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CONSIDERING OIL PRODUCTION VARIANCE AS AN INDICATOR OF PEAK PRODUCTION

BY

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These findings support peak oil forecasts in the range of 2005 to 2010 and together provide strong evidence that geological factors could presently be limiting world oil production.

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ABSTRACT

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Peak Oil predictions range from the year 2000 to 2100 with the highest concentration of informed forecasts from 2005 to 2016. Confidence in international oil reserves data is lacking. As such, different forecasters make different assumptions about future undiscovered oil amounts and oil reserves, resulting in a wide range of peak oil estimates. Viewing this wide time disparity in forecasts as problematic, the research objective was to look for an economic cross-check indicator, metric, or alternative data-based means to corroborate or refute existing peak oil estimates. The primary finding was unprecedented *statistical variance* in oil production rates as well as in oil prices beginning approximately 2005 to 2010. In the case of oil production rates, variance is at historically low levels. In the case of oil prices, variance is at historically high levels. The data indicate a new higher order of inelasticity between oil price and oil production. These findings support peak oil forecasts in the range of 2005 to 2010 and together provide strong evidence that geological factors could presently be limiting world oil production.

TABLE OF CONTENTS

CONSIDERING OIL PRODUCTION VARIANCE AS AN INDICATOR OF PEAK PRODUCTION

Introduction

Imagine an esoteric contest amongst geologists and other analysts to guess the precise year that world oil production will peak. One says peak will occur in 2005, another says 2010, and yet another predicts 2014 to be peak production year. The specific year is not important. The importance lies in the fact that their measurements, taken together, have reduced a large degree of uncertainty, and allowed us to see a probable peaking period with the fidelity of about a ten-year span.

This study provides an additional measurement tool, statistical variance, to further increase fidelity and reduce uncertainty as to peak oil's timing. The result found is an addition to the overall set of observations and measurements concerning world peak oil production timing. After providing background information on oil dependency, petroleum use, the peak oil phenomenon, and oil reserves, the study measures the statistical variance of *oil prices* and *oil production rates* from 1975 to 2010, over five-year periods. It provides the ratio of production variance to price variance during five-year periods to gain insight into the relationship between oil price movement and oil production changes over time. The study also explores an alternate means of identifying the peak of world oil production by observing oil production variance over time in relation to Hubbert's logistic curve.

Theoretically, oil production variance should be greater before and after peak as it changes with increasing production during the years before peak, and changes with decreasing production during the years after peak. A multiple-year period of relatively low world oil production variance could be interpreted as the peak period. Norway is a country known to have reached peak oil production in July 2000. Norway's oil production data is used to demonstrate the effect described, and as an example to help interpret world oil production data.

Oil Dependence

The world's oil supply is finite. Yet, most nations continue to consume fossil fuels as if the supply were everlasting. Economies, industries, and military forces are almost completely dependent on fossil fuels for transportation, materials, strategic deployment, and tactical operations. Major industries such as the automotive, metal, dairy, fertilizer, paper, plastics, and sugar industries are but a few that heavily depend on petrochemicals. It is estimated that oil is used as an essential ingredient in the manufacturing of over 6000 items. [1] Use of fossil fuels is so extensive and so pervasive to modern societies that a shortage, unprepared for, could stagger economies and destabilize global security. The U.S. is particularly vulnerable. With only 5% of the world's population and 2% of the world's remaining oil reserves[2], the U.S. consumes about 25% [3] of the world's oil produced annually, over 60% of which is imported. [4] Much of the imported amount comes from countries whose interests are inimical to our own, which tends to warp U.S. foreign policy and international relations. The U.S. borrows about $1 billion per day just to import the oil it uses. [5]

Hydrocarbon Man and the Petroleum Age

Viewed along the timeline of 5000 years of recorded history, the "petroleum age" is a short period. The age began in 1859 with the drilling of the Drake Well in northwestern Pennsylvania,[6] and will end about 300 years later, assuming today's consumption trends continue.

Oil is a one-time endowment formed over millions of years. Oil results from the natural settling and burying effect of organic-rich materials over time, heated to temperatures above 175^{o}F, thousands of feet below the earth's surface. It is predominantly formed between depths of 7,500 and 15,000 feet, which are referred to as the top and bottom of the oil window, respectively. The temperature between 7,500 and 15,000 feet cause the large organic molecules to break into smaller pieces. Those smaller pieces, or molecules, with five to twenty carbon atoms are liquid crude oil. Molecules with less than five molecules are natural gas.[7]

Over the last 150 years, oil has enabled modern civilization as we know it today. All the marvels of the twentieth and twenty-first century were made possible by our connection to cheap, plentiful fossil fuels. The plastics and synthetic materials industries[8] were created using oil as a provision. The automobile, airline, and boating industries; and their related commercial enterprises were all born of access to cheap, abundant oil. Modern conveniences from power tools, lawn mowers, weed eaters, asphalt, farm tractors, fertilizer, and rubber tires to beach balls, panty hose, cosmetics, and vinyl flooring--all owe their genesis and continued existence to the availability of cheap abundant petroleum. It is difficult to identify a commodity that is not connected to oil in some way.

