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RESEARCH ARTICLE

GLOBAL OIL DEPLETION ARGUMENTS AND COUNTER-ARGUMENTS

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ABSTRACT

Where are we standing in the history of oil? In which point of the line are we now? Where are we going? Where is the line leading us, up or down? Towards what is the world moving? Are we going to "bathe" in oil in the near or far future or are we going to say "goodbye" to oil pretty soon? Global oil depletion is one of the most debated subjects nowadays, as oil is still the most important commodity we have. Since we are so addicted to this resource, it is essential to us to know the arguments that sustain the idea that the world is running out of oil and the counter-arguments to it.

INTRODUCTION

Arguments that support the idea of Global Oil Depletion

Why is the future of oil so unsecure? Why the known data, the analysis and the philosophies that help predicting the oil production lead to such different opinions regarding the oil future, that some analysts strongly support the theory of global oil depletion and others say this idea is totally unjustified? We can start answering these questions by taking into consideration the arguments that support the idea that the end of what we call "Oil Era" is close. Are the nowadays concerns regarding the global oil depletion, raised by publications such as the GAO Report in 2007, the Hirsch Report of the Energy Department in 2005 and the article from the *Science* magazine in 2007, just false alarms? (Government Accountability Office, 2007; Hirsch *et al*., 2005 and Kerr, 2007) What are the facts that support the neo-Malthusians affirmation that the world is running out of oil? The analysts in the oil field "built their case" regarding the oil reserves depletion around the Hubbert's work and used more types of data. They bring some arguments sustaining that de maximum oil production and the decline of the global oil production are close to us.

The oil production decreased in other states also, not only in USA

The USA is the biggest oil producing nation that passed the Peak Oil, but there are also other states that followed the same path of decrease. British Petroleum affirmed that there are at least 25 countries that produce oil with a rate of at least 20% under the production maximum. This reduction is equivalent to more than 1/5 of the global oil production in 2008. The information from the USA Energy Department shows that there are 101 countries that produced oil since 1980. Out of these, 33 produced oil with lower rates after 2005. Although the majority of these 33 countries doesn't represent major oil producers, five of them produce almost 15% of the global oil production and four of them – USA, Norway, Great Britain and Indonesia – are in top 20 of the oil producing countries. Compared to the maximum production of each country, these last four states faced a production decline of 40% (more than half of this decline is due to the USA oil production decrease) (*BP,* 2008 and *World Energy Outlook,* 2008).

The production surpasses new discoveries

One of the alarming tendencies is the raise of the oil discoveries deficit, the difference between the global discoveries and production. From 2000 to 2006, there have been discovered 85 billion barrels in 140 new oilfields, which had between 11.6 and 85 billion barrels. In the same period of seven years, the production summed up 180 billion barrels. These figures suggest that, at global level, there has been discovered oil a little over half of the new oil that was produced for consume (85 versus 180 billion barrels). Moreover, the total potential production from these new discoveries is estimated at only 5.5 billion barrels per year or

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only 1/5 of the current global oil production (around 27 billion barrels per year in 2008) (Sandrea, 2006 and EIA, 2008).

The total reserves and estimations are overrated

Hubbert's followers fear that an oil crisis has already begun, since the global oil reserves estimations are greatly exaggerated and the oil production will decrease as the oilfields are depleted. The problem with the international reserves statistics is that they are auto-reported. The oil reserves estimations may and already have been manipulated and can exaggerate the quantity of easy recoverable oil. The oil producing countries have their own reasons for pretending exaggerated values of oil reserves. The best example is the reporting made by the OPEC countries. Because the exporting quantity for each country is a share from the quantity of its reserves, the higher the reported oil reserves are, the higher the quantity that can be exported is.

The oil reserves are exaggerated also by the industry

On January 9, 2004, Royal Dutch Shell announced the first from a succession of descendent reviews for its reserves. In total, there have been announced five reviews that reduced the proven reserves from Shell (registered at US Securities and Exchange Commission (SEC) with 4.5 billion barrels or approximately 23% of the reserves registered in 2002. The majority of the reviews have been associated with undeveloped petroleum regions, such as Nigeria and Oman, where the production is anticipated (1.2 billion barrels). How could such a great quantity of oil just disappear? (United States District Court, 2004) Such reviews suggest that at least one majoroil company exaggerated its oil reserves and that the true value is much lower.

There are increasingly less oilfields discovered and the production is declining

Most of the "giant" oilfields – defined as the oilfields that contain more than 0.5 billion barrels – have already been discovered and the future exploration is unlikely to have the same efficiency as the one in the past. And that is because the world discovers very few new oilfields rich in oil and we rely for production on the old and almost depleted oilfields.

There are approximately 700 "giant" oilfields, each with at least 0.5 billion barrels URR (Ultimately Recoverable Resources) discovered until 2008. Together, these "giant" oilfieldscontain approximately two thirds of the global oil production (IFP, 2005), and most of them have been discovered 30, 40 or even more years ago. 116 "giant" oilfields, each producing more than 100,000 barrels per day, are responsible for almost half of the global production, 112 of them being discovered over 25 years ago (Bahorich, 2006). The biggest 14 oilfields are the source of 1/5 of the global oil production (Horn, 2006) In medium, starting with 2000, there have been discovered 4.9 "giant" oilfields per year and a total of 10.9 oil and natural gas "giant" fields per year (Horn, 2009). The discovery of "giant" oilfields reached its peak in the '70s and, since then, it has been in a clear decline. The peak of the "giant" oilfields discoveries occurred before the peak of new oilfields discoveries and that shows that the biggest oil reserves have been discovered first. Moreover, the production in some "giant" oilfields decreased. Almost 20 years ago, there were 15 oilfields producing more than 1 million barrels per day. Until 2005, remained only four such oilfields, all of them discovered more than 30 years ago: Ghawar (Saudi Arabia), 1948; Kirkuk (Irak), 1938; Burgan Greater (Kuwait), 1927; Cantarell (Mexico), 1976 (Robelius, 2005). One of the biggest concerns regarding the global oil depletion was the aging and the questionable production potential of the "giant" oilfields, especially of the number one of the oil producers, Saudi Arabia. A lot of anxiety is focused on the Ghawar oilfield, the biggest oil reservoir in the world, which contains approx. 60% of the Saudi oil. In order to maintain the production in Ghawar, is being injected water around the oilfield's perimeter to push the oil towards the central wells. The method itself is good, except the fact that, if too much water is injected, it will find its way to the central wells. Still, it's not such a big problem as long as the fraction of water in the total produced liquids is controlled[1]. With Ghawar, this fraction raised constantly, for example from 25% to more than 36% during 1993-1999 (Nasser and Saleri, 2004). The question raised is whether the Saudi Arabia's oil, 90% of it coming from just 5 "giant oilfields", can be sustained and whether Saudi Arabia will remain or not the main provider with extra production capacity in times with very high demand.

