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Oil and Natural Gas in Egypt

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Abstract

This paper deals with oil and natural gas in Egypt. It uses a descriptive and comparative analysis for examining oil and gas markets in Egypt. The main elements used in the analysis are: reserves, production, consumption, elasticities, main stockholders and exports. Natural gas is expected to be an important source of energy in Egypt due to its vast reserves and cleaner emissions. The paper also calculates the elasticity of substitution between oil and natural gas in Egypt, to determine the degree of willingness of substitution between them; and obtains the social extraction paths of oil and gas using Hartwick's rule.

Keywords: Oil and Natural Gas; Elasticity of Substitution; Sustainability; Hartwick's rule.

JEL classification: Q1; Q30.

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Introduction:

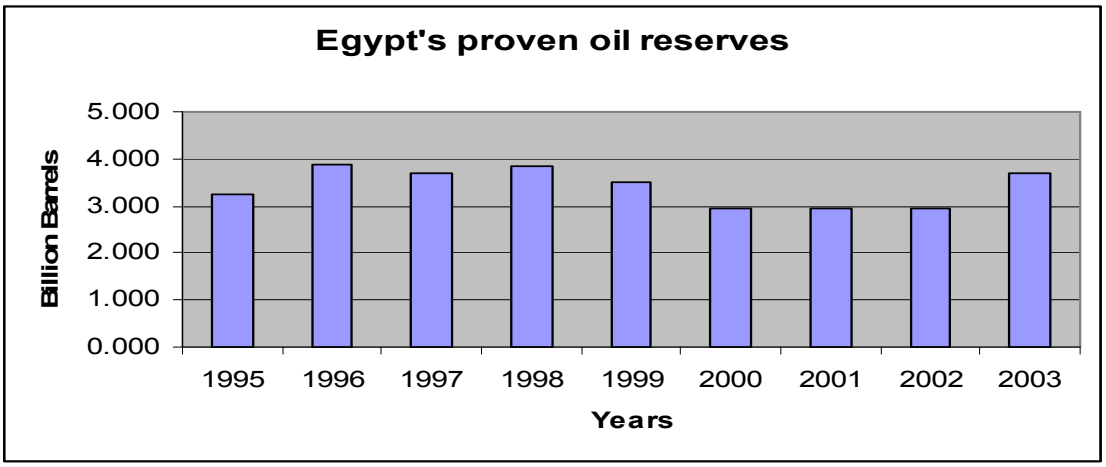
With the continuing decline in Egyptian crude oil production, Egypt's hydrocarbon future lies in natural gas. The country's gas reserves have increased so substantially over the last decade. It is now in a position to start exporting large volumes of gas as well as catering for growth in domestic demand in the coming decade. Energy sector in Egypt is mainly supervised by the Organization for Energy Planning (OEP) as it is responsible for planning, analyzing energy policies, examining energy resources and collecting data. The Egyptian government is the main player in the energy sector represented in the Egyptian General Petroleum Company (EGPC) and the Natural Gas Holding Company (EGAS). However, the private sector is rising through several joint-ventures between the government and foreign companies to explore and develop the energy resources especially oil and gas.

This paper utilizes both descriptive and comparative economic assessment of oil and natural gas in Egypt. The second and third sections are the oil and natural gas in Egypt respectively. The fourth section is a comparative analysis between oil and gas including a comparative table, besides calculating the elasticity of substitution between oil and gas and the social (optimal) extraction paths using Hartwick's rule for both oil and gas in Egypt. Finally, the fifth section is the conclusion.

Oil in Egypt:

Reserves

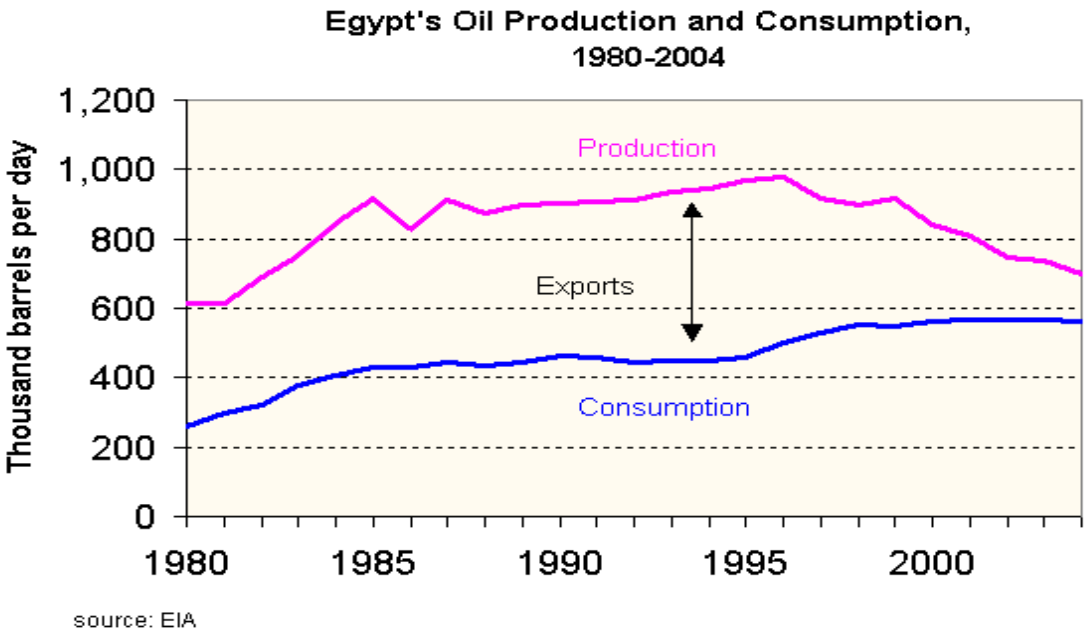
The petroleum industry plays a key role in the Egyptian economy. The export of petroleum products accounts for about 40% of Egypt's export revenues, and about 20% of Egypt's GDP comes from the petroleum industry. Egypt's proven oil reserves were estimated at 3.6 billion barrels on average from 1996 to 1999, but in January 2000, the government released a revised estimate of probable crude oil reserves, raising the figure to 8.2 billion barrels, based on new finds and increased recovery ratios. Even though the proven crude oil reserves were declined and stood at 2.9 billion barrels from 2000 till 2002 (AmCham, 2003, p.12). As at 1 January 2003, Egypt's proven crude oil reserves were estimated at 3.7 billion barrels (APRC, 2003, p.94). The figure below shows Egypt's proven oil reserves from the year 1995 till 2003.



Source: EIA.

