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The 2006–2008 oil bubble: Evidence of speculation, and prediction

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ABSTRACT

We present an analysis of oil prices in USD and in other major currencies that diagnoses unsustainable faster-than-exponential behavior. This supports the hypothesis that the recent oil price run-up was amplified by speculative behavior of the type found during a bubble-like expansion. We also attempt to unravel the information hidden in the oil supply-demand data reported by two leading agencies, the US Energy Information Administration (EIA) and the International Energy Agency (IEA). We suggest that the found increasing discrepancy between the EIA and IEA figures provides a measure of the estimation errors. Rather than a clear transition to a supply restricted regime, we interpret the discrepancy between the IEA and EIA as a signature of uncertainty, and there is no better fuel than uncertainty to promote speculation! Our post-crash analysis confirms that the oil peak in July 2008 occurred within the expected 80% confidence interval predicted with data available in our pre-crash analysis.

1. Introduction: Distinction between pre-crash and post-crash analysis

Oil prices exhibited a record rise followed by a spectacular crash in 2008. As measured in terms of daily close prices, the peak of USD 145.29 per barrel was set on 3 July 2008 and a recent low of USD 33.87 was scraped on 19 December, a level not seen since 2004. The historical high was USD 147.2 per barrel, reached in the middle of the day of 11 July 2008.

Before the July peak was reached, in May 2008, using techniques based on statistical physics and complexity theory, we began analysis of the oil price time series to address the issue of whether or not oil prices were exhibiting a bubble-like dynamics, which may be symptomatic of speculative behavior. We submitted our initial results to arxiv.org on 6 June 2008 [1], with subsequent qualitative revisions submitted on 13 June and 22 June 2008. A related analysis, based on similar principles but different implementation, was submitted on 24 June 2008 by Drożdż et al. [2], followed by a post-crash analysis in August [3]. The actual peak oil price in 2008 occurred on 3 July. Here, we present a more thorough analysis of the oil price dynamics, which includes our initial results together with a post-crash analysis.

Since our analysis has a predictive nature, it is valuable to distinguish the work we did before the peak from that we did after it. This idea motivates the organization of this paper. In Section 2, we provide our original submission from before the peak, with only minor edits of variable names for clarity. Section 3 presents a more thorough post-crash analysis, including a calculated confidence interval of dates in which a crash would most likely occur using data available only before the peak.

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We compare the results with the date of the actual observed peak. We also discuss briefly an alternative hypothesis, that oil prices have been significantly moved by growing geopolitical uncertainties.

2. Pre-crash analysis (original paper)

This section contains the full text of our original article submitted to arxiv.org *as a series of 3 revisions, with minor changes in notation and the additions of headings for clarity. The quantitative Log-Periodic Power Law (LPPL) analysis (the main basis of our assertion that oil prices were in a bubble) and comparison between prices in USD and EUR are from the first version, 6 June 2008. The subsequent two versions (13 June and 22 July 2008) added and clarified global oil supply and demand using data from IEA (International Energy Agency) and EIA (US Energy Information Administration).*

2.1. Position of the problem and methodology

Since 1995, the US markets have lived through three major episodes, now recognized by most professionals and regulators and a growing number of academics as bubbles: the new economy ICT (internet-communication-technology) frenzy culminating in 2000, the real-estate surge peaking in the US in mid-2006 and the subprime NIV (new instrument vehicle) boom, which topped in 2007. In finance and economics, the term "bubble" refers to a situation in which excessive expectations of future price increases cause prices to be temporarily elevated without justification from fundamental valuation.

Since approximately March 2008, a growing number of journalists, pundits [4], bankers[1] and academics[2] have been discussing the pros and cons of the hypothesis that commodities, and in particular oil, have entered a bubble regime. One key question is to explain the quadrupling of oil prices since 2003. Some attribute it mainly to the pricing of the growing demand (in particular from the emergent China and India markets) imperfectly balanced by the increasingly apparent limits of world oil production. Others are raising the specter of rising speculation [4].