There is a significant concern regarding the decline of the production in more and more "giant" oilfields. The researchers have analyzed a very large database of "giant" oilfields at Uppsala University in Sweden (Höök *et al.*, 2009 and Robelius, 2007). The database contains 331 "giant" oilfields, out of which two thirds are onshore and one third offshore. These oilfields have an URR estimated at 1.13 trillion barrels, but, until 2005, the production in 79% of them (261 oilfields) was declining. Assuming a constant declining rate, we can expect that the production in a declining oilfield drops with a half every 11 years. The declining rate based on these data corresponds to a study made by EIA in 2008 (World Energy Outlook, 2008), that suggests an annual declining rate of 6.7% based on the analysis of production share of 317 "giants". The "giant" oilfields that are currently producing oil have reached their peak at different moments. Predictions regarding the total oil production from the existing "giant" oilfields suggest that, collectively, they will produce until 2025 only half of the quantity produced in 2007 (Höök *et al.*, 2009 and World Energy Outlook, 2008). Still, even with the decrease of "giant" oilfields' production, IEA predicts that the global production from all the existing and new oilfields will rise with approx. 7% until 2030.

The discoveries' and drillings' decline suggest the beginning of the production decline

If the relationship between the discoveries and the production, based on USA experience, is applied to the tendency in the global production, the production's peak should occur a few years after the global discoveries' peak.

[1] www.glossary.oilfield.slb.com/Display.cfm?Term=water%20cut

The global industry is growing and the oil consume at global level raises

Another major concern of those who believe that the "Oil Era" will end up soon is represented by the raise of energy consume in developing countries. The poorer nations, with a very low GDB per capita, also have a very low oil consume per capita. These states include India and China. The nations with higher GDB per capita also have a higher oil consume per capita. These states are those from Western Europe, Scandinavia, North America and the developed countries around Pacific. There is thus a clear correlation between the raise of GDP per capita and the raise of oil consume per capita. China and India, with a low GDP per capita, had an annual consume less that 2 barrels of oil for each person in 2007, and in 2012 (China with a consume of 10.2 million barrels and India with 3.7 million barrels) China had a consume lower than 3 barrels for each person, and India a consume of approx. 1.1 barrels for each person, while USA had an approximate consume of 21 barrels for each person in 2012[2]. The big concern is that, when the economies of the states like China and India will be fully developed, their oil consume per capita will become close to the one of USA nowadays. Considering the immense and growing population, China and India will generate an extraordinary growth of oil demand.

After all, China alone has a population of approx. 1/5 of the world's population. Each year, the population grows with over 8 million persons and, until mid-2008, had an industrial growing rate higher than 10%. Although this growth dropped dramatically since the global economic crisis that started in 2008, the China's economy continues to grow in an enviable rhythm. China's economic growth slowed down, but the industrial development continues to depend on oil. China's annual oil consume almost doubled since 1996. The oil consume had an accelerated rhythm since 1980, but the oil production failed to keep up with the growing demand. At the beginning of the 1990s, China was a net oil exporter, but it became nowadays a significant importer – approx. 4% of the annual global production. Nowadays, China produces less than half of the oil it consumes. India's annual oil consume doubled in the last 14 years and it exceeds 1 billion barrels per year. It produces less than one third of what it consumes. Taking into consideration the growing incomes and economic and industrial development, it is very likely that these developing nations consume ultimately a great deal of world's oil.

The oil price is growing

The studies show that, if we consider the inflation, it's not very correct to say that the real oil price has generally risen. The table below (Table 1) shows the purchasing power of US dollar in time, based on the annual growth of the Consumer Price Index. In the Table 1 is presented the value of 100$ in 2007 throughout almost 150 years since the oil is being produced. As it can be seen in the Table below, one American dollar is not worth as much as it used to. What was purchased in 1860 with only 4$, in 2007 was purchased with 100$. From another point of view, the value of 100$ in 1960 is the equivalent of 2,500$ in 2007, as a result of the inflation. In 1960, the oil was being sold with approx. 2$ per barrel, but, due to inflation, it would cost 13$ per barrel in 2007. Thus, even if the oil nominal price rose a great deal, this is not a good indicator, considering the inflation. Practically, the oil costs more nowadays just because everything costs a lot more.

Table 1. 2007 100$ equivalent starting with 1860 (the equivalent value of 100$ in 2007, taking into consideration the inflation, based on the USA annual change of CPI)

Year	2007 100$ equivalent
1860	4.00
1900	4.10
1920	9.60
1940	6.80
1960	14.30
1970	18.70
1980	39.70
1990	63.00
2000	83.10
2007	100
2008	103.80
2009	103.20

Counter-arguments to the Global Oil Depletion

The arguments that show the imminent depletion of oil reserves are apparently convincing. Many have accepted them as an axiom. Still, there is also another side of this story. The counter-arguments are the critics over Hubbert's and his followers' assumptions and methods regarding the analysis, predictions and data interpretation.

The production rates predicted by Hubbert were incorrect

There have been many critics regarding Hubbert's approach, generally referring to the correctness of his predictions over the oil production decline in the United States and, further, over the peak and decline of the global production. Now, after 50 years from the first prediction from Hubbert, we can analyze how correct his predictions were.

