph[38] titled "OPEC Upstream Investment Plans," containing estimated capital expenditures for the period 2005-2010, whose total expenditure was $100 billion--quite close to the *WEO* datum in **Table 6**. [39]

To continue this comparison of our data on investment, and establish similarities in orders of magnitude, **Table 7** compares a published estimate of capital spending for

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suggesting the need for some fancier econometric estimations, but no claim is made that the results in Table 5 are entirely satisfactory.

[38] www.opec.org/home/PowerPoint/Supply%20and%20Capacity/OPECUpInvestplan.htm These exclude natural gas production-important to Algeria, Iran and Qatar-and "downstream" investments, such as refineries, pipelines, shipping. The format of this information, and the degree of detail, is similar to that of some of the standard business journals, such as *Middle East Oil & Gas*, or *Middle East Economic Survey*.

[39] A sub-text is the increased willingness of producer and consumer countries to share data and other information. While both sides recognize the benefits of reducing price instability, one wonders if achieving that goal might evolve into pressures to affect long term trends.

Table 6. Investments in WEO Scenarios billion dollars (2004)

From **WEO2005** (2004 $)

	All Energy Accumulated Total	All Energy Annual values	Oil Investments annual values			Gas Investments annual values		
	2004 -2030	2004 -2030	2004 -2010	2011 -2020	2021 -2030	2004 -2010	2011 -2020	2021 -2030
OPEC								
Iran	254	9.4	1.6	3.0	3.6	1.9	3.2	4.0
Iraq	96	3.6	1.0	2.0	3.3	0.0	0.4	0.6
Kuwait	86	3.2	1.9	1.8	2.7	0.1	0.3	0.4
Qatar	155	5.7	1.3	2.4	1.7	2.4	4.1	4.1
Saudi A.	332	12.3	4.9	6.1	7.9	1.1	2.0	2.1
U.A.E.	115	4.3	0.9	1.5	2.6	1.3	1.3	1.3
Algeria	114	4.2	1.6	1.5	1.2	1.3	2.3	2.7
Libya	80	3.0	0.7	1.5	2.0	0.1	0.8	1.2
MENA	1,508	55.9	16.0	22.3	27.9	10.0	17.1	19.6
Middle East	1,203	44.6	13.1	18.6	23.9	7.6	12.5	14.0
North Africa	305	11.3	2.7	3.7	4.0	2.4	4.5	5.6

From **WEIO 2003** (2000 $)

	All Energy Accumulated Total	All Energy Annual values	Oil Investments Annual Values			Gas Investments Annual Values		
	2001 -2030	2001 -2030	2001 -2010	2011 -2020	2021 -2030	2001 -2010	2011 -2020	2021 -2030
US & Canada	3,164	117.2	20.8	17.2	16.5	28.8	28.6	28.2
EU15	1,603	59.4	5.3	3.7	2.7	13.7	12.3	10.5
Trans. Econ	1,672	61.9	12.4	15.4	17.0	15.4	17.4	16.4
China	2,253	83.4	3.9	4.1	3.9	2.2	3.1	4.5
Middle East	1,044	38.7	12.3	16.6	23.4	7.3	8.3	10.6

Sources: *WEO* 2005, *WEIO* 2003.
Notes: Separate estimates for Indonesia and Nigeria were not provided in *WEO 2005*.
The North Africa estimate includes Egypt.

Table 7. Comparison of Capital Spending Data for Countries and State Companies

	Estimated Capex 2005-2010 annual values (million $US	Oil Investments 2004-2010 annual values (million US$PPP)	Capital Spending Budgets for State Companies (million $)	1996	1997	1998
U.A.E.	667	857	Adnoc (Abu Dhabi-UAE)	2,000	2,000	2,100
Saudi Arabia	4,167	4,857	Aramco-Saudi Arabia	3,600	3,500	3,850
Iran	1,667	1,571	INOC-Iran	n.a.	n.a.	n.a.
Kuwait	1,667	1,857	KPC-Kuwait	3,200	3,300	3,400
Nigeria	4,500	n.a.	NNPC-Nigeria	2,000	1,200	1,300
Libya	1,000	714	NOC-Libya	n.a.	n.a.	n.a.
Venezuela	1,000	n.a.	PdVSA-venezuela	n.a.	n.a.	n.a.
Indonesia	667	n.a.	Petramina-Indonesia	n.a.	n.a.	n.a.
Algeria	667	1,571	Pemex-Mexico	4,640	4,510	5,500
Qatar	3,000	1,286	Petronas?—Malaysia(?)	1,940	2,580	2,800
Iraq	n.a.	1,000				

Sources: The first set of data corresponding to countries: the Estimated Capex is taken from the graph on the OPEC web site http://www.opec.org/home/PowerPoint/Supply%20and%20Capacity/OPECUpInvestplan.htm, while the Oil Investments are from the *WEO-2005*. The last set of data is taken from the *PIW* Feb. 16, 1998 p. 1, and is offered to show relative orders of magnitude.