Based on analogies with statistical physics and complexity theory, we have developed in the last decade an approach that diagnoses bubbles as transient super-exponential regimes [5]. In a nutshell, our methodology aims at detecting the transient phases where positive feedbacks operating on some markets or asset classes create local unsustainable price run-ups. The mathematical signature of these bubbles is a log-periodic power law (LPPL) [6–10]. The power law models the faster-than-exponential growth culminating in finite time. The log-periodic oscillations reflect hierarchical structures [8,9] as well as competition between the trading dynamics of fundamental value and momentum investors [11].

Here, we present a brief synopsis of an extended analysis that we have performed, to address the question of whether oil prices exhibit a bubble-like dynamics, which may be symptomatic of speculative behavior. We have obtained robust and reliable diagnostics (i) by comparing different implementations of the LPPL theory, called the simple LPPL model [10], the second-order Weierstrass model [12] and the second-order Landau model [13–15], (ii) by performing extensive sensitivity analyses with respect to many different time windows used to calibrate the models and (iii) by using bootstrap methods to resample the residues over monthly time scales so as to keep, as much as possible, the statistical properties of the time series in the bootstrap scenarios. In our detailed analysis, we condition the calibration on a certain number of additional constraints that ensure the statistical significance of the LPPL structure, which include bounds on the key parameters informed from previous analyses [10,16], and the statistical significance of the power law and log-periodic components [17]. In addition, to address the question of a possible interplay between oil price increase and US-dollar depreciation, we perform the same analysis for oil price expressed in euro and in other major currencies.

2.2. Faster-than-exponential price growth diagnoses a speculative bubble

Fig. 1 shows a typical result of the calibration of the simple LPPL model to the oil price in USD. We model the data over varying time windows defined by two dates, (t_1, t_2). The starting date t_1 of consecutive time windows increases by 3 months. The last date t_2 is fixed for all time windows, 27 May 2008 (last available data for our original analysis). To be clear, t_2 is *not* a predicted crash time but is the date of the last observed point in the time series. One particular useful feature of the LPPL models is that, in contrast with most econometric models, they describe transient regimes ending at a critical time t_c beyond which the bubble is supposed to cross-over to another regime, either by crashing or through a more progressive transition [16,18]. Fig. 2 shows the predicted critical time t_c obtained using the three LPPL models (simple LPPL, second-order Weierstrass and second-order Landau) as a function of the beginning time t_1 for the fixed $t_2 = 27$ May 2008. Extensive scanning of t_1 and t_2 confirms the main messages of Figs. 1 and 2 of (a) a reliable detection of a LPPL regime confirming the existence of a bubble in oil price expressed in USD and (b) a robust and stable diagnostic that the bubble is close to a local peak (and actually may have already reached it). We cannot however exclude the possibility that the proximity to a critical time t_c is only a temporary process embedded in a larger-scale bubble, that could develop in the coming months and years.

Fig. 3 shows the three fits with the simple LPPL, second-order Weierstrass and second-order Landau model of the oil price expressed in euros. This confirms that the bubble is genuine, and not solely a consequence of the weakening of the USD. The

1 Credit Suisse, The Investment Committee Meeting of 27 May 2008.

2 See Siegel, J. and W. Henisz, What's Behind the Flare-ups in Oil Prices? Jeremy Siegel and Witold Henisz Weigh In, Knowledge@Wharton, May 28, 2008; also see Krugman, P., More on oil and speculation (The Conscience of a Liberal), The New York Times, May 13, 2008.