Oil production in USA

There have been over 50 years since Hubbert's first prediction and we can evaluate it by comparing his data with the current data regarding US oil production. Many critics have been brought to Hubbert's predictions regarding the oil production. David Deming, professor at Oklahoma University, analyzed in detail Hubbert's numbers from 1956, watched the predictions' evolution in time and showed that Hubbert's predictions weren't so accurate (Deming, 2000 and Deming, 2003). Based on the information available in 1956, Hubbert adopted the value of 150 billion barrels as his best estimation on the US total amount of oil. Hubbert's prediction regarding the moment

[2] conform consumului din *BP Statistical Review of World Energy 2013* și populația conform *US Census Bureau's population clock*

of Peak Oil in US wasn't that correct using his best prediction on the total oil production. Hubbert asserted that the Peak Oil will occur in 1965, only 9 years after the publishing of his predictions from 1956. But the peak occurred in 1970, 14 years later and Hubbert under-predicted the peak's value with more than 25%. Moreover, oil production rate in 2008 predicted by Hubbert was of 0.5 billion barrels per year, while the real value, that we know now, is of approx. 1.55 billion barrels per year. Thus, it seems that Hubbert was wrong with two thirds.
With the increased value of 200 billion barrels (instead of 150 billions), Hubbert's predictions in 1956 shows best the current quantity and the moment of appearance of Peak Oil in USA. Still, even if we use the amount of 200 billion barrels, when we project it on the beginning of 2009, we realize that Hubbert's estimation over production wasn't that small. As Deming also noted, it is not clear that Hubbert knew which prevision was the best, even at the moment of Peak Oil in 1970.

Hubbert didn't use the logistic curve (bell shaped) to make his predictions in 1956 (Hubbert, 1956). On the contrary, he drew the curve by hand. This is obvious since the curve is not symmetric; some see a smooth "tail" after Peak Oil. Hubbert explained: "In my figure of 1956, showing two complete cycles for U.S. crude-oil production, these curves were not derived from any mathematical equation. They were simply tailored by hand subject to the constraints of a negative-exponential decline and a subtended area defined by the prior estimates for the ultimate production. Subject to these constraints, with the same data, I suggest that anyone interested should draw the curves himself". In a curve drawn by hand is a high degree of subjectivism, especially because is not known yet the decline path after Peak Oil, and the value of the area below the curve, the total oil amount, is so uncertain. Part of the subjectivism was eliminated later on, when Hubbert adopted the usage of logistic curve instead of the one drawn by hand, but the problem of estimating the total oil amount is still unresolved.

Bell shaped curve

An attraction of Hubbert's original approach is that it is based on a mathematical model that looks like the familiar image of a bell. Even with the failure of the predictions from the last ten years, the success of Hubbert's approach was that the US oil production was based on this curve. Nevertheless, why does the global oil production's trajectory has to be shaped as a bell? There is no convincing reason for the growing production to reflect the decline. The oil production's curves for each oil area tend to show a rapid growth of production culminating with production's peak and then a decline in time. Though, even when the production's curves are in decline, they don't show the beautiful symmetry of the logistic curve. For all the countries, continents or the entire world, it is not expected that the oil production present a symmetric curve bell shaped. At global level, the production of only 8 non-OPEC countries out of 51 follow the bell shaped curve (Lynch, 2003). We may think that, because of the medium effects, it is more likely that a subassembly of a smaller region in a wider region shows a history of production shaped as a bell than the smaller regions. Still, if we study the registrations of 139 oil producing regions, we find that the wider area regions don't adhere to Hubbert's mode more than the smaller regions (Brandt, 2007) North America has an oil production rate rather stable. Europe is the only wide region where the oil production's values show a significant decline and produces less than 7% of the world's production.

Global oil production

In 1956, Hubbert ventured to apply his approach to the entire world's oil production (Hubbert, 1956). He assumed a total quantity of oil (the cumulative sum of production, known reserves and projected discoveries) of 1.25 trillion barrels and predicted the Peak Oil moment around the beginning of the millennium (around the year 2000), with a peak value of 12.5 billion barrels per year. Comparing the current data with his prediction, we can see that the peak moment has not arrived yet, the production being at approx. 31 billion barrels per year in 2012 (more than his prediction's double) and the current estimation of USGS of total oil amount is more than 3 trillion barrels (almost 2.5 times more than Hubbert's estimation). A correct prediction, using Hubbert's method, shouldn't be based on US experience. The US is unique, because it was exploited for oil more than any other place on earth. Actually, only in Texas there were almost 1 million wells, towards 2,300 in Iraq (Maugeri, 2006) (Iraq's size is 70% of Texas' size, but the latter has 435 more wells). US, having in 2012 approx. 2.1% of the world's oil reserves (http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf), has 35,000 oil reservoirs, while in the rest of the world, which has 98% of total reserves, were developed only 12,500 reservoirs (Robelius, 2007).

At the end of 2008, in the US were almost 500,000 wells producing oil towards 870,000 in the rest of the world. In all the OPEC countries there were approx. 38,000 wells producing oil (only 1/14 of the number of those in USA). Saudi Arabia, member OPEC, has the largest oil reserves in the world (20%), but has only 1,560 wells producing oil (http://downloads.pennnet.com/pnet/surveys/ogj/071224ogj_24-25.pdf). To say that US is an oil region very well developed is a modest affirmation. Still, the US is very productive and is on the third place in the top of the biggest oil producing countries. We are not at the moment when we should predict global oil production's peak based on the US experience and on the logistic curve. Prediction about Peak Oil have come and passed over the time. The discussions about Hubbert's method's flaws have no intention to discredit his scientific expertise. He has put his assumption, model and predictions on the table so that they can be analyzed by others. And the previous and following experiences can confirm or infirm the previous assumptions and, in some cases, Hubbert's model wasn't accurate.

A decline in production doesn't necessary mean that the resources are over

An implied assumption of the catastrophic prediction regarding the oil resources depletion is that the oil reserves guide the demand. This means that we use very quickly the produced oil, which suggest that, as the production rate is diminishing after

Peak Oil, there won't be enough oil to satisfy the world's growing demand. Let's take a look at resources' scarcity and at its relationship over time. The production of a certain product may follow the curve of a logistic curve, as Hubbert also assumed in his latest predictions, but there is no particular reason for the growing line and the decrease one to be symmetric, as it is in a bell shaped logistic curve. The production's growing, peak and decrease, for both renewable and non-renewable resources, doesn't necessarily reflect that resource's depletion. It is more a clue that there are more available resources, the price decreases and the production is no longer profitable. Around the world, there is no common non-renewable resource, globally traded, that follows the pattern of production peak and the decline described by Hubbert's curve.