Note: The US$PPP data are estimates evaluated in US $ of purchasing power parity, which uses a different exchange rate than the market exchange rate. Values of the PPP conversion factor for early 2000s are: Algeria, 0.4, Iran 0.32, Kuwait 0.96, Saudi Arabia 0.7, and UAE (1998) 0.85 (source: WDI online).

/Oilinvest/noc

Table 8. Comparison of National Accounts Estimates of Petroleum Sector Investment in 1990 with Adelman's Calculations of Oil Investment. (million US$)

	Adelman's Calculations		National Accounts
	Oil Inv.	Oil Inv. * 1.6	
Algeria	188	301	n.a.
Indonesia	543	869	n.a.
Iran	92	147	1,402
Iraq	187	299	1,239
Kuwait	45	72	123
Libya	280	448	n.a.
Nigeria	146	234	n.a.
Qatar	39	62	n.a.
Saudi Arabia	186	298	1,131
Venezuela	871	1,394	1,735

Source: Adelman's calculations from Adelman (1995). SNA estimates from the sources in listed in the appendix.

Note: Adelman's methodology can be summarized as estimating the cost of digging oil wells, and adding on 60% as cost of exploration. /OilInv.xls/noc

several national oil companies, with the OPEC and IEA/WEO projections.[40] These projections of capital expenditures for the next five years are quite similar—this would not normally be remarkable, except that they represent an acceleration of spending. Additionally, that table reproduces a set of estimated capital spending for several state owned oil companies, which appeared in *Petroleum Investment Weekly*, citing a business consulting firm. Although the data refer to a period five years earlier, there is evidently considerable compatibility in these sources.

A related comparison is that reported in **Table 8,** of Adelman's estimated investment expenditures with our national data on oil investment. The strong indication is that Adelman's are much lower. Adelman's estimates were generated as part of an argument that the OPEC countries could afford to expand output, which is a position with which this paper is in agreement, although it would seem that his calculations are too small. In addition, however, to the extent that his calculations are significantly smaller than the national accounts totals, this would call into question his broader research approach of applying cost coefficients from the US and the UK to analyze situations in the OPEC countries, where unskilled labor would be cheaper but technology more expensive.

Macroeconomic Feasibility of the Projections

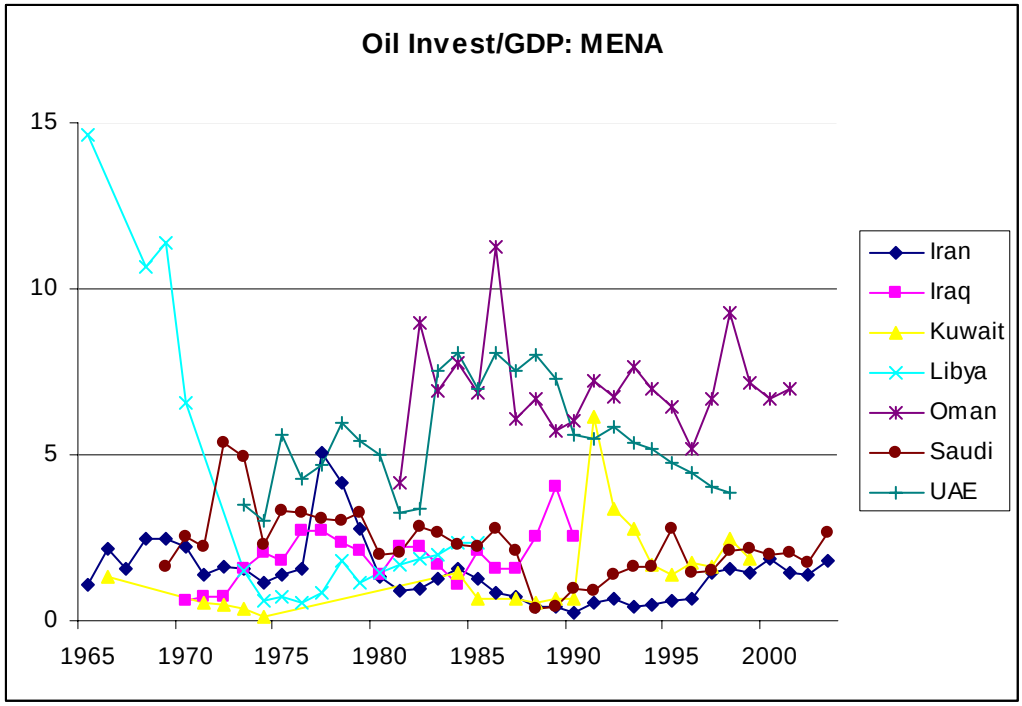
One mode of analysis of the *WEO*'s scenarios for energy, oil and gas is to compare, for each country, the amount of investment needed, to their projected GDP. This is done in **Table 9**. The levels for Qatar are high, while those for Kuwait, UAE and some others are also noticeable. In fact, these are the countries which have turned toward the international markets for funds and technology. What is striking in that table is the general message that even though the absolute magnitudes of energy investment may seem high, they currently are not large as a fraction of GDP, and are projected to decline.