Aside from the hydrocarbon base molecule used to manufacture products, most people simply do not realize the tremendous amount of energy stored in a barrel of oil or a gallon of gasoline. There are 42 gallons in a barrel of oil which contain about 1667 kilowatt-hours of energy. A gallon of gasoline energy content is about 33 kilowatt-hours. In perspective, 33 kilowatt-hours is the equivalent of a healthy male pedaling a stationary bike for 330 hours--if he can maintain 100 watts per hour. If he pedals 40 hours per week, he will generate the same amount of energy as in one gallon of gasoline in about eight weeks. Pedaling 40 hours per week for just over eight *years* equates to 1667 kilowatt-hours of energy in a barrel of oil.[9] Now, if we attach a financial cost per hour to the pedaling, we begin to understand what is meant by “cheap” abundant fossil fuels. At the current $7.25 per hour minimum wage, the cost of pedaling 330 hours (energy in one gallon of gasoline) is $2,392.50; and pedaling 16,667 hours (energy in one barrel of oil) cost $120, 835.00. Today’s price for a gallon of gasoline is about $2.50, and around $73.00 for a barrel of oil. We have exploited this cheap abundant source of energy for over 150 years.

In the same way that historians have marked 1859 as the beginning of the oil age, future historians are likely to choose an event to mark the end of the petroleum age--say-- between 2140 and 2180. But the end of the petroleum age is less important than its midpoint for today's global economies that must make the transition from an era of cheap abundance to an era of scarcity, high prices, and potential resource wars. In this center area when about half of the petroleum that can ever be extracted has been produced, oil production rates will be highest, followed by inexorable production rate declines year after year toward depletion.

Inexorable Peak Oil

> "The term Peak Oil refers to the maximum rate of the production of oil in any area under consideration, recognizing that it is a finite natural resource, subject to depletion."
> --Colin Campbell (*Energy Bulletin, April 2009)*

The U.S. can be used as a surrogate of sorts for what may happen on a global scale. In 1956, geophysicist Dr. M. King Hubbert mathematically calculated that the United States would reach its maximum crude oil production capacity in 1970. His forecast, as history would show, proved to be correct.[10] For example, in 1960 the U.S. produced 7.04 million barrels per day (MB/D), and by 1965 was producing 7.80 MB/D. Then as Dr. Hubbert predicted, the U.S. reached its maximum production capacity of 9.64 MB/D in 1970 and production has decreased ever since. The U.S. was able to produce only 4.96 MB/D in 2008.[11] Why is this? Oil is a finite resource and there are basic laws that govern any finite resource described below as three successive phases:

(1) Production starts at zero

(2) Production rises to a peak which cannot be surpassed

(3) After the peak, production steadily decreases until the resource is depleted

These laws were highlighted and described for us by Dr. Hubbert in his famous paper Nuclear Energy and the Fossil Fuels.[12] *Global Peak Oil Production* (phase 2 above) is the time when the maximum rate of global petroleum production is reached. After which, the rate of production enters a terminal state of decline. This is not the end of oil, but it does mark the beginning of the end of oil where it becomes progressively more expensive to extract each additional barrel of oil. In essence, it marks the point where all the low hanging fruit has been picked.

Dr. Hubbert's successors (Colin Campbell, Ken Deffeyes, and Jean Laherrere) have presented data that indicate all nations together will reach collective maximum crude oil production capacity between 2004 and 2010.[13] A more optimistic view, and the result of one of the most advanced and thorough studies on the subject, is given by the U.S. Energy Information Administration (EIA). The EIA predicts that global oil production peak will occur after 2020 and more likely after 2030.[14] There is little dispute over whether or not *Global Peak Oil Production* will occur; only differing opinions of when.