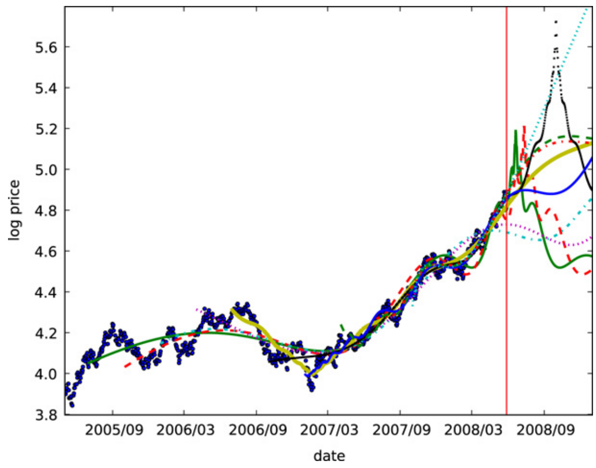

Fig. 1. Typical results of the calibration of the simple LPPL model to the oil price in USD. We model the data over varying time windows defined by two dates, (t_1, t_2). The starting date t_1 of consecutive time windows increases by 3 months. The last date t_2 is fixed for all time windows, 27 May 2008 (last available data for our original analysis). To be clear, t_2 is *not* a predicted crash time but is the date of the last observed point in the time series.

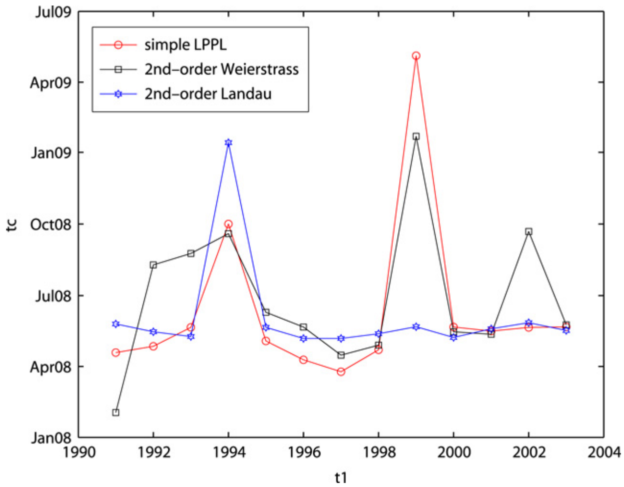

Fig. 2. Predicted critical time t_c obtained using the three LPPL models (simple LPPL, second-order Weierstrass and second-order Landau) as a function of the beginning time t_1 for the fixed $t_2 = 27$ May 2008.

values of the critical time t_c determined from these and other calibrations in different time windows and using other major currencies, are found similar to those reported in Fig. 2, confirming the existence of a bubble phenomenon. In addition, our analysis points to a distinct change of regime in the oil price dynamics in USD occurring between the last quarter of 2005 and the first quarter of 2006, beyond which a net acceleration can be observed, perhaps correlated with the deregulation of Intercontinental Exchange (ICE) oil futures in US markets by the US Commodity Futures Trading Commission.

2.3. Evidence that oil price was not primarily driven by supply-demand imbalance but rather by uncertainty fueling a speculative bubble

One last issue needs to be addressed: could the faster-than-exponential price rises demonstrated here result from a faster-than-exponential rise in demand which is not met by supply? If the answer is positive, our interpretation that we are seeing speculation unfolding would be incorrect.[3] Could it indeed be that the recent price surges are explained for instance by a faster-than-exponential rise in demand from economies such as China and India? The recent paper [19] by former President Jiang Ze-Min himself debunks this hypothesis, at least for China (see Fig. 3 with caption in English in Ref. [19]).

To investigate this issue further, we took the values on World liquid fuel supply and demand reported by the International Energy Agency in its May, 13, 2008 Oil Market report [4] and by the US Energy Information Administration

3 http://arxivblog.com/?p=462.

4 International Energy Agency, Oil Market Report, Issue 13 May 2008, see Table 1, p. 51, www.oilmarketreport.org and http://omrpublic.iea.org/.