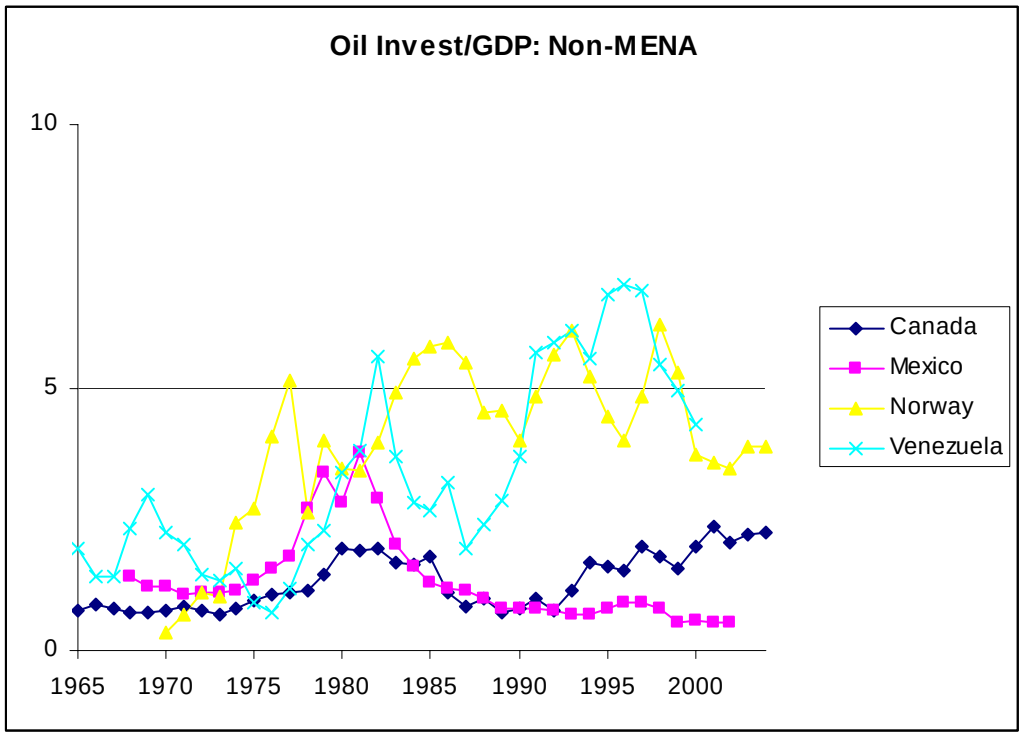
We can attempt to put the data in that table in perspective, by looking at the historical trend of Oil Investment/GDP, shown in **Graph 6**. Data for MENA and some other important oil exporters are shown. The levels for the MENA countries are just slightly higher than for the others, and within MENA, Oman[41] and UAE currently have the highest values, while Libya's ratio was quite high in the mid-1960s.[42] While there are several interesting stories to tell about individual countries, the overall picture is that the projections in **Table 9** are compatible with historical experience.

Is a situation of oil investment at five percent of GDP sustainable? This paper's answer is basically affirmative. First of all, in most countries the oil sector has accounted for less than twenty percent of total investment-see **Graph 7**--this is not out of line with the experience in other countries. Thus, there is little reason to believe that increased oil