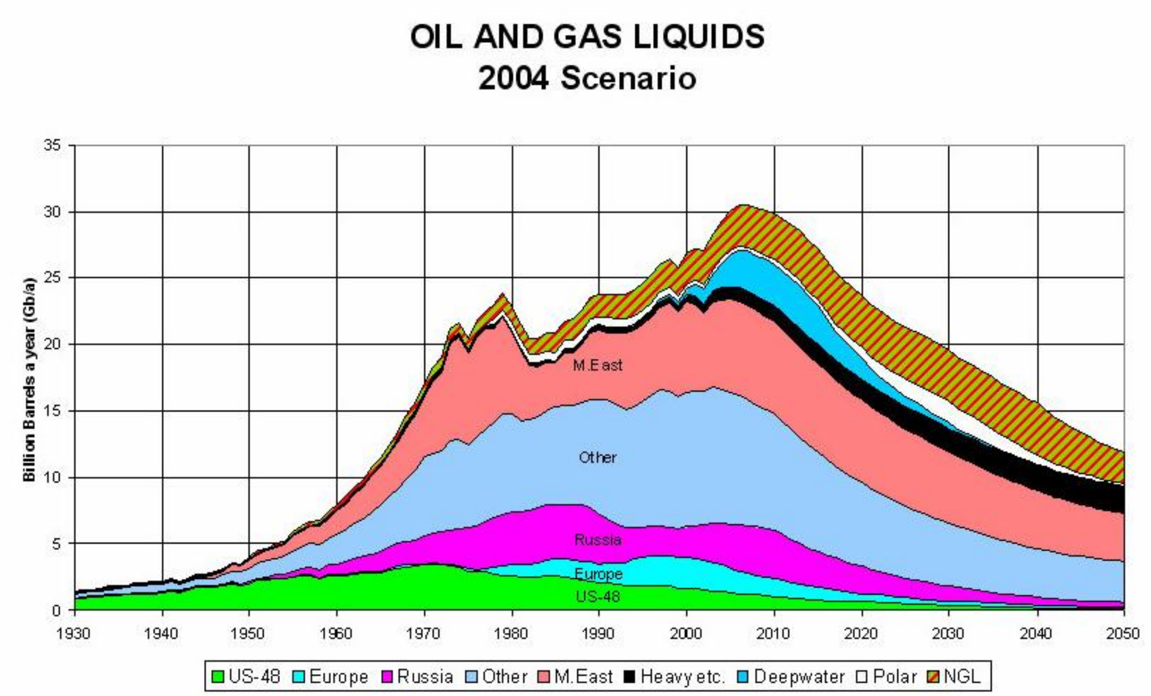

Figure 1. Projected world oil production based on analyses from the Association for the Study of Peak Oil (ASPO).

Dr. Hubbert postulated that the United States' ability to produce oil depended entirely and linearly on the unproduced fraction of oil remaining in the U.S. He implies that nothing else matters but the unproduced fraction. Richard Deffeyes, one of Dr. Hubbert's successors, describes this effect using the equation, $P = a(1-Q/Q_t)\, Q$, where P is the ability to produce, Q is the cumulative production, Q_t is the cumulative total, and a is the annual production expressed as a fraction of the total production. In Deffeyes words, "Inside the parentheses…is Hubbert's heavy magic. Q/Q_t is the fraction of the total oil that we have already produced and $1-Q/Q_t$ is the fraction yet to be produced. That equation says that our ability to produce, P, is linearly dependent on the fraction of oil that remains."[15] Deffeyes, a Professor Emeritus at Princeton University, and author of "Beyond Oil", points out that U.S. oil production data from 1958 thru 2003 fits Hubbert's model reasonably well, and that Enhanced Oil Recovery (EOR) methods such as 3D seismic, deep water drilling; and increased gas prices have apparently made no "abrupt dramatic improvement." [16]

The part of the equation that causes such a large range in forecasts is Q_t, which represents the cumulative total amount that can be produced when the last barrel of oil is extracted. For the U.S., it is clear now that that amount is about 228 billion barrels. [17] Globally, this amount is referred to as the Ultimate (U) recoverable amount. Most U estimates range from 1.7 trillion barrels to 2.3 trillion barrels. This translates to a wide range in forecasts because each .1 trillion, or 100 billion barrels of oil is consumed over ~38 months at the current global consumption rate of 86 million barrels per day (MB/D) or 31.4 billion barrels per year (BB/Y). The differing estimates of U, or alternately stated $Q_{t,}$ are the fundamental cause for wide ranging peak oil production estimates.

Peak will occur at the approximate midpoint of depletion of the total, Ultimate (U) amount. The EIA estimates U to be 2.248 trillion barrels[18], and therefore the midpoint to be

1.124 trillion. When proven reserves are depleted to less than 1.124 trillion barrels, peak production will have occurred according to Hubbert's model where the ability to produce depends almost entirely on the unproduced fraction. The EIA posts two figures for proven reserves as of January1, 2008. The low estimate is 1.18 trillion barrels, and the high estimate is 1.32 trillion barrels.[19] If the lower estimate of 1.18 trillion is accurate, reserves will be depleted below 1.124 trillion in early 2011. Assuming the higher estimate of 1.32 trillion, reserves will be depleted below 1.124 million in 2014. Here we assumed the 2009 global consumption rate of 86 MB/D remains constant.

Ken Deffeyes' best estimate of U is 2.013 trillion barrels, and Dr. Hubbert's optimistic estimate was 2.1 trillion. [20] Estimates of extractable remaining oil vary some as well. Deffeyes, Hubbert, and the EIA may all be wrong, but odds are, they are not very wrong. If their estimates are in the realm of accurate, they all point to about the same ten-year period.