Production and Consumption

Egyptian oil production in 2003 averaged 618,000 barrels per day (b/d), down sharply from a peak in 1996 of 922,000 b/d, but only modestly below the 631,000 b/d in 2002 (AmCham, 2003, p12; EIA). In contrast, domestic demand for oil has been climbing from 501,000 b/d in 1996 to 585,000 b/d in 1999 due to rapid economic growth between 1995 and 1998. Then it reaches its peak in 2003 at 566,000 b/d. The sharp increase in local oil consumption over the past decade can be attributed to two factors: economic growth in the late 1990s contributed to higher oil needs and government subsidies as most oil products are subsidized by the government to prevent rising prices. The prices of most types of fuel have not changed for the past decade, which has encouraged over-consumption (AmCham, 2003, p.19). Increased exploration, particularly in new areas, may lead to hope to find enough new discoveries to enable production above the



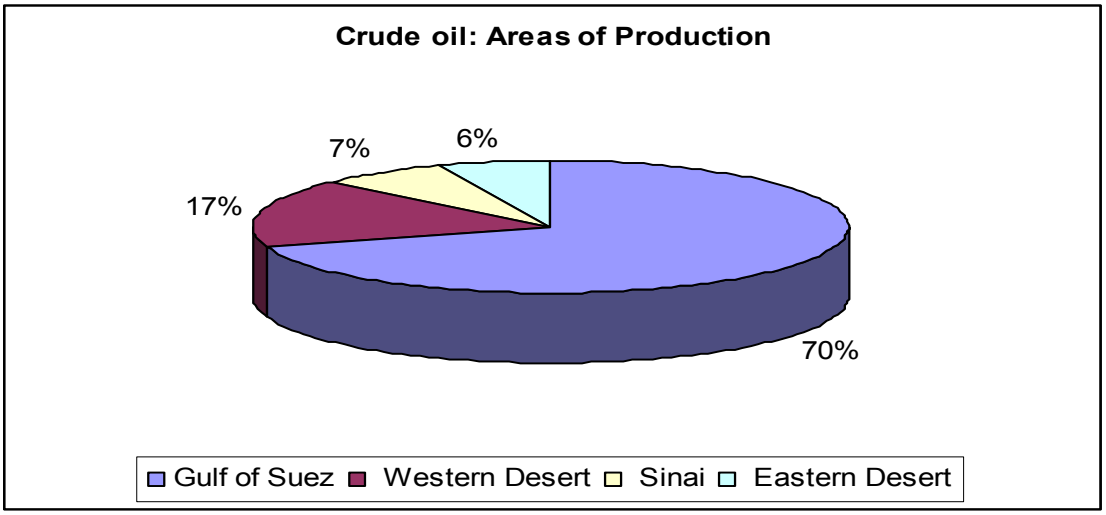
source: EIA

800,000 b/d level. The above figure shows the trend of production and consumption of oil in Egypt from 1980 till 2004.

So despite the buoyant level of exportation activity and the large number of discoveries made each year, which are brought into production as rapidly as possible, there seems little prospect of Egypt reversing the decline in its crude oil output in the future. Not only is oil production steadily decreasing, but domestic oil consumption continues to rise, putting a double squeeze on the amount of oil available for export. Some analysts suggest that Egypt could cease to be a net oil exporter between 2007 and 2010 (APRC, 2003, p.94).

Areas of Production

The Gulf of Suez remains by far the biggest producing region in Egypt, accounting for about over 70% of total oil production, although its share is falling. The second biggest oil-producing region is the Western Desert, which accounts between 17%. Egypt also draws oil from the Sinai Peninsula (7%) and the Eastern Desert (6%) as shown in the figure (APRC, 2003, p.94; OFE, 2001).



Oil Market

The state-run Egyptian General Petroleum Company (EGPC) controls the petroleum industry and is the only company authorized to import and export crude oil and petroleum products. EGPC is active in the upstream, downstream, and petrochemical sectors.

Oil in the Gulf of Suez is produced mainly by Gupco (Gulf of Suez Petroleum Company), a joint venture between BP-Amoco and EGPC. The fields in this region are mature; having been in operation since the 1960s and 1970s, and as such has been seeing declining levels of production. Still, this area remains a significant source of Egypt's production; contributing around 360,000 b/d. Gupco is trying to extend the operating life of the fields through investments in production efficiency and greater exploration. BP-Amoco has announced plans to invest $450 million over the next six years to improve technology. Petrobel, Egypt's second largest oil producer is also planning technology

improvements to extend the life of the Belyim fields near the Gulf of Suez. Petrobel is a joint venture between EGPC and Italy's ENI-Agip. Other major companies in the Egyptian oil industry include the Badr el-Din Petroleum Company (BAPECTO) (a joint venture between EGPC and Shell); Suez Oil Company (SUCO) (a joint venture between EGPC and Deminex); and El Zaafarana Oil Company (EGPC and British Gas), and Shell.

Overall, petroleum production has not declined in Egypt as sharply as in the Gulf of Suez, due to new discoveries in the Western Desert and Upper Egypt. Production levels at the Qarun Block in the Western Desert, operated by independent producers Apache and SeaGull Energy, surpassed 60,000 b/d in mid-2000. Development of new fields in the Qattara Depression and El Alamein are expected to add 40,000 b/d in new production as they come online. In October 1997, Apache and SeaGull announced a major discovery estimated to contain around 100 million barrels of crude oil in the Western Desert at the East Beni Suef Concession. Other recent discoveries in the Western Desert include one south of Daba near Alexandria, another at the Qarun Concession near Cairo, and one in the Meliha Concession near Mersa Matrouh.

Egypt is conducting offshore exploration in the Mediterranean Sea. In February 1999, Shell won the rights to the largest concession yet in deep water off Egypt's Mediterranean coast. BP-Amoco and Elf Aquitaine and ENI-Agip have also won concessions. It is believed large oil reserves may lie off the coast of the Nile Delta, while Shell has high hopes for its North East Mediterranean Deepwater Concession.

In the first quarter of 2001, Egypt placed 32 exploration areas on the auction block for international bidding, including virgin deepwater territory in Egypt's western Mediterranean close to the Libyan border. Acreage in the gas-rich Nile Delta, Gulf of Suez, and Western Desert are also available. Bids are due to EGPC's Geological & Geophysical Centre in Nasr City by November 15, 2001. The 2001 auction follows a failed 1999 bid round when commercial negotiations for 15 blocks resulted in no significant activity. Egypt decided to subdivide the 15 exploration blocks into smaller, more manageable blocks in hopes that more companies will have incentive to invest in Egyptian territory. Increases in world oil prices, and recent international tenders by Algeria and Libya likely will raise more interest in this recent round of bidding (OFE, 2001).

Suez Canal & Sumed Pipeline

Egypt has strategic importance because of its operation of the Suez Canal and Sumed (Suez-Mediterranean) Pipeline, two routes for export of Arabian Gulf oil. The SCA offers a 35 percent discount to liquefied natural gas (LNG) tankers, with even deeper discounts for the largest LNG tankers, as well as other discounts for oil tankers (AmCham, 2003, p.14; OFE, 2001)

The SCA is continuing enhancement and enlargement projects on the canal. The canal has been deepened so that it can accept the world's largest bulk carriers, but it will need to be deepened further to 68 or 70 feet, from the current 58 feet, to accommodate fully laden very large crude carriers (VLCCs). The SCA has attempted to reach an agreement

with its main competition for northbound crude traffic, the Sumed pipeline. Such an agreement could bar any tanker small enough to traverse the canal from transporting oil through the pipeline. The SCA offers incentives for tankers to off-load a portion of its cargo through the Sumed, allowing for passage through the canal, and reloading at the other end of the pipeline (AmCham, 2003, p.14; OFE, 2001).