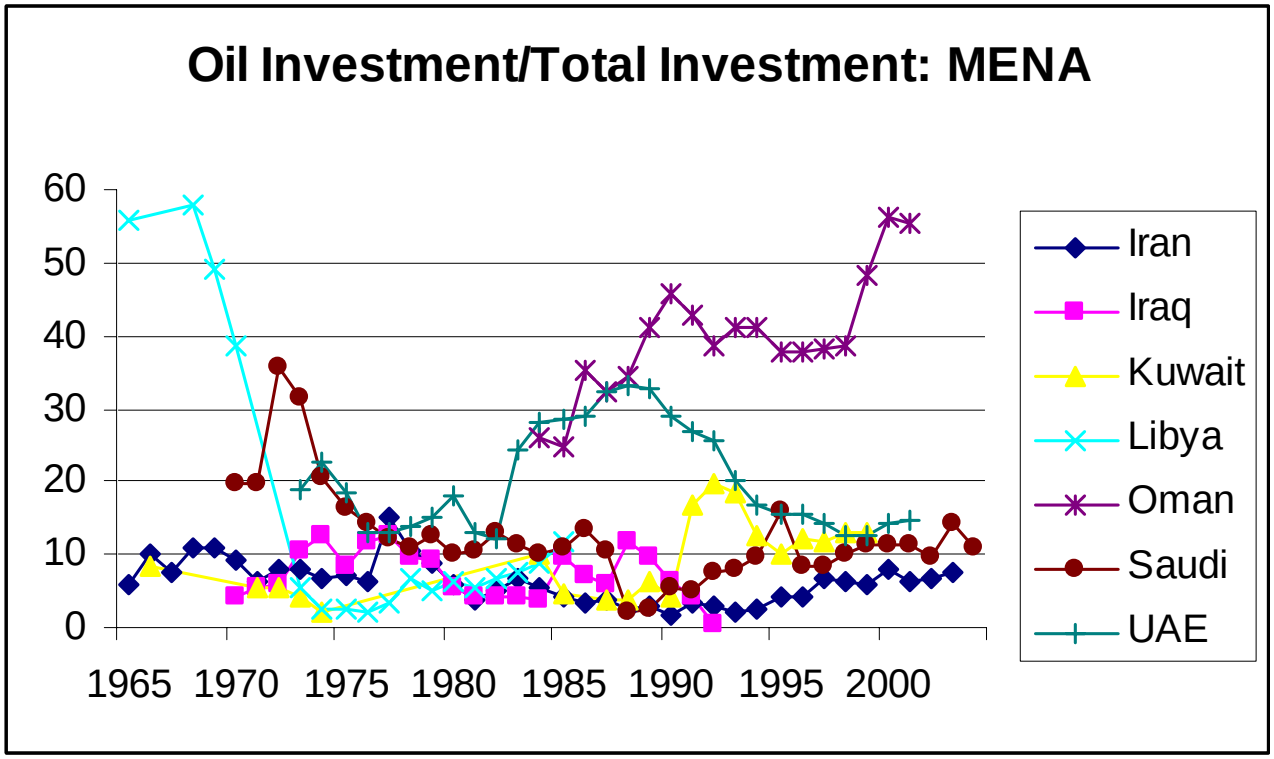
[40] One of the chapters of the new *WEO 2006* due for public release November 7, 2006 will be titled "Tracking Petroleum Investment."
[41] Note the lack of completeness of the data: Qatar has a high level in **Table 9**, and is not included in **Graph 6**, while Oman has a high level in the Graph, but is not included in the Table as it is not in OPEC.
[42] Oman's high values can be explained as resulting from the belated start of the oil industry there, while the high levels in Libya correspond to when the sector was just getting started