Table 1. Global Peak Oil Production Forecasts

Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhitari, A.M.S.	Iranian Oil Executive
2007-2009	Simmons, M.R.	Investment banker
After 2007	Skrebowski, C.	Petroleum journal Editor
Before 2009	Deffeyes, K.S.	Oil company geologist (ret.)
Before 2010	Goodstein, D.	Vice Provost, Cal Tech
Around 2010	Campbell, C.J	Oil company geologist (ret.)
After 2010	World Energy Council	World Non-Government Org.
2010-2020	Laherrere, J.	Oil company geologist (ret.)
2016	EIA nominal case	DOE analysis/ information
After 2020	CERA	Energy consultants
2025 or later	Shell	Major oil company
No visible peak	Lynch, M.C.	Energy economist

Source: Peaking of World Oil Production: Impacts, Mitigation, & Risk Management, Robert L. Hirsch, SAIC Project Leader, February 2005 [21]

Oil Discoveries in Perspective

Concerns about declines in annual oil discoveries are highlighted by data. Cumulative worldwide petroleum oil discoveries in the realm of 60 billion barrels per year are cited in the 1960s. By the 1970s, the largest cumulative annual discoveries decreased to around 40 billion barrels, and then further decreased to roughly 25 billion barrels annually in the 1980s and 1990s. In 2007, newly discovered was 23.7 billion barrels of oil. In 2008, only 15.4 billion additional barrels were found, and an even lesser amount of 10.2 billion barrels in 2009.[22] New discoveries will probably continue for a time span that can be measured in decades; however, extrapolating these historical data show an oil discovery trend line becoming asymptotic and approaching zero.

Often, oil discovery reports, whether from government, corporate, or general media, do not provide a meaningful reference point or criterion to judge the discovery's magnitude. The finds are usually presented simply as stand-alone numbers, quoted in millions or billions of barrels of oil. What, for example, is the significance of a three-billion barrel oil discovery? Should it lessen oil depletion concerns?

The criterion used here to judge the magnitude of a reported oil discovery is the current U.S. and global annual consumption rate. The result is a length of time given in months and weeks that the oil discovery will support at either the U.S. or global consumption rate. Some examples of reported oil finds are given here to illustrate relative significance of reported oil discoveries.

On September 2, 2009, Bloomberg published that British Petroleum (BP) had discovered a "giant" oil deposit in the U.S. Gulf of Mexico, possibly having more than three billion barrels of oil. The find was located about 250 miles southeast of Houston and, incidentally, lauded BP's technological achievement of drilling to approximately 35,055 feet, "greater than the height of Mount Everest." BP would now be able to boost production by 50 percent, to 600,000 barrels a day by the year 2020. According to the report, this giant find was equal to about a year's worth of output from Saudi Arabia-- and its size roughly matched all oil reserves in the United Kingdom.[23] Referencing the size of the find to the United Kingdom's reserves, or Saudi Arabia's annual output, has little real significance. The U.S. consumes oil at a rate of about 20 million barrels per day (MB/D),[24] which translates to approximately 7.3 billion barrels per year (BB/Y). At a consumption rate of 7.3 BB/Y, it can be seen that the three-billion barrel discovery represents a 4.9 month supply to the U.S. This harvest of oil, however, is not fenced for the U.S. It will be traded internationally. So, how significant is the three-billion barrel discovery with reference to global consumption? Globally, oil is consumed at a rate of 86 MB/D[25]or 31.39 BB/Y, which means that BPs discovery of three billion barrels of oil, represents a 1.15 month supply to the overall global market.

McMoran Exploration Company announced on January 12, 2010 what it said could be one of the largest oil and natural gas discoveries in decades in the shallow waters of the Gulf of Mexico. The find was 10 miles off the coast under just 20 feet of water but at a total depth of 28,263 feet (more than five miles deep). An initial test had found a "135 foot column of hydrocarbon-filled sands" estimated to be "two trillion cubic feet of resources." The company pronounced the potential prize could be up to 165 million barrels of oil and natural gas. McMoran Exploration Company stock rose by more than 25 percent that morning after the announcement. This *potential* discovery, couched as one of the largest discoveries in decades in the Gulf, represents 8.25 days of oil supply for the U.S. at the U.S. consumption rate of 20 MB/D. For China, 165 million barrels would be exhausted in 21 days. Referencing the global consumption rate, this discovery represents less than a two-day supply.