Debate generalization

The debate on non-renewable resources' depletion is between two sides. On one side there is the group of "resources' economist", who claim that the resources' global depletion will never occur. On the other side there are the ones that strongly believe that the world is heading towards a disaster of global depletion under the pressure of population growth. Although the attention is currently focused on the future of global oil resources, in 1980 the members of the two parties couldn't reach a common opinion regarding a debate on the scarcity and destiny of mineral non-renewable products in general. John Tierney from *New York Times* (Tierney, 1990) describes a famous bet. On one side was the biology teacher Paul Ehrlich from Stanford University and on the other side was the economy teacher Julian Simon from Maryland University. Ehrlich's famous book, *Population Bomb*, talks about the future that cannot be avoided, a nightmare world affected by starvation, pollution and resources' scarcity. In contrast, Simon's book from 1981, *The Ultimate Resource*, optimistically predicts the world's permanent improvement regarding human health and longevity, environmental quality and products' abundance, all because of the gains brought by technologic innovations and efficiency.

The two science men made a bet on the prices of metal products, adjusted with inflation. Ehrlich's affirmation was that the resources' scarcity would lead to price increase and such an increase would be a clear proof for the ongoing resources' scarcity. Simon sustained that the imminence of resources' scarcity is a myth and the price for any product basket should drop. According to the bet, Ehrlich had to select a basket of 5 metal products with a market in 1980 of 200$ for each metal (a total of 1,000$) that he believed would be more expensive in 10 years. Ehrlich would have won the bet if the price, adjusted by inflation, would grow, and Simon would have won if the price would decrease. The bet's value was the difference between 1,000$ and the basket's price in 1990. It should be noticed that Simon had a very high risk if the prices grew, but Ehrlich could have lost 1,000$ the most if the products were cheaper at the end of the bet. Ehrlich chose tin, tungsten, chromium, copper and nickel as the least probable to lessen. Simon won. These products didn't become rare, although the population grew with 21% from 1980 until 1991 (www.census.gov/ipc/www/worldpop.html). Simon would have won the bet even without inflation adjustment, because the medium price for the basket decreased with 36%. Moreover, after adjusted with inflation, each metal chosen by Ehrlich decreased in price with at least 17%. Although Simon won the bet because the price for the entire basket decreased, he would have won even for each metal. The lesson taught from Simon-Ehrlich bet is that, although it seems intuitive that the pressure of population growth must lead to a permanent growth of prices under the circumstances of global scarcity, this didn't happen for any significant non-renewable resource globally traded. During the ten years in which the Simon-Ehrlich bet was available, the technology improved and some minerals became less wanted as cheaper substitutes appeared. Consequently, the prices decreased as the demand's tendency was decreasing comparing to the growing supply. On long term, the price for many non-renewable resources globally traded, adjusted with inflation, decreased, even if the demand, reflected by consume, grew. Still, one of the difficulties resulted from using the price as a measure of scarcity is that the products' price is volatile. The prices' tendency is affected by temporary forces that may prevent the extraction and delivery. And these forces are not small. These forces may vary from workers' strikes to changes in governmental politics regarding commerce agreements, as well as political disturbances and wars.

More than the delivery interruptions, there may be peaks that cannot be anticipated, which may lead to prices' growth. The technological changes and worries regarding the environment can lead to a rapid substation of resources. The decline may be fast, because the replacement with new technologies may occur vary fast. There are a lot of common articles whose substitution was determined by technological innovations or worries regarding the environment. It is important to remember that the technological progress can create a "jump effect", when some products become useless even before they were adopted and, thus, some consumers "jump" over their usage. For example, the mobile phone technology is progressing in such a rhythm that in many parts of the world people will never see phone wires because of the technological jump to wireless systems, which made the wires useless. In long distances locations in Indonesia's islands, mobile phones are a common commodity, and wires have never been a part of technological landscape. Now, the question is whether oil will follow a production pattern similar to that of non-renewable products as metals.

Hubbert's curve indicates that the maximum peak of global production should be around 50 billion barrels per year. The data show that in 2012 there were produced approx. 30 billion barrels per year (http://www.bp.com/content/dam/bp/pdf/statistical-review/statistical_review_of_world_energy_2013.pdf), a value much under Hubbert's peak. The exponential growth that appeared 120 years after drilling the first well in the 1980s didn't continue. Starting from the exponential tendency of Hubbert's curve from 1980, the current tendency of oil production is, from then, a linear one, constant in the last 30 years. It seems that the oil production, from 1983 until 2012, actually grew proportionally with the population's growth. In the last 30 years, both the world's population and the global oil production grew with approx. 40%. It's not needed more than a simple mathematics and a correct estimation of population growth. Projecting this until 2075, when the population is expected to be at its maximum, using also the United Nations' estimates over the population's maximum as being 9.2 billion people, it may be estimated (multiplying 9.2 billion by 4.1) a future value of the oil production of just 38 billion barrels per year (United Nations, 2004). That means that 38 billion barrels per year will be the maximum value of production in the next 60 years (until 2075), when the world will have a population bigger with more than one third. This is being led much after the estimated dates of Peak Oil. Getting back to the data of US oil production, there is an explanation for the match in time and the immediate causes of Peak Oil appearance in USA have nothing to do with production and consumption. One cause of the US oil production's decline is the cheap imports. From 1955 to 1970, the imports represented approx. 10% of US oil consumption, but this value doubled in the next 5 years (the imports between 1955 and 1970 have been in medium 12.6% from the sum of production and imports; 26.5% in 1973; reached 33.4% and 39.9% in 1975 and 1976 and between 1971 and 1986 the medium was of 34.5%). What is the relationship between cheap imports and the decline of US own production? It may be assumed that the size and match in time of imports appeared because of own reserves' decline, as Hubbert suggested, or the availability of a cheap alternative also played an important role?

This owes at least to the technical innovation of petroleum super-tanks, which led to a raise of cheap imports in Persian Gulf by USA after 1971. From 1965 to 1970, the petroleum tank's capacity raised by 76% and the total tonnage rose by 118% (432 super-tanks) in 1970. Maybe there is no coincidence that Peak Oil and US oil production's decline started. Hubbert considered that the oil's depletion was the only force that sustains his model, but didn't consider back then that other mechanisms may be responsible for Peak Oil beginning, such as the relationship between the own expensive oil production and the cheap imports from Persian Gulf, the insufficient developed provision lines, the current transportation technology or the conflicts in Middle East. The impossibility from 1965 of importing oil means that that the decline in US oil production that started in 1965, predicted by Hubbert, would have left USA with no sufficient oil. The peak in 1965, predicted by Hubbert, followed by insufficient reserves, never occurred.