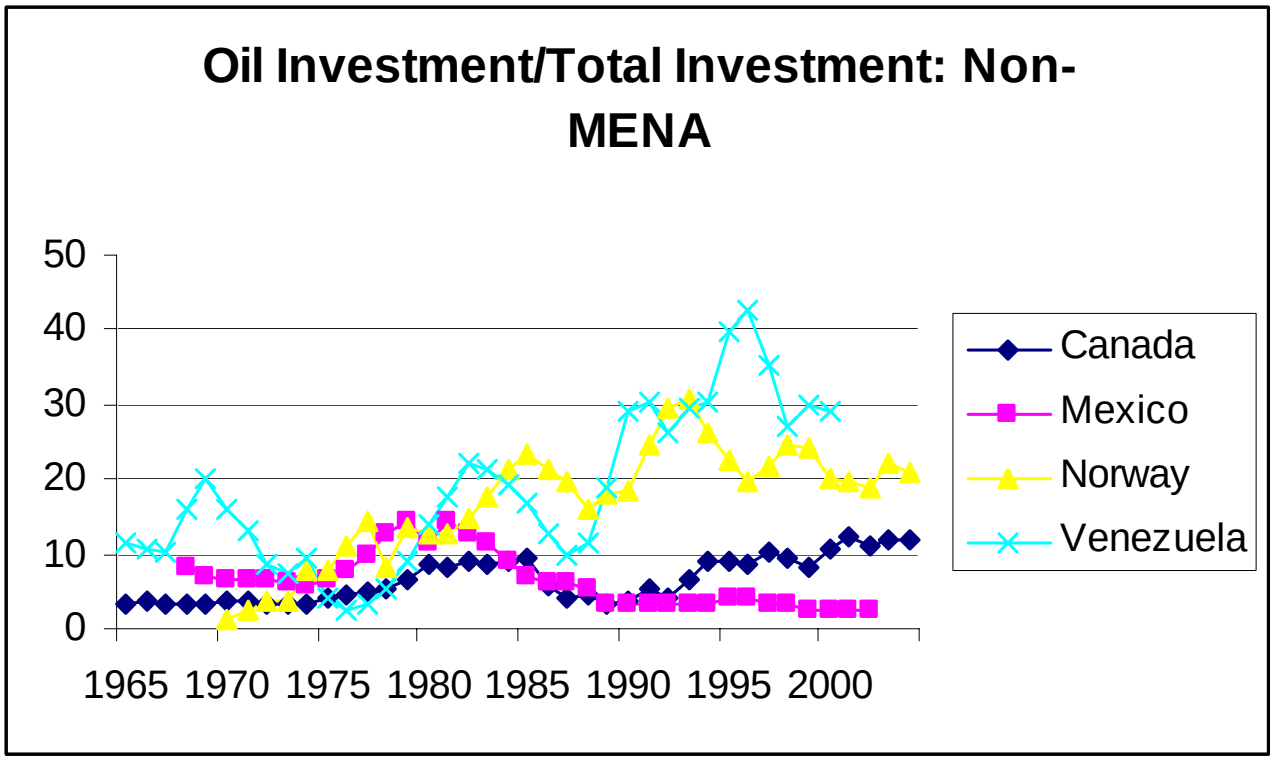
Graph 6. Oil Investment/GDP, MENA and Non-MENA Countries