The ‘East African’ newspaper and website (allafrica.com accessed 15 MAY 10) reported on March 22, 2010 that a Chinese exploration team had struck a high concentration of gas indicating oil was nearby, and quoted Kenyan Energy Minister Kiraitu Murungi as "bubbling with optimism" over the prospect. At about 17,000 feet, the well is the deepest ever attempted in Kenya. It should be noticed that the explorations, wherever they might be, tend to be setting records for depth, and are in harsh, forbidding places. This potential find is estimated to be two billion barrels.[26] Referencing the global consumption rate of 31.39 BB/Y, two billion barrels represents a 3-week supply to the community of nations as a whole. Theoretically, if the U.S. were to purchase the entire amount, at its consumption rate of 7.3 BB/Y, the two billion barrels would be exhausted in three months plus one week. To China, which consumes oil at 8 MB/D[27] or 2.9 BB/Y, the find represents eight months plus one week.

In the final example, recently on May 18, 2010, Zion Oil and Gas Company, a Delaware Corporation, reported that the Israeli Petroleum Commissioner had awarded the company an extension of one year on its petroleum exploration licenses. One license, the “Asher-Menashe License,” covers an area consisting of about 78,824 acres located on the coastal plain between Caesarea and Haifa. The other license, known as the “Joseph License,” covers an additional 83,272 acres also along the coastal plain area but between Caesarea and Netanya. The lease extension will allow Zion Oil and Gas to drill additional wells until October 10, 2011. According to a U.S. Geological Survey (USGS) report, the renewed-lease areas *may* have 1.7 billion barrels of recoverable undiscovered crude oil as well as a natural gas find.[28] Governments and corporations increasingly express great excitement over finding yet smaller and smaller amounts of *possibly* recoverable petroleum. It is as if we are literally scraping the bottom of the barrel. This lease extension, covering more than 165,000 acres, may recover 1.7 billion barrels of oil, amounting to a 19-day supply to the world and two months and 24 days to the U.S.

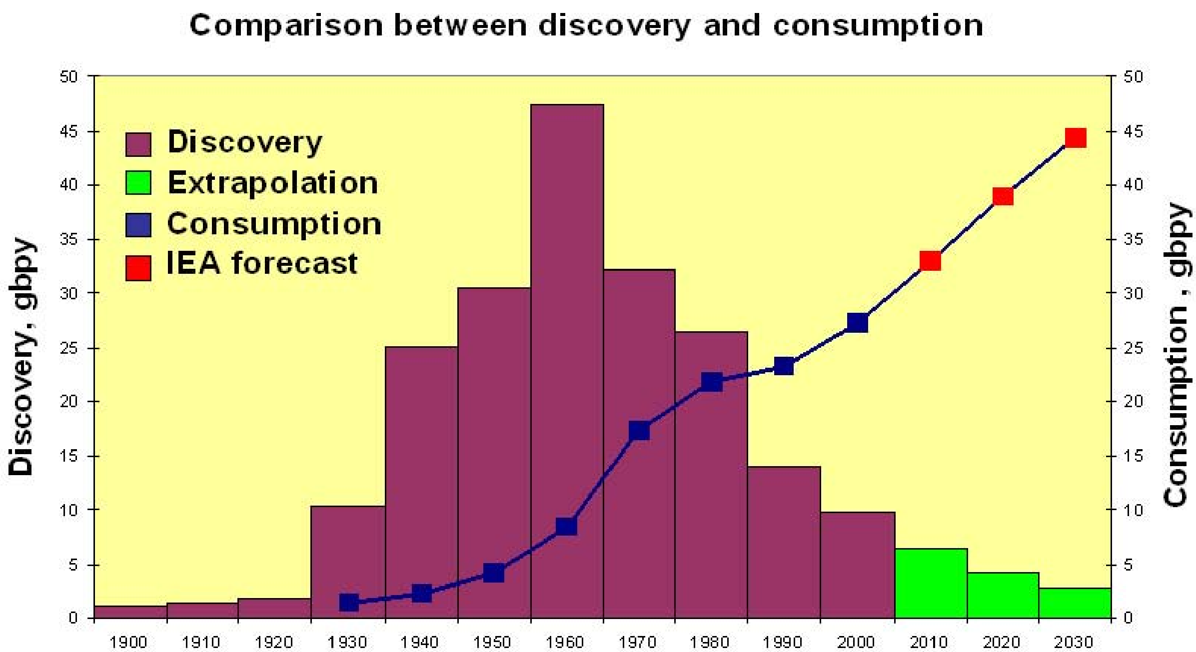

Figure 2. World oil discoveries as depicted by the Association for the Study of Peak Oil (ASPO).

In sum, if an oil find is not reported in the multiple 10's of billions of barrels or higher, the amount is simply yet another relatively small find that was expected according to the extrapolated data and does not significantly change the world oil supply situation. The outlook for petroleum oil future discoveries is not good.