The Sumed pipeline is an alternative to the Suez Canal for transporting oil from the Arabian Gulf region to the Mediterranean. The 200-mile pipeline runs from Ain Sukhna on the Gulf of Suez to Sidi Kerir on the Mediterranean. The Sumed's original capacity was 1.6 million b/d, but with completion of additional pumping stations, capacity has increased to 2.5 million b/d. The pipeline is owned by the Arab Petroleum Pipeline Company (APP), a joint venture between Egypt (50 percent), Saudi Arabia (15 percent), Kuwait (15 percent), the U.A.E. (15 percent), and Qatar (5 percent). The APP also has been increasing storage capacity at the Ain Sukhna and Sidi Kerir terminals (OFE, 2001).

Refining

Egypt has nine refineries with a combined crude oil capacity in excess of 727,000 b/d in 2003, and is Africa's second leading refining center (following South Africa). The largest refinery is El-Nasr refinery at Suez with a total capacity of 146,300 b/d. The Egyptian government controls all refinery operations in Egypt through its state-owned subsidiaries. The El Mex and Amerya refineries in Alexandria are operated by the Alexandria Petroleum Company. There are two refineries at the port of Suez; the El Suez Refinery Company manages one of them, while the El Nasr Refining Company operates the other. The Mostorod Refinery and the Tanta Refinery are both near Cairo and are operated by the Cairo Oil Refining Company. The largest refinery in Egypt is the Mostorod complex near Cairo with a capacity of almost 157,000 b/d. The Assyout Petroleum Company operates the Assyout Refinery, south of Cairo, and the El Nasr Refining Company operates the Wadi Feiran Refinery on the Sinai Peninsula.

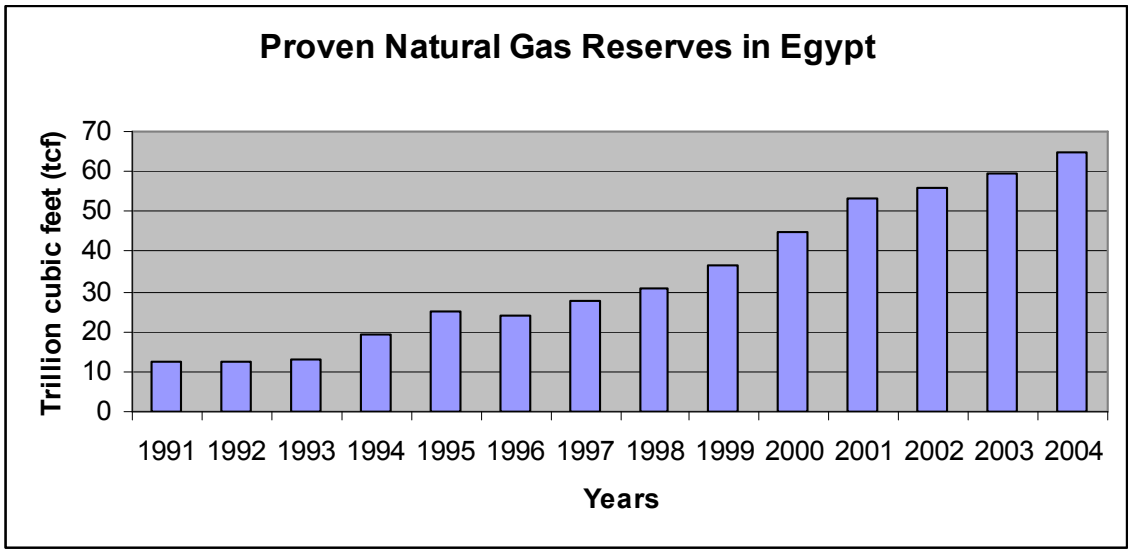
The Egyptian government wants to spend $2.5 billion to build five additional refineries and petrochemical plants. Included in this plan is construction of a 35,000 b/d, $450 million hydrocracker at the El Nasr Petroleum Company refinery in Suez; This will boost the refining capacity at the Asyut refinery to about 100,000 b/d.

In July 1997, the Egyptian government awarded a contract to an Egyptian-Israeli private sector joint venture for construction of the 100,000 b/d MIDOR refinery at Sidi Kerir, near Alexandria. The refinery started trial production in April 2001, and includes a 33,400 b/d hydrocracker and a 22,800 b/d coker. Initially the refinery was set up to take Gulf crudes from the Mediterranean terminal of the Sumed pipeline to sell product to Israeli and other Mediterranean markets. Arab countries, however, have been refusing to supply petroleum due to Israel's interest in the refinery, which caused the refinery to run on Egyptian crudes supplied by EGPC. In May 2001, Israel’s privately-held Merhav MNF Ltd. sold its 20% stake in MIDOR to the National Bank of Egypt (NBE), putting the refinery entirely in the hands of the Egyptian government (OFE, 2001).

Exports
Egypt has little crude oil available for export, since its domestic refining industry requires nearly 700,000 b/d of feedstock whereas oil production fell to 618,000 b/d in 2003. EGPC is still able to export a small volume of crude, but its exports of refined products are now greater in volume as well as in value. Taking account of domestic oil consumption of some 566,000 b/d, the country was a net exporter of around 50,000 b/d of oil in 2003 (AmCham, 2003, p.19; EIA). However, net exports surplus sharply decreased since 1995 from 460,000 b/d as shown in next figure. Some analysts suggest that Egypt could cease to be a net oil exporter between 2007 and 2010 (APRC, 2003, p.94).

Natural Gas in Egypt:

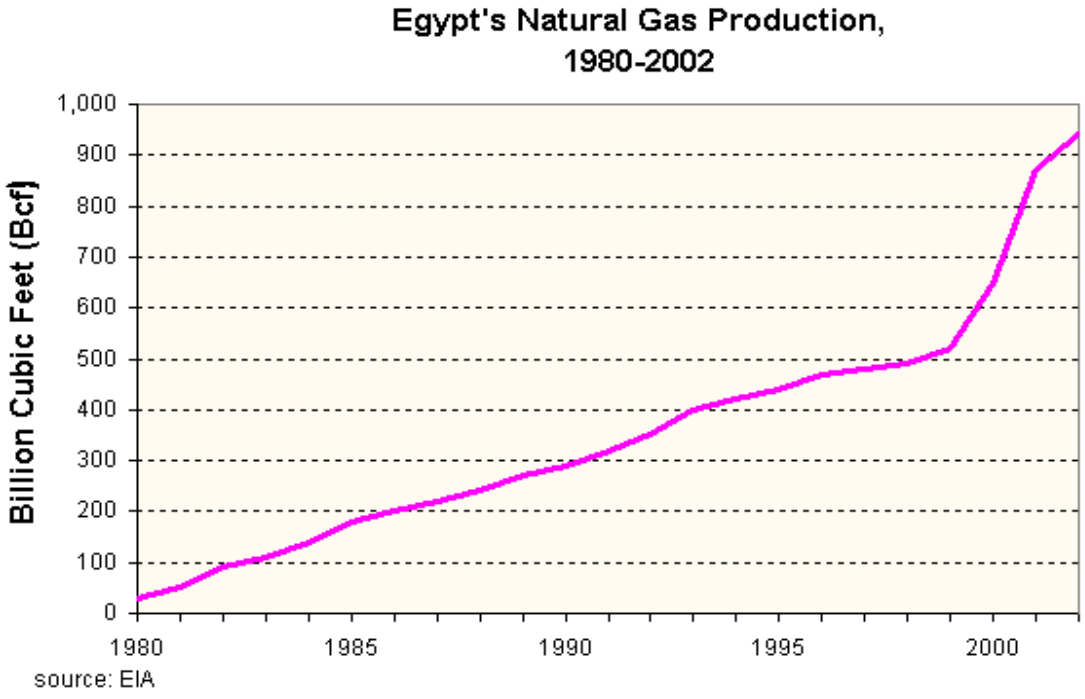
Reserves and Main Areas
Natural gas is destined to become more and more important to the energy future of Egypt because of the major recent discoveries. There are vast reserves of natural gas with a strong potential for more discoveries. Beginning in the early 1990s, foreign oil companies began more attractive exploration for natural gas in Egypt, and very quickly found a series of significant natural gas deposits especially in the Western Desert, the Nile Delta, and under the Mediterranean Sea. Proven reserves stand at 65 trillion cubic feet (tcf) in 2004 up from 55 tcf in 2002 and 40 tcf in 2000, with probable reserves estimated at 120 tcf. Major discoveries between 1997 and 2000 in the Nile Delta and the Western Desert have doubled Egypt's proven reserves. Next figure shows the increase in the Egypt's natural gas proven reserves.



Studies carried out by international companies indicated that there were some 80-117 tcf of gas reserves remaining to be discovered- 65-84 tcf in the Mediterranean and Nile delta regions and 15-33 tcf in the Western Desert (APRC, 2003, p.102).

Production and Consumption

Egypt's natural gas sector is expanding rapidly, with production having nearly doubled from 1997 and 2002. Production stood at more than 3 billion cubic feet per day (bcf/d) from 1.6 bcf/d in1999, and is expected to reach 7 bcf/d by 2006. Output from the Abu Madi and Badreddin fields accounts for more than half of the country's production.



Egypt has been increasing domestic gas demand by converting its power plants to run on gas. Thermal power plants account for about 65% of Egypt's total gas consumption. Large industrial consumers have also been switching to gas, including petrochemical plants, a large new fertilizer plant in Suez, and several major new steel projects in Alexandria, Suez, and south of Aswan. Some 20,000 taxis in Cairo have been modified to run on CNG as part of a pilot program. The construction of (17 CNG) service stations are supporting the project. Egypt is trying to improve the availability of natural gas for residential customers by allocating service areas to several private companies, beginning in 1998. British Gas heads a group that includes Orascom (an Egyptian construction firm), and Edison International SpA that will invest $220 million in a distribution network to serve Upper Egypt down to Assyout, an area with no existing gas service. The network may be expanded as far south as Aswan.

Gas Market

A decision by the government to form joint ventures with private companies and pay the world price for gas from any discoveries served to encourage exploration beginning in the late 1980s and early 1990s. This incentive led to major discoveries of gas deposits in the Nile Delta and Western Desert. However, these discoveries turned out to be a mixed blessing for Egypt -- the Egyptian government had to pay the going market price for gas that it was not using, and was unable to export this unused gas because it lacked the necessary infrastructure to liquefy or export any surplus natural gas. A remedy was finally implemented in November 1999, when the Egyptian government decided to allow the producers themselves to export the gas.

That decision spurred the creation of even more joint ventures between the government and the private sector. Gupco announced plans in March 2000 that would raise Egypt's gas production from 1.8 bcf/d to 3.8 bcf/d by the end of 2000, by starting operations at the Hapy Gas Field. In April 2000, BP-Amoco announced a deal with EGPC to build a gas treatment and separation facility around the Gulf of Suez. The Anglo-American Company plans two complexes on the Mediterranean coast to process and ship liquefied natural gas (LNG) throughout the region. Shell will cooperate with EGPC to explore for gas offshore in the Mediterranean. The two companies plan to have two wells online in 2000 or early 2001 with three more to follow. EGPC has agreed to supply a new LNG plant in Edku, east of Alexandria with gas from the West Delta Deep Marine Concession. The plant will be owned and operated by EGPC, British Gas and Edison International SpA.

The top six foreign energy companies involved in Egyptian gas exploration and production in terms of reserves are ENI-Agip, BP, British Gas, Shell, Edison International SpA, and Repsol-YPF. (In June 1999 Repsol acquired Argentina’s YPF.) With the exception of Repsol-YPF, all plan significant investments in the future. Shell has plans to spend around $1.6 billion between 2000-2005 on gas exploration and development. BP-Amoco plans to spend $450 million by 2000, while ENI-Agip and BG also plan significant expenditures in this area. As part of Repsol-YPF's debt reduction

plan since taking over YPF, Repsol-YPF also agreed to sell its stake in three oil and gas exploration and production blocks in the Nile Delta to Germany's RWE-DEA for $80 million. Likewise, Repsol-YPF recently sold its Egyptian interests to Apache Corp. for $410 million. The acquisition raises Apache Corporation's interest in the Khalda concession to 90%, and it has become the operator of the concession.

The Obeiyed and Khalda areas in the Western Desert have shown great potential for further increasing Egypt's gas production in the near future. The Obeiyed Field recently started producing 300 million cubic feet per day (MMcf/d), after the completion of a pipeline linking it to Alexandria. Production of 300 MMcf/d has also started at Khalda, and the output from Obeiyed and Khalda will be transported to Alexandria by a 180-mile pipeline.

The International Egyptian Oil Company (IEOC), an ENI-Agip subsidiary, is the country's top natural gas and overall hydrocarbons producer with operations in the Western Desert, the Gulf of Suez, and the Nile Delta. It has teamed up with BP-Amoco to invest $1 billion in exploration and development of natural gas reserves in the Nile Delta region. Both companies hope their efforts will yield about 365 bcf per year.

In November 1997, BP-Amoco, EGPC, and IEOC reported a $248 million development plan in the Hapy Gas Field in the Ras el-Barr Concession. It is estimated that this Nile Delta Project will yield up to 2.0 tcf per year. The IEOC, in cooperation with BP-Amoco, ENI-Agip, and EGPC, announced plans to invest $700 million to develop the Temsah Gas Field also in the Nile Delta. Gas reserves at Temsah are estimated at 3.9 tcf. The deal calls for gas sales to begin at 35 MMcf/d and increase to 480 MMcf/d by 2003.