As Edward Porter, research manager at American Petroleum Institute in 1955, wrote in his amazing analysis over US and global depletion: "The decline in US supply after 1970 did not indicate that US was "running out" of oil, but rather that the costs associated with much of the remaining Lower 48 resources was no longer competitive with the imports from lower cost sources worldwide. Consequently, the decline in US supply after 1970 represented not a signal of growing global resource scarcity, but rather a signal of growing global resource abundance" (Porter, 1995). Even with the warning regarding the absence of a free and uninterrupted oil market, the oil price adjusted with inflation followed a flattened path in the last 100 years, except for the price peaks (and the following panic) that had nothing to do with oil depletion. They were temporary prices growths associated with worldwide events and with the OPEC control over production. For example, the oil price jumped in 1973 because of the oil embargo imposed by OPED, followed by Yom Kippur war (Arabian-Israeli). The price raised again in 1978-1980 because of the Iranian revolution and of the Iran-Iraq war. In 2003 grew again because of the workers' strike in oil industry in Venezuela, back then the fifth biggest oil exporter and the source of 12% of US imports. Adjusted with inflation, the annual oil price from 2008 of 94$ grew over 93$ per barrel, exceeding the medium price in 1980. If the oil price grows in the next years, the oil demand will diminish as new alternatives will appear.

The resources' evaluations don't provide the total estimations

Peter McCabe, researcher for 20 years at US Geological Survey in Denver, Colorado, is an expert in analyzing the global oil reserves. He analyzed the historic estimations of the total oil quantity, made between 1949 and 1996 by USGS and other reliable sources. The estimations showed o distinct tendency (McCabe, 1998). The evaluations successively made in the last 50 years provide us varied estimations of the total quantity of US crude oil. Not only the historic successive estimations differ, but they show a systematic growth from the first evaluation made in 1948, of 110 billion barrels, until the USGS estimations in 1996 of 330 billion barrels and until the DOE estimation in 2006 of 398 billion barrels of US conventional oil. Over the time, the evaluations added to the total US oil quantity 5 billion barrels per year. At its moment, each estimation was thought to be the most correct and reliable than the one before. In reality, oil wasn't more in one period than in another, but the evaluations' values grew constantly. For example, the estimation from 1955 of the US total oil quantity was of approx. 150 billion barrels and still this quantity was produced by 1990. There were no signs of complete depletion in 1990, although the estimated oil quantity in 1955 was over. With a similar analysis, McCabe showed that the US reserves' estimations grew sequentially with the evaluations. In any moment in time, in the last 80 years, the estimated oil reserves have been predicted to be sufficient for satisfying the US demand for the next 10-15 years. With each successive evaluation, the prediction about oil depletion was pushed further with another 10-15 years.

McCabe also analyzed the historic evaluations of global oil resources. The evaluations regarding global total oil quantity rose from 0.6 trillion barrels in 1948 to over 3 trillion barrels in the last evaluation made by USGS. The evaluations grew the value of total oil quantity with almost 35 billion barrels per year, being higher than the biggest annual global oil production rate. The available oil remained constant and maybe grew a little from the first report. Consistent with McCabe's evaluation on the data regarding the US total oil quantity, the available oil in the entire world is sufficient to assure the production for 45-50 years. The last evaluation made by USGS suggests that the available oil will last even more than 40-50 years. McCabe's results regarding the global oil have two important implications. The first: it is remarkable that the successive evaluations seem to find constantly enough oil for the next 40-50 years. And that is because the widow to the future evaluations doesn't allow us to see that far, even if we evaluate the resources in 1950, 1970 or nowadays. Secondly: the fact that the evaluation's value is not the same contradicts the appliance of Hubbert's logistic curve method. So obscure and annoying, the total quantity's value, assumed to be fixed, actually follows a growing path with successive evaluations. The constant growth of the evaluated total oil quantity means that we never know how much oil is really left. This is valid even if we use methods more and more sophisticated in the successive evaluations. The belief with every evaluation is that "this time, we have it all", but each new and improved value is ephemeral. The second fact that explains McCabe's time window of 40-50 years for oil consumption is more subtle, but it probably can be called the phenomenon "enough not to worry". The estimated value of the total oil quantity represents an adequate volume in order to meet the demand for a specific period of time. So it's not worth to start looking and identifying new resources since the available quantity is sufficient for the next half of century. Part of the difficulty of oil evaluations is that the terms "resource" and "reserve" are not clearly defined, which leads to subjective estimations. Both for the mineral deposits extracted from mines and for the extracted oil and energetic products, a reserve is the known material that is technically recoverable and profitable in a determined period of time.

O resource contains the material that is to be discovered and the known accumulations that cannot be recovered. In order to quantify a reserve, one must not only locate the oil, but also to define and "freeze" both the economic current conditions and the extraction technology state. Mainly, a series of instant evaluations made under the condition of fluctuating prices can categorize oil as resource in one year, reserve one year later and then almost resource the next year. As we have mentioned above, the definition for resource includes also the oil that wasn't discovered or profitable enough to be recovered. It is too much to ask to the geologists and engineers to make an evaluation of the resource in order to correctly speculate the potential locations and the oil quantity that can be produced under unknown and unpredictable economic and technologic conditions. All that can be done is to make assumptions about the technology nature and the price that can exist in a reasonable period of time and then estimate the locations and quantity of oil accumulations. This was made by USGS in the report in 2000. The researchers chose a period of time of 30 years, starting from 1996, as the most distant period of time in which they could foresee the recovering technology's state on which to base their estimations of total quantity. There is no surprise that, over time, one cannot foresee consume on more than 40-50 years. Further, the time frame, demand, economic conditions and technology cannot be predicted with a reasonable certainty.