Strategic Petroleum Reserve (SPR)

The U.S. Department of Energy (DOE) maintains a 727-million-barrel U.S. Strategic Petroleum Reserve (SPR) which hedges the risk of a temporary disruption in U.S. oil supply. [29] The 2007--2008 average U.S. daily oil consumption rate was approximately 20 MB/D. At that rate, if theoretically used as the U.S. sole source of oil, the 727-million-barrel SPR represents a 36-day supply. In creating the SPR, the DOE assumes a recovery of oil supplies following the disruption. A terminal decline however, is by definition permanent. Production falls never to rise again, and requires adaptation to lower and lower levels of production year after year. It is important to make the distinction between a temporary oil supply disruption and oil's terminal production decline. Managing the risk of one is much different than managing the risk of the other.

Oil Production Variance

Statistical variance is a measure of dispersion notated for a sample as $S^2 = \frac{\sum(X-\mu)^2}{n}$ or for a population as $\sigma^2 = \frac{\sum(X-\mu)^2}{N}$. In Figure 3, line **a** represents a multi-year period prior to peak.

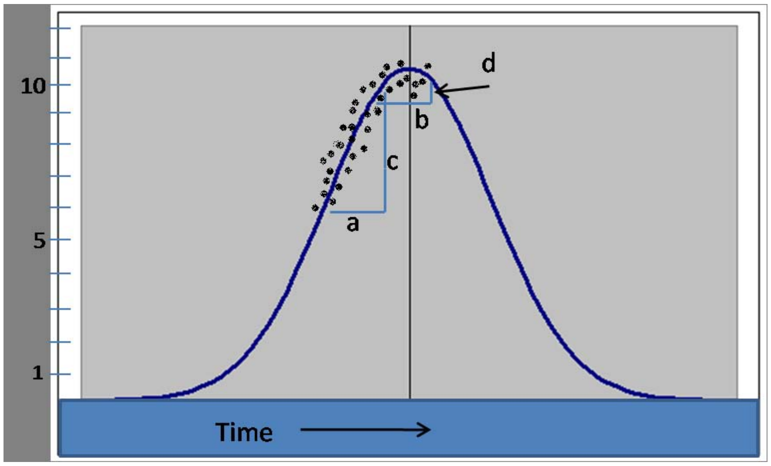

Figure 3. Introductory concept of production variance before and during peak production.

Line **b** represents a time period during peak, with equal number years as **a.** The range of line **c** contains all the values, or production rates, for time period **a**. The range of line **d** contains all the values, or production rates, for time period **b**. The statistical variance should gradually decrease as time periods adjust up the curve from **a** to coincide with **b**, and **c** shortens to equal the length of **d**. Post-peak, production rate variance will increase for a given time period, but now the variance is due to decreasing production rates. This is an introductory concept put forth first in this study.

To test the concept proposed in Figure 3, we need data on a field or geographical area known to have reached and passed beyond peaked. It is now accepted that Norway reached its peak production in 2000, and Norway's monthly production data Is available from the EIA. Norway's highest seven monthly production rates exceeded 3.3 MB/D. One occurred in December 1999, three occurred in 2000, and three in 2001. The highest monthly production rate was 3.41 MB/D in July 2000. The last time a monthly production rate exceeded 3.3 MB/D was December 2001 at 3.36 MB/D. Norway's monthly oil production has continued to decrease since then, and in February 2010 was 2.04 MB/D. [30]

Table 2. Oil Production Statistical Variance: 5-year periods

	Oil Production Variance	
Period	World	Norway
Feb 10 – Mar 05	.51 Peak?	.063 Post Peak
Feb 05 – Mar 00	4.70 Pre Peak	.033 Peak JUL 00
Feb 00 – Mar 95	3.04 Pre Peak	.042 Near Peak
Feb 95 – Mar 90	.82	.129 Pre Peak
Feb 90 – Mar 85	6.42	.079 Pre Peak
Feb 85 – Mar 80	6.29	.012
Feb 80 – Mar 75	13.73	.009

Norway's low production variance shown in Table 2, March 1975 thru February 1985, is the left "tail" at the beginning of the logistic curve as production ramped up. Moving up the logistic curve, production variance increased from March 1985 thru February 1995 as production increased, then began to decrease beginning March 1995 approaching the peak period in 2000. Norway's production variance during its peaking period reduced three to four times from the preceding five-year period. In the five-year period following Norway's peak (March 2005-February 2010), the production variance can be seen to increase again, but now the variance is due to decreasing production over time on the descending (right) side of the logistic curve. In the future, we would expect to see Norway's oil production variance to decrease one last time as the data paints the right "tail" of the logistic curve. The real-world data for Norway supports the concept offered in Figure 3.

In their natural form, logistic curves show a smooth beginning, growth, maturity, decline, and end of a non-renewable resource. The data that paint Norway's oil production logistic curve is an example that follows the logistic curve model relatively well. However, *world oil production data* is the result of more complexities and artificialities than Norway's.