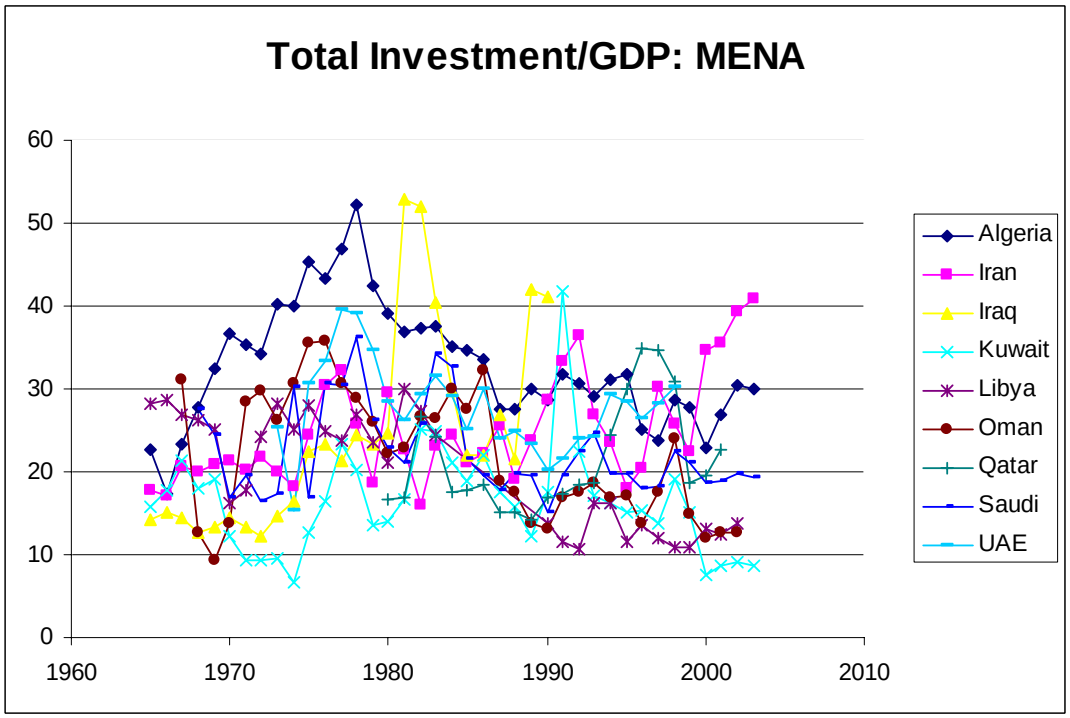


Graph 7. Oil Investment/Total Investment: MENA and Non-MENA Countries





Graph 8. Total Investment/GDP, MENA and Non-MENA Oil Exporters. Percentages



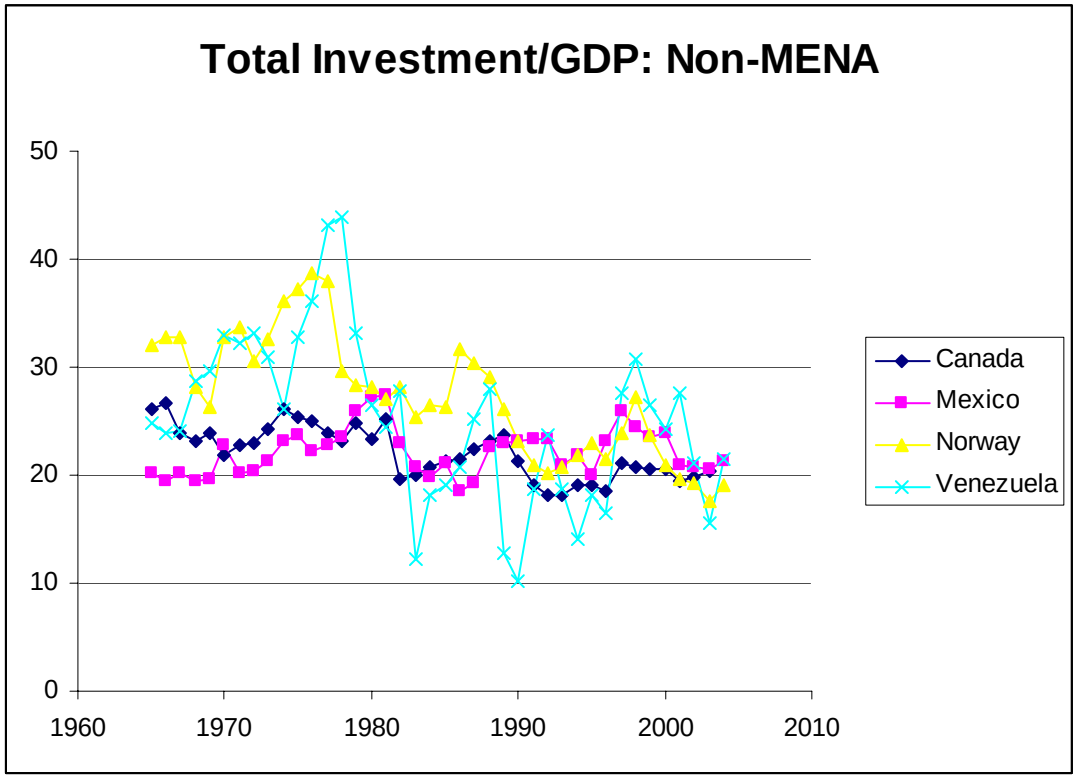


Table 9. Energy Investments: Value and as a Fraction of GDP, in the *WEO* Reference Scenario

	Total Energy Investments Annual Values (US$ bill)			Ratios of Annual Energy Investment to GDP		
	2004 -2010	2011 -2020	2021 -2030	2004 -2010	2011 2020	2021 -2030
MENA	44.9	55.8	63.7	1.9	1.6	1.4
Middle East	36.4	44.3	50.6	2.4	2.0	1.7
North Africa	8.4	11.5	13.1	1.0	1.0	0.8
OPEC						
Iran	7.3	9.3	11.0	1.3	1.1	0.9
Iraq	2.3	3.1	5.0	5.7	3.9	3.6
Kuwait	3.0	2.8	3.7	6.5	4.3	4.2
Qatar	4.1	6.7	5.9	13.0	13.1	8.6
Saudi A.	10.6	12.7	13.1	3.0	2.4	1.8
U.A.E.	3.7	4.0	5.0	4.0	2.9	2.7
Algeria	3.4	4.5	4.5	1.4	1.3	1.0
Libya	1.4	3.0	4.0	3.9	5.6	5.5

Source: Author's calculations from *WEO* 2005. The GDP values are calculated mid-period.
Note: For these countries, investment in oil and gas was typically about half of total energy investment.

/scen3a

Table 10. Estimated Ratio of Overseas Accumulations to GDP, 1970s-2000. (%)

Iran	107	Qatar	196
Kuwait	692	Saudi Arabia	146
Libya	295	U.A.E.	290
Nigeria	71	Venezuela	61

Source: Twomey (2006, Table 6), and separate calculations for Nigeria and Venezuela.

Notes: The numerators of these ratios were estimates of overseas accumulations, estimated from the balance of payments-as the current account surplus, or the capital account deficit, reflated by two means-using a price index, or applying an international interest rate to each year's nominal amounts. The numbers in the table are the averages of four measures.
Other MENA oil exporting countries did not have positive accumulations (Algeria, Bahrain, Egypt, Syria), or very slightly positive (Oman). Data for Iraq are incomplete.

investment will crowd out investment in other sectors. Moreover, it is the case that the trend in the ratio total investment/GDP has been declining in oil exporting countries, since the heady days of the late 1970s, as shown in **Graph 8**. The basic story was that oil funds were used to boost government expenditures (infrastructure, defense) and consumption.