The Nile Delta is home to other recent discoveries such as the Sigan-1 field by Petrobel, Wakkar by ENI-Agip/EGPC, and Rosetta-5 and Rosetta-6 by British Gas. Germany’s RWG-DEA discovered gas at its concession in the Nile Delta, with a flow rate of 30 MMcf/d. Italy's Edison International SpA (not affiliated with the U.S.'s Edison International) and British Gas made a significant discovery in May 1999 in the West Delta Deep Marine Concession, with a flow rate of 45 MMcf/d. A month later, the companies tested Simian 1 at 44 MMcf/d. Egyptian hopes for more natural gas discoveries are brightened by tests suggesting that the same geological formations that contain gas in the Nile Delta stretch into the Mediterranean Sea due to the flow of the Nile River.

Exports

Egypt currently consumes most of its natural gas production, but the host of deepwater discoveries offshore Egypt are starting to look more commercial. Turkey, Israel, Jordan, Libya, and the Palestinian territories have been mentioned as possible export markets. In December 1999, an agreement was reached with Israel to build a gas pipeline from El-Arish in the Sinai to Israel and Gaza by 2002. The pipeline would eventually go on to Lebanon, Syria, and Turkey. However, Israel has since become optimistic about offshore gas discoveries in its own waters and has frozen talks to import Egyptian gas until it can better gauge the size of its reserves.

The rapid rise in natural gas reserves has led to a search for export options, which has become particularly important to Egypt's future international balance of payments due to the decline in oil exports. In late 1999, the Egyptian government stated that natural gas reserves were more than sufficient for domestic needs, and that foreign firms producing gas in Egypt should seek export customers. In early 2000, the government announced a moratorium on new purchase agreements by EGPC for domestic consumption, as previously signed agreements would meet projected demand for the next several years. It also announced in September 2000 a new pricing policy which includes ceiling and floor prices, designed to protect both consumers and producers from the risks of prices indexed to oil.

The idea of exporting natural gas to Israel has been under discussion since the mid-1990s, and after being sidelined for several years by the Israeli-Palestinian violence which began in late 2000, seems to again be under serious consideration. The original version of the plan would have involved construction of an offshore pipeline from El-Arish in Sinai up the coast of Israel, with a possible extension onward to Turkey. The East Mediterranean Gas Company (a consortium of EGPC, Merhav of Israel, and Egyptian businessman Hussein Salem) had been set up to pursue the project. ENI completed a pipeline up Egypt's Mediterranean coast to El-Arish, which could serve as a starting point for the export pipeline. This would involve a short offshore pipeline to Ashkelon from northern Sinai, bypassing Gaza. A framework agreement between the two governments was concluded in February 2005, and negotiations for a binding natural gas sales contract with the Israel Electric Corporation (IEC) are underway.

Another export pipeline to Jordan began commercial operation in July 2003, making possible Egypt's first exports of natural gas. Egypt was responsible for building the section from the existing pipeline terminus at El-Arish to Aqaba in Jordan, with a subsea section in the Gulf of Aqaba bypassing Israeli waters. Construction of the section of the pipeline from Aqaba to northern Jordan is being undertaken by a Jordanian firm, the Al-Fajr Company for Natural Gas Transportation. A contract was awarded in January 2004, and construction is scheduled to be completed by the end of 2005. Egypt, Jordan, and Syria agreed in principle in early 2001 to extend the pipeline into Syria, with eventual natural gas exports to Turkey, Lebanon, and possibly Cyprus. The feasibility of this option is questionable, though, as Turkish demand probably would not support another source of piped gas (beyond agreements in place with Russia, Azerbaijan, and Iran). A more modest version of the plan could include the addition of pipeline links to only Syria and Lebanon.

Egypt's other option for exports is LNG. Two LNG projects are currently underway. The Spanish firm Union Fenosa is building a two-train liquefaction facility at Damietta, which shipped its first cargo in January 2005 upon the completion of the first train, with a capacity of 268 Bcf per year. Unlike most previous LNG projects, this one is not tied in directly with upstream natural gas production. Union Fenosa has contracted with EGAS for the supply of natural gas from its distribution grid, and will take 60 percent of the LNG output itself for use at the company's power plants and distribution to other users in

Spain and elsewhere in Europe. ENI also has become involved in the project, purchasing a 50 percent stake in Union Fenosa's natural gas business in December 2002. BP signed an agreement for sales of natural gas from its offshore fields to supply the second train at Damietta in July 2004.

The second LNG export project ("Egyptian LNG"), at Idku, is to be built by BG in partnership with Petronas. The project is tied in to natural gas reserves from BG's Simian/Sienna offshore fields, and began production ahead of schedule in March 2005, with a second liquefaction train operational by late 2005. Gaz de France is to be the main offtaker for the Idku LNG project's first train, having signed a contract in October 2002 for 127 Bcf per year beginning in 2005. An agreement to purchase a similar quantity of LNG from the second train was signed in September 2003 by BG LNG Services. The LNG will initially be delivered to the Lake Charles, Louisiana import terminal for the U.S. market, starting in mid-2006. Later, probably in 2007, BG will switch the output from Idku to an import terminal under contrauction at Brindisi, Italy, and use additional production from Trinidad to supply the Lake Charles terminal. BP and Shell both are also contemplating potential LNG projects in Egypt (EIA, 2005). Another potential use for Egypt's natural gas reserves is gas-to-liquids (GTL) projects. Shell has proposed a 75,000-bbl/d GTL plant to be co-located with its LNG export terminal when it is built, using reserves from its offshore NEMED find as feedstock. No final agreements have yet been reached on the proposal (EIA, 2005).

Comparative Analysis: Oil and Natural Gas in Egypt

Egypt’s proven oil reserves were estimated at 3.6 billion barrels on average from 1996 to 1999, but in January 2000, the government released a revised estimate of probable crude oil reserves, raising the figure to 8.2 billion barrels, based on new finds and increased recovery ratios. Even though the proven crude oil reserves were declined and stood at 2.9 billion barrels from 2000 till 2002. As at 1 January 2003, Egypt’s proven crude oil reserves were estimated at 3.7 billion barrels (APRC, 2003, p.12, p.94). On the other hand for natural gas, there are vast reserves with a strong potential for more discoveries. Beginning in the early 1990s, foreign oil companies began more attractive exploration for natural gas in Egypt, and very quickly found a series of significant natural gas deposits. Proven reserves stand at 65 trillion cubic feet (tcf) in 2004 up from 55 tcf in 2002 and 40 tcf in 2000, with probable reserves estimated at 120 tcf. Major discoveries between 1997 and 2000 have doubled Egypt's proven reserves.