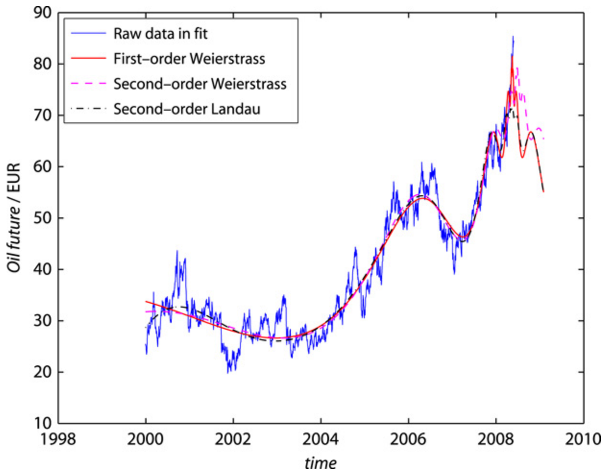

Fig. 3. Three fits with the simple LPPL, second-order Weierstrass and second-order Landau model of the oil price expressed in euros.

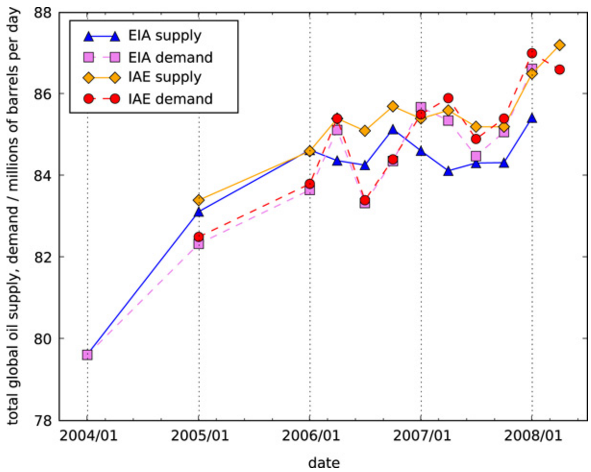

Fig. 4. Time series from 2004 to the first quarter of 2008 of the World total liquid fuel demand and total World supply, as estimated by two agencies, the International Energy Agency (IEA) and the US Energy Information Administration (EIA) (http://www.eia.doe.gov/emeu/international/oilother.html).

(EIA) (http://www.eia.doe.gov/emeu/international/oilother.html). Fig. 4 shows the World total liquid fuel demand and total World supply, as estimated by these two agencies (IEA and EIA).

While the two agencies report approximately consistent demand figures over this time period, there is a more worrisome discrepancy between the supply values, with the EIA reporting a supply value about one Mb/d smaller than the IEA, since 2006. The EIA data suggests that oil demand has exceeded supply over the last 5 quarters shown here, suggesting that fundamentals play a major role in the price run up. In contrast, the IEA data suggests a much weaker effect. We tried to understand the causes of these different values. For one, each of these estimated numbers aggregate global statistics coming from many sources and countries. Second, there is also a degree of extrapolation and guess work, which is handled differently in the two agencies. There are often revisions coming later (not unlike revision of GPD estimates in macro-economics) that close the gap between these differences. It seems to us that one message is that the discrepancy between the EIA and IEA provides, in fact, a measure of the estimation errors. In other words, these numbers are not to be believed at face value given the uncertainties.

Given these uncertainties, one feature seems to emerge with a reasonable degree of certainty: until the end of 2005, both agencies were in line and supply was systematically exceeding demand. Since 2006, this deterministic fact has broken down with the ushering into an epoch of uncertainty. In our opinion, one should not conclude that demand has exceeded supply or vice-versa since 2006, but rather that the oil market has entered an opaque regime. Rather than a clear transition to a supply restricted regime, we interpret the discrepancy between the IEA and EIA as a signature of uncertainty. Here, we should immediately stress that there is no better fuel than uncertainty to promote speculation!