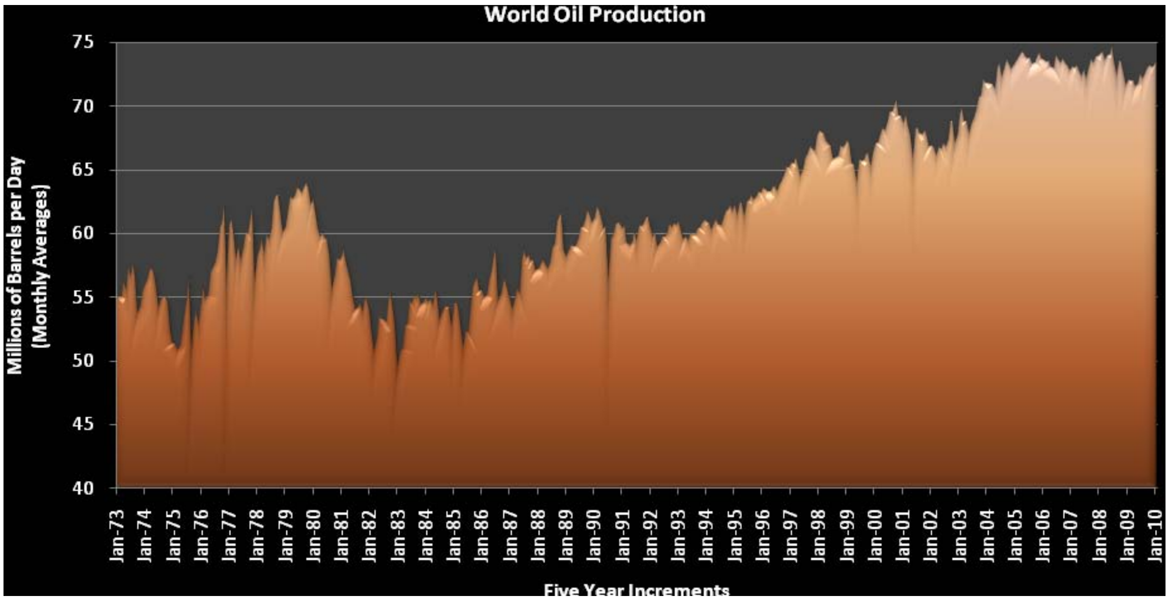

Figure 4. World Oil Production. Source: Data used to construct the illustration was acquired from the EIA (www.doe.eia.gov/emeu/aer/inter.html).

For example, we know that the Organization of Petroleum Exporting Countries (OPEC) has in past decades purposely restricted production to keep oil prices high, within an acceptable pain threshold to buyers. If production were restricted to the point of causing excessively high prices, demand would be destroyed, and petroleum users would seriously look to alternative energy sources long term. We do not know for certain today if OPEC has excess production capacity, or if the leveling-off of production rates seen in the data from 2005 through 2010 represents <u>all the production capacity</u> OPEC and the rest of the world can muster. Since the ability to produce oil is a function of the unproduced fraction of oil remaining, per Hubbert's model, has one-half or more of the all the oil that is recoverable been extracted? The measurement of world oil production variance in Table 2 indicates a leveling-off of production from 2005 to 2010 and supports the majority of world peak oil production forecasts shown in Table 1.