On the production level, Egyptian oil production in 2003 averaged 618,000 barrels per day (b/d), down sharply from a peak in 1996 of 922,000 b/d, but only modestly below the 631,000 b/d in 2002 (AmCham, 2003, p12); While Egypt’s natural gas sector is expanding rapidly, with production having nearly doubled from 1997 and 2002. Production stood at more than 3 billion cubic feet per day (bcf/d) from 1.6 bcf/d in1999, and is expected to reach 7 bcf/d by 2006. On the consumption level, domestic demand for oil has been climbing from 501,000 b/d in 1996 to 585,000 b/d in 1999 due to rapid economic growth between 1995 and 1998. Then it reaches its peak in 2003 at 566,000

b/d. The sharp increase in local oil consumption over the past decade can be attributed to two factors: economic growth in the late 1990s contributed to higher oil needs and government subsidies as most oil products are subsidized by the government to prevent rising prices. The prices of most types of fuel have not changed for the past decade, which has encouraged over-consumption (AmCham, 2003, p.19). For natural gas there is an increase in domestic demand by converting Egypt's power plants to run on gas. Thermal power plants account for about 65% of Egypt's total gas consumption. Large industrial consumers have also been switching to gas, including petrochemical plants, a large new fertilizer plant in Suez, and several major new steel projects in Alexandria, Suez, and south of Aswan.

Comparing the main areas of production for both oil and gas, it was found that the Gulf of Suez remains by far the biggest producing region in Egypt, accounting for about over 70% of total oil production, although its share is falling. The second biggest oil-producing region is the Western Desert, which accounts between 17%. Egypt also draws oil from the Sinai Peninsula (7%) and the Eastern Desert (6%). While natural gas production mainly concentrates in the Nile Delta, the Western Desert and under the Mediterranean Sea.

Egypt is currently adapting a new gas price formula where gas is linked to oil with a ceiling and a floor. However, government has been pushing not just locally, but also internationally to formulate a new gas price formula independent from oil. For price elasticities, it was found that demand price elasticity of oil is 0.2, while it is 0.26 for natural gas, which shows that both are inelastic; even though, oil is relatively inelastic (it is difficult to be substituted) due to its importance and necessity in most of Egyptian industries.

Egypt has little crude oil available for export, since its domestic refining industry requires nearly 700,000 b/d of feedstock whereas oil production fell to 618,000 b/d in 2003. Egypt is still able to export a small volume of crude, but its exports of refined products are now greater in volume as well as in value. Taking account of domestic oil consumption of some 566,000 b/d, the country was a net exporter of around 50,000 b/d of oil in 2003 However, net exports surplus sharply decreased since 1995 from 460,000 b/d as shown in next figure. Some analysts suggest that Egypt could cease to be a net oil exporter between 2007 and 2010. On the other hand, Egypt currently consumes most of its natural gas production, but the host of deepwater discoveries offshore Egypt are starting to look more commercial. Turkey, Israel, Jordan, Libya, and the Palestinian territories have been mentioned as possible export markets. The rapid rise in natural gas reserves has led to a search for export options, which has become particularly important to Egypt's future international balance of payments due to the decline in oil exports. Accordingly, increasing the dependence on natural gas as a substitute for oil should be implemented. So Egypt is now in a position to start exporting large volumes of gas as well as catering for growth in domestic demand in the coming years.

Comparative Table: Oil and Natural gas in Egypt:

	Oil	*Natural Gas*
Reserves	A recent decline in reserves since 2000.	Vast reserves with strong potential for more discoveries.
Production	A decrease in production since 1996 due to subsidizing, technical reasons and recent decline in reserves.	Production has doubled between 1997 and 2002 due to increase in reserves, and the increase in demand and to substitute oil as it is environmentally friendly.
Consumption	An increase in consumption due to economic growth and subsidizing.	An increase in domestic demand mainly by thermal power plants.
Pricing	Pricing is based on international prices.	Natural gas price is linked to oil with a ceiling and a floor using a certain gas price formula.
Price Elasticity	Demand price elasticity is 0.02 (completely inelastic).	Demand price elasticity is 0.26 (inelastic).
Cross Elasticity	Cross elasticity between oil and gas > zero, they are substitutes.	
Income Elasticity	Income elasticity is 0.43 which shows that it is a necessary good.	Income elasticity is 1.4 (normal good).
Areas of Production	70% from the Gulf of Suez, 16% from the Western Desert, 7% from the Sinai Peninsula and 6% from the Eastern Desert.	The Nile Delta, The Western Desert and under the Mediterranean Sea.
Main Players	EGPC (state-run), Gupco, Petrobel, Badr el-Din Petroleum Company, El Zaafarana Oil Company and Shell.	EGPC (state-run), IEOC, Eni-Agip, BP-Amoco, British Gas, Shell, Edison, International SpA and Repsol-YPF.
Transportation	Suez Canal and Sumed Pipelines.	Pipelines.
Exports	A decline in exports from 1999 due to an increase in local consumption accompanied by a decrease in production.	Beginning of exports from July 2003 looking for new opportunities after the recent increase in its reserves.
Elasticity of Substitution	It was found that the elasticity of substitution between oil and gas in production is 3.4; while the elasticity of substitution in consumption is 4.06.	
Energy/GDP elast.	Oil/GDP elasticity is 0.3.	Natural Gas/GDP elasticity is 0.9.

Now, the paper will calculate the elasticity of substitution between oil and gas in Egypt to determine the degree of willingness of substitution between both resources. And then it calculates the social extraction rate from which the social extraction paths for oil and gas can be determined.

Trade offs and Elasticity of Substitution between Oil and NG

One of the most common measures of the economy's energy substitution possibilities is the elasticity of substitution (σ). The elasticity of substitution defines the relative change in input proportions (in this case, we talk about oil and natural gas) in response to a relative change in their prices. In general, it is possible that the elasticity of substitution to vary; however, it is convenient to assume that elasticity of substitution is constant as it is assumed in this paper (LeBel, 1982, p.293; Nicholson, 2002, p.279). The elasticity of substitution between oil and gas in Egypt is calculated for both the production and consumption side using the following model for the period 1991-2003:

$$\ln\left(\frac{Q_{OIL}}{Q_{NG}}\right) = \alpha + \sigma \ln\left(\frac{P_{NG}}{P_{OIL}}\right) + \varepsilon$$

where, Q_{OIL}= quantity of oil production or consumption (barrels of oil equivalent).
Q_{NG}= quantity of natural gas production or consumption (barrels of oil equivalent).
P_{OIL}= price of oil (US$ per barrel).
P_{NG}= price of natural gas (US$ per barrel).
σ= elasticity of substitution between oil and gas.

The value of σ is always positive, as the oil-gas ratio moves in the same direction as gas-oil price ratio. If σ is high ($\sigma \to \infty$), it means that oil and gas can be thought of as perfect substitutes for each other. On the other hand, if σ is very low ($\sigma=0$), this case shows that both oil and gas should be used in a fixed ratio regardless change in its price ratio. Running the above regression for Egypt for the period 1991-2003 for both production and consumption side, it was found that the elasticity of substitution between oil and gas in production is 3.4; while the elasticity of substitution between oil and gas in consumption is 4.06.