In light of the relatively small fraction of oil investment in total investment, or in GDP, it is rather anti-climatic to ask if the countries can afford this investment. Within the confines of the projections discussed in this paper, we must answer yes. In particular this is true for those countries which appear to have accumulated savings overseas greater than a year's GDP: this would include Iran, Kuwait, Libya, Qatar, Saudi Arabia, and U.A.E. (Twomey, 2006), see **Table 10**. Although these overseas savings belong both to the state and to private individuals, they are certainly indicative of excess capital. The converse of this message is that, of the OPEC countries, only Algeria revealed significant balance of payments deficits; Indonesia is no longer an important oil exporter, and Iraq is unfortunately a case apart.

Current Trends

At the time of writing (summer, 2006), there are three points to mention. There are several indications from the business press that several countries are currently on schedule in terms of investment and output expansion, as reported on the OPEC Secretariat's web-page, which--as noted--is quite consistent with the scenarios of DoE/IEO and IEA/WEO. This is clear for Saudi Arabia[43] and the UAE.[44] Kuwait[45] also shows promise, although its linchpin, Project Kuwait, is planned to involve participation by the IOCs, which is opposed by significant voices inside that country. Algeria yes, under a new Minister intent on opening the sector using World Bank strategies, although some articles comment that the private sector is held back by OPEC quotas.[46] Iran is very definitely not judged to be on schedule, although one cannot discount political bias in the media.[47] Venezuela shows little indication that its current regime is interested in

[43] See *MEED* Jan. 20, 2006; Feb. 17, 2006; June 2, 2006; *PIW* Jan. 3, 2005; April 25, 2005; July 18, 2005; Aug. 22, 2005; January 23, 2006; March 27, 2006; May 22, 2006; April 17, 2006; *O&GJ* May 23, 2005; *PE* Dec. 2005; June 2006; *IPF* January, 2004. The position that the prospectus for Saudi Arabia is more positive than for its near neighbors in the Gulf is presented in *PIW* Oct. 31, 2005. One notes that the Saudi Ministry of Petroleum is said to have criticized a high-ranking former official of Saudi Aramco, for publicly doubting that the kingdom could reach its new targets *PIW* Nov. 21, 2005.

[44] See *O&GJ* June, 2006; *MEED* March 10, 2006; Dec 2, 2005. There are some hints that the Abu Dhabi National Oil Company is getting bogged down in bargaining with the IOCs.

[45] *MEED* Feb. 4, 2005 and March 31, 2006; *IPF* December, 2005; The cross-currents of political crisis over electoral reform, and parliamentary support of Project Kuwait are mentioned in *PIW* May 29, 2006; Al-Attar (2004)

[46] On plans, see *MEED* March 3, 2006, *PE* March, 2006, and *PIW* April 10, 2006. Legal reform *PIW* March 28, 2005.

[47] Issues include the hostility of some western powers to the country's nuclear program (*PE* Oct. 2005, *PE* July 2006), the populist (read: anti-petroleum) orientation of the political establishment (*O&GJ* Feb. 10, 2003) and of President Ahmadinejad, which reached the extreme of difficulty in appointing the oil minister, and a broadly felt hostility to foreign oil companies (*O&GJ* Jan. 12, 1998)

petroleum-led growth.[48] Recently Libya has announced what is equivalent to an about-face on economic policy, re-emphasizing the oil sector and foreign investment.[49] Qatar has been involved with a very ambitious gas project,[50] which-although conceptually distinct from the petroleum issues of this paper-does reveal both a willingness to make risky high value investments, as well as the openness to re-engage with the large international oil companies.[51] The mention of Nigeria in the business media is most often accompanied by comments about how difficult it is to do business in that country. Oman-not an OPEC member--does not receive the enthusiastic press coverage of its bigger neighbors, as the country struggles with technical problems.[52]

There certainly are valid doubts that the populist political orientations of current governments in countries like Iran and Venezuela will permit considerable investment in oil. Both of those countries currently have major disagreements with the United States, which has imposed sanctions on Iran for some years, discouraging foreign investment there. It is also the case that several countries in MENA are tentatively stepping back from the technology development strategy of the 1970s and 1980s that pursued independence from the IOCs. Other major oil producers and exporters with political problems that have reduced output are Russia and Nigeria. Where these political processes will lead is a puzzle.

Secondly, several indicators of investment activity are high, such as oil rig use and price. Nevertheless, this reader ends this paper with the comment that the situation today, a tight market with projections of Saudi output rising to the mid-teens in a few years, is quite reminiscent of that of several times during the last three decades, which never real realized.