Counter-arguments for the exaggerated reserves by OPEC and industry

At the end of the '80s, there was a significant worry that OPEC exaggerated its estimated reserves, in the conditions of a sudden raise of the reported values by the member states. Still, when USGS compared the raise of the reserves in "giant" oilfields from OPEC with the ones non-OPEC, the raise from non-OPEC reserves, of 63%, was almost 3 times bigger than the reserve reported by OPEC, of 22%, from 1981 to 1996 (Charpentier, 2005; Klett *et al*., 2000 and Klett and Schmoker, 2003). Even if OPEC raised the value for its reserves, their exaggeration failed compared to the estimated growing rate of the "giant" oilfields from the non-OPEC rivals. Although OPC operates behind a secret door, its reports of reserves' raise are not an alarming cause taking into consideration the context of the bigger raise of the non-OPEC reserves. The best example of extracting oil reserves in private sector is that of Royal Dutch Shell in 2004, when this company announced a succession of reviews in decrease (five in total) of oil reserves registered in 2002, totalizing a reserve decrease of 20% (Demirmen, 2004; United States of America, 2004; BBC, 207 and www.iht.com/articles/2008/07/31/business/31shellNEW.php). The reason for exaggerating the reserves might be the sustenance of the executive compensation or maybe there were fears that they would lose the bonus in Nigeria for new reserves.

The Shell case raised even a bigger problem of corporate reporting of the "registered reserves" that persists, but has little to do with known quantities of exploitable oil. Reserves' registration implies two different stages: estimating how much oil exists in a certain target oilfield and sub-classification of the reserves estimated as being viable or not from a commercial point of view. SEC revised its reporting rules for oil reserves, entered into force in 2010, in order to reduce uncertainty in revealing. The modifications include: (1) classification of proven reserves based on a medium price in the last 12 months instead of the price at the end of year; (2) authorization of using the new technologies in order to define the volume of proven reserves; (3) categorization of coal that can be turned into oil and natural gases as oil; (4) define the reasonable uncertainty based on more quantitative methods and (5) not being necessary the revealing of probable and possible reserves (Curtiss, 2009). These reviews should bring more transparency to the process of reserves' registration.

After so many exploitations, there is still enough oil to be discovered

The concern regarding the oil depletion continues, even if the reserves continue to have bigger and bigger growths – 1.67 trillion barrels (Economides, 2007), a raise of 14 billion barrels in 2012 compared to 2011 and 340 billion barrels over 2008 (January, 2009). Assuming that the figure of the total oil quantity in the world in known and fixed at 3 trillion barrels (using the figure of USGS evaluation), almost a third has already been consumed.

US oil: reserves

The proven oil deposits are estimated and subject for reviewing. In US, the reserves' values of oil deposits previously discovered grew more than consistently. In the last 10 years, 75% of the new reserves in US have been "discovered" inside or near the known deposits (Bahorich, 2006). In the last 60 years, only 15% of the American produced oil came from discoveries in regions that haven't already been identified as oil deposits and given into production. The completions to oil reserves by reviewing the estimated reserves, the extensions of the deposits and of the new discoveries in existing regions have produced the equivalent of oil volume in Prudhoe (Alaska) at every 5 to 6 years in the last 60

US oil: discoveries

Taking into consideration the United States (that are in many areas the worse example for oil perspective), the oil has been discovered here in 1935, Peak Oil appeared in 1970 and the production's decline lasted more than 35 years. The Prudhoe Bay oilfield, estimated at 13 billion barrels, has been discovered in 1967 and started to produce in 1977. In 8 years, the total oil production in US grew by 5%. From the discovery of Prudhoe Bay, in US have been discovered less than 14 giant oilfields with more than 0.5 billion barrels, summing up 10 billion barrels. The US have also other huge oil sources, that are recoverable with nowadays technology, according to US Minerals Management Service estimations (http://www.boem.gov/uploadedFiles/2011_National_Assessment_Factsheet.pdf). In total, this region is estimated at 68 billion barrels of oil and 75 billion barrels of oil equivalent in natural gases (1 cubic meter of natural gas represents the equivalent of 172.3 barrels of oil). More than half of these petroleum resources are under the Mexico Gulf.

The geology teacher Larry Cathles from Cornell University estimates that there may be even more oil and natural gas than that: 1 trillion barrels of oil and natural gas in just a fraction of Gulf's sediments, although there will be necessary unconventional recovery methods to be produced (Pinsker, 2003). In 2006, the Department of Energy (DOE) maintained the affirmation that there was much more oil to be recovered in US that previously estimated. DOE estimation is more than 1 trillion barrels of American oil in that place, 430 billion barrels from the total being liquid conventional oil or recoverable using improved methods. The conventional oil resources, as undiscovered oil and reserves' growth, represent 190 of 430 billion barrels. The improved recovering methodsare projected to produce another 240 billion barrels. If we take into consideration the 197 billion barrels produced until 2008 (in the US surroundings and Alaska), the total overcomes 625 billion barrels. If we put into perspective 430 billion barrels from the remaining potential of US reserves, at the rate of production from 2008, the depletion won't appear for more than 200 years.

The US production was more than replaced by the ads of new reserves in less than half of the years between 1995 and 2008. At the beginning of 2009, the US oil reserves were a little more than ten years before. In 2007, the big US oil companies replaced 105% of their American production of oil by adding new reserves. The offshore reserves' growth wasn't so big compared to the offshore production, the replacement was of only 79%, but the onshore replacement was of 117% (Department Of Energy, 2005 and Department Of Energy, 2008). The big oil companies that report to DOE have shown a medium replacement of the US reserves of 92% from 1981 to 2007. Clearly, the US is a mature and heavily exploited region, the most part of the production is in decline, but oil is still discovered and a big part of production continues, the US remaining the third biggest oil producer in the world.

Global oil: reserves

At global level, one can see a brighter image. From 1986, the annual medium prices for oil (in 2007 American dollars) grew more than three times, and in this period the global oil reserves grew from 0.7 in 1986 to 1.3 trillion barrels in 2008 and reached 1.6 trillion barrels in 2012. After the beginning of the '80s, the grown oil prices started to stabilize. From 1987 to 1990, both the oil reserves and the oil price grew with approx. 45%. During the '90s, the prices stayed low, the medium being less than 25$ per barrel and the reserves stayed at the same level. Together with the preparation and start of the war in Iraq, with USA as a leader, in 2003 the oil prices more than doubled and the reserves grew with almost 25%. It's not just a coincidence that, as the prices grew, more oil resources have been converted to profitable resources. The global oil resources, sufficient to satisfy the demand, have been maintained because of both new discoveries and reserves' growth (in deposits there was much oil than anticipated). Let's take into consideration the global reserve's growth. In its predictions, USGS estimated that a quarter of the total global oil quantity (recoverable oil until 2025) would come from existent sources as reserves' growth.