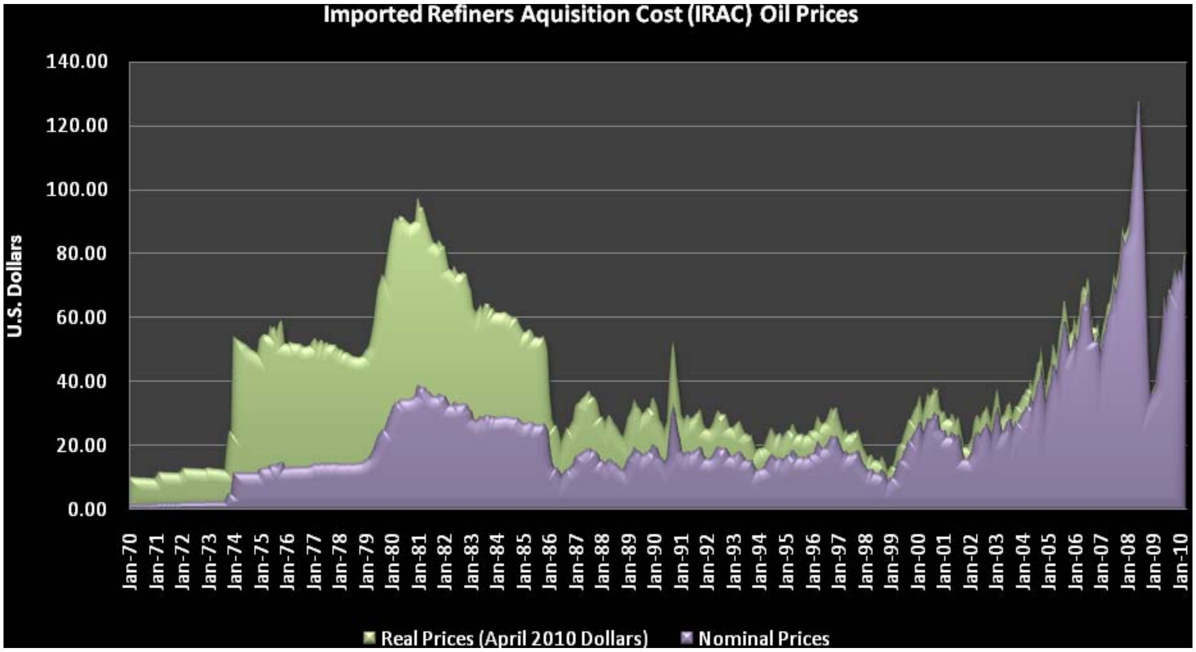

Figure 5. Imported Refiners Acquisition Cost (IRAC) Oil Prices. Source: Data used to construct graph acquired from the EIA (http://tonto.eia.doe.gov/country/timeline/oil_chronology.cfm) . The EIA reports crude oil price per barrel based on the average monthly price American refiners pay for imported oil called the Imported Refiners Acquisition Cost (IRAC).

<u>Production vs. Price – Variance Comparison</u>

Oil production variance and oil price variance have never been so far apart. Normally, production influences price, and price influences production in cycles; however, the data suggest that this dynamic is severely curtailed from March 2005 to February 2010. Price variance, itself, with a value of 389.94 from March 2005 to February 2010 is more than eight times higher than during the previous 15 years, while the production variance value of .51 is about seven times reduced from the previous 10 years.

Table 3. Oil Production Variance vs. Oil Price Variance: 5-year periods

	February 2010 to March 1975		
Period	Production Variance	Price Variance	Production/Price
Feb 10 – Mar 05	.51	389.94	.001
Feb 05 – Mar 00	4.70	42.65	.11
Feb 00 – Mar 95	3.04	31.25	.10
Feb 95 – Mar 90	.82	46.47	.018
Feb 90 – Mar 85	6.42	100.89	.060
Feb 85 – Mar 80	6.29	167.51	.038
Feb 80 – Mar 75	13.73	91.12	.15

Together, these two values suggest extreme inelasticity between oil production and oil price. The Production/Price ratio of .001 from March 2005 to February 2010 shown in Table 3 indicates an inelasticity at least ten times greater than at any time during the previous 30 years, and 100 times greater than during the previous decade. One might conclude that what we have considered 'normal' oil production and oil price cycles have ceased to exist.

Queueing theory may provide additional insight. Single queue-single server such as at the grocery store; and single queue-multiple server such as at the airline counter become chaotic when the burden exceeds the capacity of the system. [31] Customers arriving randomly find their time waiting in the queue becomes very long. A graph of natural gas prices when North American natural gas peaked around 2001 looks eerily similar to the oil prices in Fiqure 5 beginning about 2006 to present.

Conclusions

The measurements of oil production and oil price statistical variance in this study support world peak oil production forecasts in the range of 2005 to 2010. World oil production variance from March 2005 to February 2010 is about seven times reduced from the variance during the previous 10 years, which is what we might expect to see approaching and crossing the crest of a logistic curve, as illustrated in Figure 3, and seen in Norway's oil production data.

Additionally, the data show that oil price has aberrant high variance March 2005 to February 2010. Comparing the relative variances of production to price as a ratio, the data seem to indicate a new higher order of inelasticity between price and production. The synchrony of unprecedented low production variance, unprecedented high price variance, and the number of peak oil forecasts in the range of 2005 to 2010 provide strong evidence that, regardless of price pull, geological factors could be presently limiting world oil production.

Future Considerations for Research

Consideration 1: The U.S. reached peak production in 1970. Monthly U.S. oil production data prior to January 1973 could not be found at the time of this study. Obtain U.S. oil production data prior to its peak, or data for an oilfield or nation known to have peaked. Calculate the oil production rate variance over time before, during, and after a known peak as was done with Norway's production data, to further test the concept proposed in this study.

Consideration 2: Before, during, and after peak production, oil storage inventories are likely to decrease. Perform a study on U.S. oil storage inventories from ~1990 to present.

Consideration 3: North American *natural gas* reached production peak in 2001. Price changes were minimal until about 1987 when the load on the 'system' approached capacity resulting in large price swings. Using oil prices, can queueing theory be used to tell us if the oil production and supply 'system' is approaching capacity? Is it becoming chaotic?

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