The period from 1991 to 2003 witnessed an economic growth due to implementing the ERSAP in Egypt from 1991. However, economic growth slows down from the period 1997. For expecting the growth of energy demand as a whole or growth of oil and natural gas consumption separately, Energy/GDP elasticity of 0.5 was calculated covering the period 1991-2003. This shows that when the Egyptian GDP grows at 1%, energy consumption would grow at 0.5%. Therefore, by applying that for an anticipated 4% rate of Egyptian economic growth, then it should be expected that energy will grow by 2%. The Oil/GDP elasticity is 0.3 and the Natural Gas/GDP elasticity is 0.9. This indicates that for 1% GDP growth, oil would grow at 0.3% and natural gas at 0.9% which shows that natural gas consumption is related to the general demand in the Egyptian economy.

This can be attributed to the heavily dependence on natural gas residentially and commercially especially for the last decade.

Social (Optimal) Extraction Paths

Both oil and gas are exhaustible resources that are irreversible in the way that if they are consumed, they can not be reversed; and if they are not consumed, then there is an opportunity cost of not using them. In an influential paper in 1977, John Hartwick proposed a rule for ensuring non-declining consumption through time, in the case where an economy made use of a non-renewable resource (such as oil or natural gas) in its economic process. Hartwick shows that, so long as the stock of capital did not decline over time, non-declining consumption was also possible. Hartwick stated clearly what has come to be known as Hartwick's rule for this type of economy: "*if the accumulation of capital always exactly compensates in value for the resource depletion, then the level of consumption remains constant"* (Cairns et al., 2000, p.1; Hanley et al., 1997, p.426).

Hartwick argued that a sufficient condition to enjoy a constant consumption path is to invest in reproducible capital all the returns from the exhaustible resource use. Using Hartwick's rule to get the social extraction rate to reach a sustainable consumption path for Egypt, we have to use the following formula:

$$r = \rho + \eta g$$

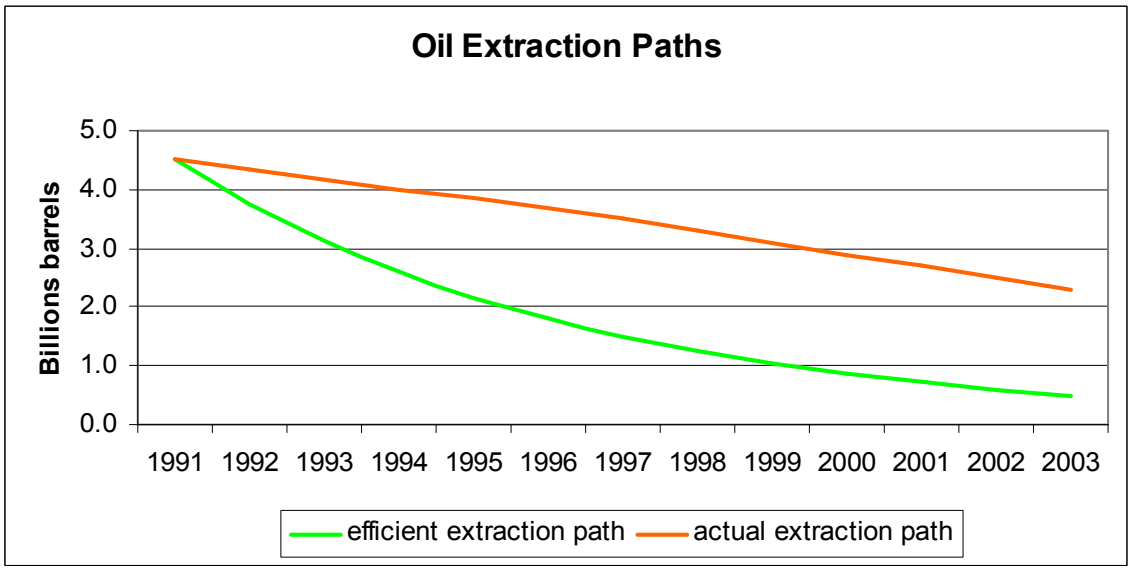
where, r is the social (optimal) extraction rate.

ρ is the social discount rate.

η is the risk aversion.

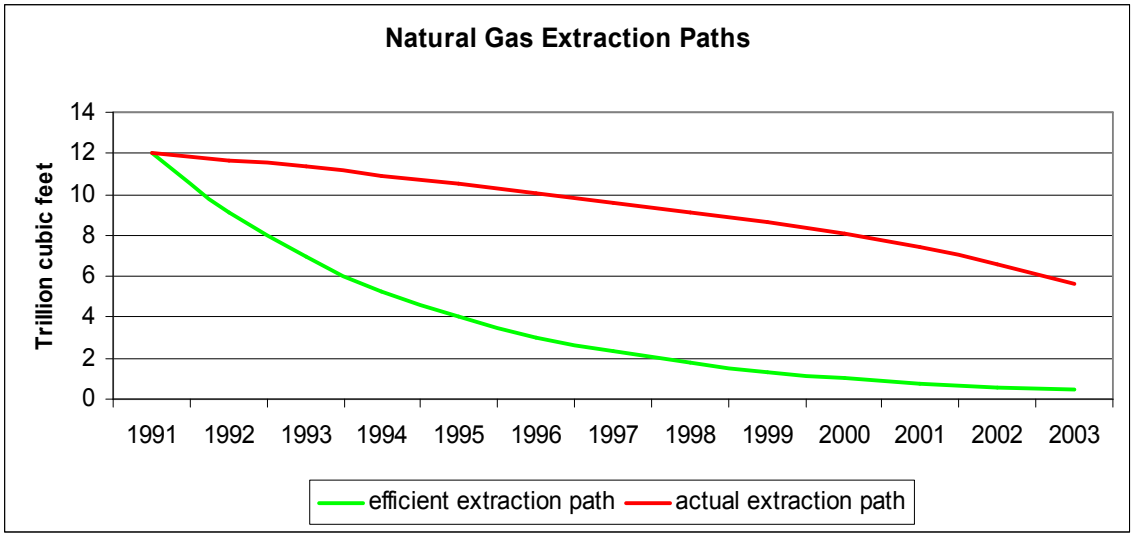
g is the growth of consumption of the exhaustible resource (oil or gas).

By applying the above formula to Egypt, and substituting for ρ=15% (the social discount rate in Egypt), η=1 (assuming risk neutrality) and g_o= 1.8% (growth rate of consumption of oil in Egypt) and g_{ng}= 9% (growth rate of consumption of natural gas in Egypt); the social extraction rate for oil and natural gas will be 16.8% and 24% respectively. This result is acceptable in the way that the social extraction rate for natural gas is greater than that of oil, which is a normal result. New discoveries of natural gas reserves in Egypt lead to an increase in consumption, which will reflect normally on its optimal extraction rate.