In 2005, USGS published a post-audit of its report from 2000, focusing on the predictions regarding the global reserves' growth from 1996 (the year analyzed in the report). From the beginning of 1996, there have been discovered 2,142 oil accumulations in the known areas. In these areas, the oil reserve's growth for 1996-2003 has been of 28% of the previous estimations. This value is taken as reference by the USGS estimation, taking into consideration that eight years mean 27% from the time period of 30 years. The natural gas deposits grew by 51% during the 8 years, suggesting that USGS underestimated the natural gas reserve's growth. During the post-audit period, the reserve's growth appeared in the first place in Middle East and North Africa, but also in Central and South America. The area with the biggest discoveries was Sub-Sahara Africa (Klett *et al*., 2005). The USGS post-audit showed that the oil and natural gas discoveries in new areas (versus previously discussed reserve's growth) contained only 10% of the reserve's growth, which is less than the USGS prediction, assuming a uniform rate of discoveries.

However, there are two factors that weren't taken into consideration. First, the USGS post-audit was published in 2005, one year before the announcement of new offshore discoveries under the Mexico Gulf and along the Brazilian coast, so USGS couldn't include these into the report. Second, the USGS values took into consideration only the conventional oil and gas resources and didn't include the significant growth of Canadian oil sands, that are now taken into consideration together with the conventional oil and categorized as part of global reserves by *Oil and Gas Journal* and reported by EIA of DOE. If USGS included the whole Canadian oil sand, the oil discoveries would have reached 37% of the USGS total, again overcoming the predictions of 27%. Separately from the reserve's growth prediction, the ads to the oil reserves reported in the entire world overcame in time the global oil production. Actually, from 1990, the reserves grew enough to insure 170% of the cumulated global oil production. The ads to the reserves not only equaled the volume of past cumulative production, but were in surplus in 2008. During this period, the lifetime of global reserves grew with more than 12 years (at the rate of production from 2008). Even if the Canadian oil sands, that are now part of the global reserves, are ignored, the ads to the conventional reserves overcome the global cumulative production with 165 billion barrels from 1990 to 2008.

Global oil: discoveries

At global level, the number of new discoveries of "giant" oilfields and natural gases' fields decreased significantly after the '70s. Still, some modern tendencies are significant. The first, the volume of oil discovered in "giants" from 2000 to 2008 was bigger than the one discovered in the '90s (57 vs. 43 billion barrels). In the '80s and '90s, a medium discovered "giant" used to have approx. 1.3 billion barrels of recoverable oil, while between 2000 and 2008 the medium volume was of 2.25 billion barrels. Of course, while these volumes are substantial, they represent only half of the medium of 4.5 billion barrels from the "giants" discovered between the '40s to the '60s. The second tendency is that the volume coming from the condensation of natural gases is more likely to be a significant source of oil. For the period 2000-2008, the volume of oil as condensed natural gases from the discoveries of "giant" fields (42 billion barrels) rivals with the volume of oil from new "giant" oilfields (57 billion barrels) (Horn, 2009). It is possible a growth of condensed natural gas, as half of the recent discoveries were of natural gas versus oil.

There are two things deriving from the discovery tendencies in the last years. The first, in the future it is possible a bigger global production of offshore oil. The data indicate that every 10,000 exploring wells have a consistent efficiency of approx. 150 billion barrels of oil – around 5 years of global production at the rate of production from 2008 (Sandrea *et al*., 2007). From the '60s to the '80s, approx. a third of the "giant" oilfields have been discovered offshore. Taking a look at the fields from 1999 to 2006, there have been discovered at global level 140 fields, most of them (127) offshore and 53 in deep water (over 7,000 legs depth) (Sandrea, 2006). The second thing that derived is that a fundamental premise of many statistical models of oil discoveries is probably incorrect. This premise is that the first to be discovered are the big oilfields, then the small ones. The statistical extrapolation based on the notion that the big oilfields are the first discovered, leaving behind the small ones, may seriously underestimate the remained oil resources.

How well has the world been exploited for "giant" oilfields? The oil discovered in the "giant" oilfields from 1956 to 1970 was of 525 billion barrels, with a rate of 35 billion barrels per year. During the 15 consecutive years from 1971 to 1985, the discovery rate decreased to 8 billion barrels per year (74 billion barrels in total), and from 2001 to 2006 the rate decreased to 3.7 billion barrels per year. Only in 2007 and 2008 such discoveries of "giant" oilfields raised the rate to over 11 billion barrels per year. Why such a dramatic decline in the oil discoveries during the last 20 years? The first reason is obvious: because of the definition of "easy oil". Most of the "easy oil" has already been discovered. To discover oil and then bring it to the market require huge investments. The second and most profound reason is that the exploitation hasn't been followed persuasively or at least it hasn't been followed clever by exploiting the most promising regions. Because of both low oil prices and small profit margin in the refineries in the '90s, the investment in the oil global exploitation was weak. This small interest persisted almost two decades, until soon. At the beginning of '80s, the international oil companies reported at DOE expenses of approx. 35 billion dollars per year for exploitation. But from 1986 to 2004, the investment in exploitation suddenly dropped la approx. 10 billion dollars per year (2007$) (Fletcher, 2006). The global expenses in 2005 for exploitation were smaller than the figure from 1981. Once the oil price raised and the exploitations expanded, the number of discoveries of "giant" oilfields rose from 1 in 2006 to 11 in 2008 (Horn, 2009).

The arctic oil in Russia and in the world

If the world is running out of oil, it means there must be alternative sources. It's obvious that the most oil is concentrated in Middle East and the resources of this region continue to be a mystery. But the Middle East is not the only promising region for the global supply. The Russian oil, in reserves of 87 billion barrels in 2012, is being produced and represents almost 13% of the global market of oil in 2012, with a production close to the one of Saudi Arabia. The Russian oil production grew, at the middle of the '90s, with more than 50% after the break of Soviet Union and the economic reform of Russia. Russia's economic future on short term is tied up to its natural resources.