What will happen to oil prices? At the end of the day we must confront the incompatibility between optimism related on the argument that the market works, and recognizing that prices have been rising dramatically. Several explanations are offered in the media for the behavior of prices; short term economic factors include the tightness of oil refinery capacity, that the expansion of drilling is hindered by the scarcity of available rigs, inventory fluctuations and adverse weather conditions. More fundamentally, prices are inflated by the political-military instability in the Gulf and other OPEC countries such as Venezuela and Nigeria, and the longer term reduction in production from Iraq. Clearly, given this paper's methodological orientation, we are unable to qualm the doubts about that instability.

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[48] *PE* April, 2004; Feb. 2006; *Economist* April 8 2006. See also the editorial in *O&GJ* April 10, 2006, entitled "Investing in Venezuela," and the article on the front page of the *WSJ* April 24, 2006 on the same topic. The national petroleum company (PdVSA) was a center of opposition to President Chávez in December 2002. Concern from the US is indicated in US-GAO (2006).
[49] *PE* Jan 2005.
[50] See *PE* January 2006; *ME* July/Aug 2001; June, 2005; *O&GJ* April 27, 1998; *AME Info* Mary 2, 2006; various EIU *Country Reports* . Recently the government has imposed some moratoria on new projects, due apparently to over-extension, with respect to construction and middle-level managers-see *PE* Nov. 2005.
[51] It is widely known that the IOCs are expanding investment: see the annual estimates reported in *PIW*.
[52] Oman see *PE* May 2006, *O&GJ* March 5, 2001.

Conclusions: By several accounts, the next quarter century's call on OPEC oil represents an unprecedented increase in production. Econometric studies find few indications of any significant short term price sensitivity of output by OPEC members. In addition, there are few indications of a concerted action by the OPEC member governments to affect the price of oil, either by restricting output or by increasing it to maintain a price band. There is evidence that prices affect investment in the sector, but not with enough impact to avoid major supply deficiency. It would not appear that financial considerations will be a constraint on output expansion. The current outlook for oil production plans is rather mixed, with some countries embarked on ambitious expansion projects, while the attention of others is focused on other politico-economic goals.

Data Sources:

Annual Production from US EIA/DoE web page; series Table 4.1a. [Crude Oil Production (Including Lease Condensate) 1970-2004: Thousand barrels/day]

Production Capacity: up to 1992, from various issues of U.S. CIA, *International Energy Statistical Review*, and its predecessor *International Oil Development Statistics* For the 1992-1994, *PIW*. Deutsche Bank For 2001-to the present, US DoE/EIA *Short Term Energy Outlook* Additional sources are: *Petroleum Intelligence Weekly*, International Energy Agency, *Oil Market Report*, the OPEC Secretariat's web page. The US DoE apparently utilized the US CIA's data; on the DoE website is a graph of world excess capacity from 1970. The US DoE's *International Energy Indicators* for a few months in 1980-81 (e.g. February, 1981) provided monthly data for Iran, Saudi Arabia, and "other OPEC" from mid-1974. The data used in this paper included one observation per year, but in principle this could be done monthly or quarterly.

Production Quotas: for the period 1983 to the present, the OPEC Secretariat has these posted on their web page, and they are also in *OPEC Review* of March, 2003. In addition, the US CIA presents these in the *International Energy Statistical Review*, and some are in the *Petroleum Intelligence Weekly*.

Wells producing and drilled: from *World Oil*, usually the August issue.

Real Price of oil: from the British Petroleum *Statistical Review* appendix that is published each year.

National Accounts Investment in Petroleum Sector: For Iran, Mexico, Norway, Saudi Arabia, and Venezuela national sources were used--directly from the web for Iran, Norway, and Saudi Arabia. The other countries used United Nations publications, either *National Accounts Statistics*, or ECWSA. Venezuela data from As government-owned PEMEX is the country's only upstream operation, Mexican data came alternately from issues of INEGI *La Industria Petrolera en México*, INEGI *El ingreso y el gasto público en México*, and INEGI *Información sobre el gasto público 1970-1980*. Canada data from Statistics Canada, *Fixed Capital Flows and Stocks, Historical* [Cat. No. 13-568], updated with *Private and Public Investment in Canada* [Cat 61-205]; Norway's data was downloaded from http://statbank.ssb.no/statistikkbanken/default_fr.asp?PLanguage=1 Venezuela data from several tables in Jorge Salazar-Carrillo and Bernadette West *Oil and Development in Venezuela during the 20th Century*. In almost all cases the price index used to deflate the current values was the GDP deflator.

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