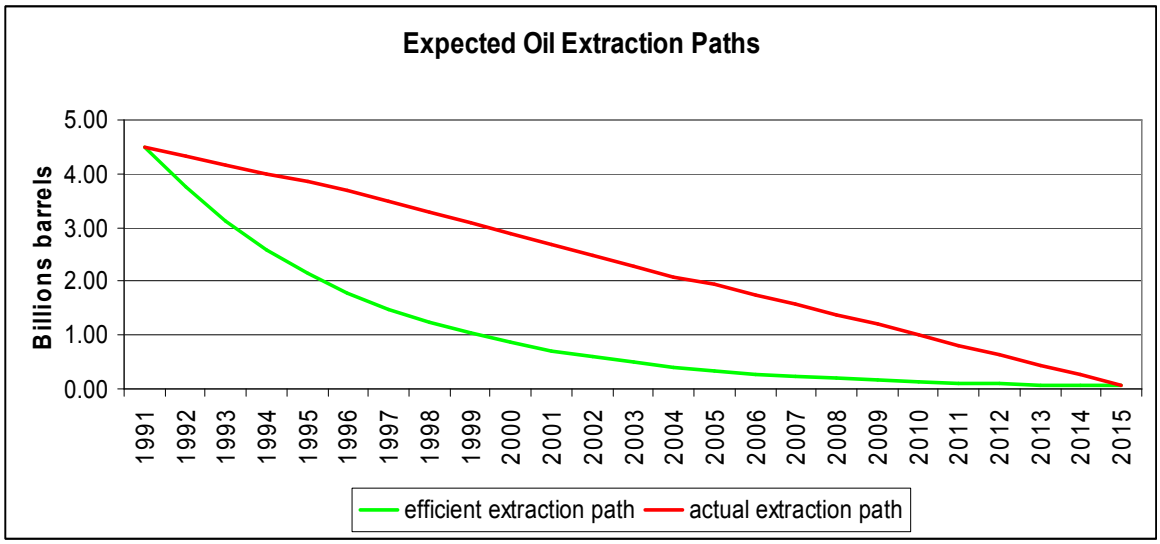
Optimal extraction rates of oil and natural gas in Egypt will be used to get the efficient extraction paths for both energy resources. To make it simple, the paper assumes oil and gas reserves in year 1991 to begin with; then, calculates for each resource an efficient and an actual extraction path.

It was observed for both resources that the actual path is higher than that of the efficient one showing that oil and gas have not been extracted efficiently in Egypt. But it also shows that Egypt is actually extracting less than it should be and that may be related to immaturity of some fields or to the inefficient technology used.

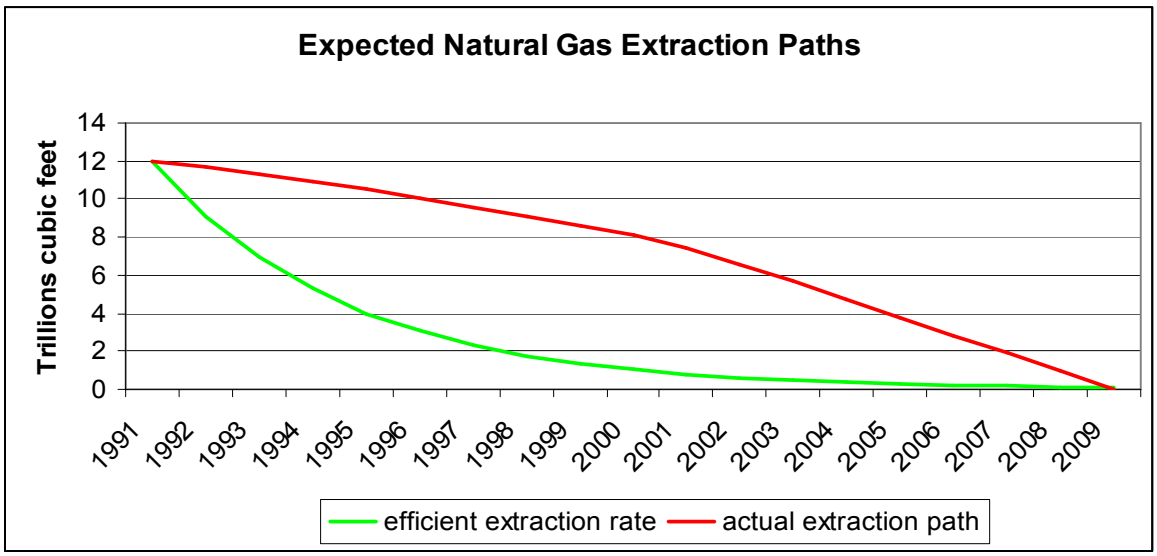


However, both graphs show that the actual path is decreasing with a decreasing rate while the efficient is decreasing with an increasing rate. From which it can be concluded that both curves will intersect in the future. And by forecasting both paths for oil and natural

gas, it was found that the two paths will intersect in 2015 for oil and in 2009 for natural gas as shown in the next graphs.



As Egypt faces a decrease in oil reserves, it will slowly decrease (or increase in decreasing rate) its oil extraction. The two paths for oil will intersect in 2015. On the other hand, the actual extraction path for gas is expected to decrease sharply due to high expected extraction of gas, as Egypt will depend totally on it for consumption and exporting due to its new reserves discoveries. That expected sharp increase in natural gas extraction will lead to the intersection between the actual and the efficient extraction paths for natural gas in 2009 even before oil, as shown in the figure below.



Conclusion:

Egypt will continue to experience obstacles in developing further oil reserves, especially with a continuing decline in Egyptian crude oil production and a subsidies system that encourages over consumption. While natural gas is destined to become more and more important to the energy future of Egypt because of the major recent discoveries that increases its reserves with a strong potential for more discoveries. Accordingly, increasing the dependence on natural gas as a substitute for oil should be implemented. So Egypt is now in a position to start exporting large volumes of gas as well as catering for growth in domestic demand in the coming decade. However, building natural gas exporting infrastructure will entail large amounts of spending which will require a large amount of investment. Therefore, energy development in Egypt rests upon the ability of the private sector to generate the required capital, while helping to open new markets for natural gas exports.

According to the actual and efficient extraction paths in Egypt, It was observed for both resources that the actual path is higher than that of the efficient one. However, the actual path is decreasing with a decreasing rate while the efficient is decreasing with an increasing rate for both natural gas and oil, from which it can be concluded that both curves will intersect in the future. By forecasting, it was found that the two paths will intersect in 2015 for oil and in 2009 for natural gas. This can be explained as the actual extraction path for gas is expected to decrease sharply due to high expected extraction of gas, as Egypt will depend mainly on gas consumption and exporting due to its new reserves discoveries. That expected sharp increase in natural gas extraction will lead to the intersection between the actual and the efficient extraction paths for natural gas in 2009 even before oil. On the other hand, the actual extraction path for oil will decline smoothly in almost a linear declining trend due to expected shift of government policies of combating over consumption of oil.

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