According to the World Bank, Russia's oil and gas may represent a quarter of its GDP and every rise of oil price of 10$ per barrel raises Russia's GDP with 3.5% (EIA).Three quarters of Russian oil is produced in West Siberia Basin, a region that contains one of the biggest oil accumulations in the world. With a surface of 2.2 million square kilometers (850,000 square miles), it is the biggest oil basin in the world. Most of the "giant" oilfields in West Siberia Basin have been discovered more than 40 years ago, the production starting at the beginning of the '70s. The basin has been moderately exploited. Two "giant" fields of natural gases have been discovered along the Russian coast in Kara Sea, being remarkable that only two operation shafts have been drilled.

How much oil one can find in the West Siberia? Until 2003 there have been discovered 144 billion barrels and it's estimated that there are 55 billion barrels of oil still undiscovered (Ulmishek, 2003). Taken together, these represent three times the current Russian oil reserves, the eighth biggest in the world in 2007. Moreover, Russia has 32.9 trillion cubic meters of natural gases discovered in 2012 and it is estimated that there is more to be discovered. Adding these numbers, the oil and natural gas from West Siberia may represent an energy quantity equivalent to more than 530 billion barrels of oil. This region alone can sustain the energetic equivalent of global production of oil for 20 years (Ulmishek, 2003).

The world can still afford to raise the oil use, even if the developing countries ask for more oil

When it comes to oil accessibility and the raise of developing countries, there are two different aspects that deserve to be brought into attention. The first one has something to do with the expected oil demand of the developing countries and the second with the oil as a control agent in the world economy.

The future demand of developing countries

Maybe the strongest argument that sustains the concern regarding the imminent global oil depletion is that the developing countries will need a growing oil quantity as they industrialize. The global oil demand will rise as the life standard raises in emergent economies as China and India. The figure below shows the relationship between the oil consume in barrels per person per year and the economic well-being according to the GDP per capita, adjusted with inflation. As we expect, the developing nations have a low intensity of oil usage, because they use too little oil for economy. In a strong contrast we can find the developed countries that use more oil per capita in order to sustain the level of economic activity. The biggest concern is that, when China and India rise their life standards, their annual consume won't remain anymore at the current level, but it will tend towards US current annual level.

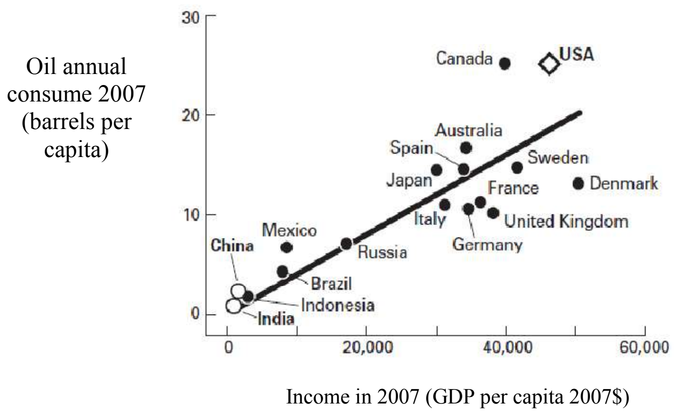

Figure 1. Oil consume per capita versus income per capita in 2007 (2007$), based on the GDP of the shown countries (source: oil consume, EIA; population and GDP, Economic Research Service, USDA)

Let's consider China. As regards the GDP, China's income per capita in 2012 was 10% of the American one (in 2012, the annual medium income in China was estimated at 5,720$, compared to 52,340$ in US, according to the World Bank), and the oil consume per capita was less than 1/10 of the American one. This would result in a huge consume of the global resources, if China's industrial development will be the same as the United States' in terms of industrial production, raising simultaneously the consume of oil per capita and the life standards. But what is not taken into consideration in the scenario "when the developing countries will be fully developed" is that the patterns of oil consume in the developing countries won't be the same as the historical patterns of the developed countries such as the USA. Considering the oil consume, the world has become more efficient in the past 25 years from energetic and petroleum point of view, particularly in China. In some very industrialized countries, oil consumers, such as Great Britain, Japan and Switzerland, the total annual consumed oil quantity (versus consume per capita) remained mostly unchanged, compared to the beginning of the '80s, and in France, Germany, Italy, Sweden, Finland and Denmark the consume (not in terms of per capita) even decreased compared to the values from 1980. In Eurasia, the oil consume is less than a half from the value in 1980. There is no doubt that the world as a whole consumes more and more oil in time. Still, how much oil we will need depends on two factors: (1) the efficiency of the oil consume and (2) the industrial developing rate and the raise of developing countries.

Globally, the oil-use intensity, defined as the consume of oil necessary for producing the national income per capita, decreased in the last 25 years. The data regarding the oil consume suggests that the world, China in particular, has become more efficient than the US. China didn't adopt the historic pattern for the oil consume of the modern industrialized nations. China's intensity of oil consume decreased with two thirds from 1980 – it consumes one third of the oil consumed in 1980 in order to generate one unit of income. The pattern of global oil consume and of the industrialization suggest that the developing nations would rather consume less oil per capita in order to produce their incomes, compared to the historic consume needed by the developed nations.

India's story is different from China's one. The intensity of oil consume in India grew indeed, but remained low. India, with a GDP per capita only half of the Chinese one, is extremely poor and couldn't rival with China's oil consume. India is still at the beginning of the industrialization process and consumed 3% or even less from the world's annual oil in the last 25 years. Only recently India started to be efficient in the oil consume in order to generate income. From 2000, its consume intensity decreased significantly. In conclusion, India's pattern suggest that is not imposed a short term stress regarding the world's oil supply and it consumes only one third from China's rate.

Conclusion

So, how much can we believe from the arguments that sustain the idea of global oil depletion? Not much, we believe. Yes, we don't have the certainty that oil is enough. We are aware that, little by little, oil reserves are diminishing. And yes, at some point, they will probably finish. But we still have a long way until that. Rumors for oil scarcity are the perfect tool for raising the oil price, as we know this is one of the economic and political policies. The oil crises in the past (such as the one in 1970) have warned the industrialized countries, the energy security becoming a vital problem for them. Expensive programs have been initiated for constructing nuclear plants and important subventions have been allocated for alternative resources, first in the public sector then in the private one. Thus, the world is moving and is not standing doing nothing, waiting to run out of oil and then die. It changes. And it changes fast. So it is very likely that we leave oil before it leaves us, as Faith Birol suggested.

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