In conclusion, the present study supports the hypothesis that the recent oil price run-up, when expressed in any of the major currencies, has been amplified by speculative behavior of the type found during a bubble-like expansion. The underlying positive feedbacks, nucleated by rumors of rising scarcity, may result from one or several of the following factors

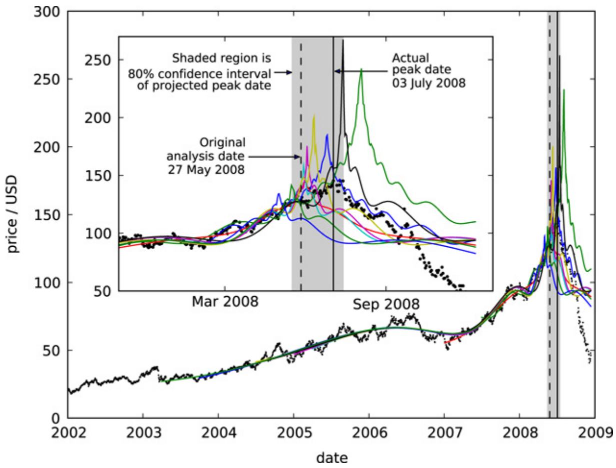

Fig. 5. Time series of observed prices in USD of "NYMEX Light Sweet Crude, Contract 1" from the Energy Information Administration of the US Government (see http://www.eia.doe.gov/emeu/international/Crude2.xls) and simple LPPL fits (see text for explanation). The oil price time series was scanned in multiple windows defined by (t_1, t_2), where t_1 ranged from 1 April 2003 to 2 January 2008 in steps of approximately 3 months (see text) and t_2 was fixed to 23 May 2008. Shaded box shows the 80% confidence interval of fit parameter t_c for fits with t_c less than six months beyond t_2. Also shown are dates of our original analysis in June 2008 and the actual observed peak oil price on 3 July 2008.

acting together: (1) protective hedging against future oil price increases and a weakening dollar whose anticipations amplify hedging in a positive self-reinforcing loop; (2) search for a new high-return investment, following the collapse of real-estate, the securitization disaster and poor yields of equities, whose expectations, endorsed by a growing pool of hedge, pension and sovereign funds, will transform it in a self-fulfilling prophecy; (3) the recent development since 2006 of deregulated oil future trading, allowing spot oil price to be actually more and more determined by speculative future markets[5] and thus more and more decoupled from genuine supply-demand equilibrium.

3. Post-crash analysis

3.1. Confidence interval for the oil price peak

The main result of our post-crash analysis is shown in Fig. 5. Using a new version of our analysis code as a check of our initial results, we scanned the oil price time series in multiple windows defined by (t_1, t_2), where t_1 ranged from 1 April 2003 to 2 January 2008 in steps of approximately 3 months[6] and t_2 was fixed to 23 May 2008, a date slightly before 27 May 2008 used in our initial analysis. Of the 21 time windows analyzed, we ignored those whose fit parameter t_c (the critical time) was greater than six months beyond t_2, since the predictive strength of the LPPL model falls off considerably at longer time scales. We used the 9 remaining fits to calculate the 80% confidence interval of t_c, which was found to be 17 May 2008 to 14 July 2008 and is shown as the shaded box in the main and inset plots of Fig. 5. The actual peak oil price was observed to be 3 July and the steep descent in price began on 11 July. Both dates are within the confidence interval calculated with the LPPL model using data through the last week of May. This confirms that the simple LPPL model was a successful predictor of the 2008 oil price bubble.

This post-crash analysis illustrates a general procedure that we have developed and will be implementing systematically in the future to diagnose non-sustainable bubble regimes in a variety of assets. It is based on the determination of confidence intervals for the critical time t_c obtained from an ensemble of windows and bootstraps, as illustrated briefly in the present application.

3.2. Possible alternative hypotheses

Our main conclusion is that a substantial part of the observed oil price climb is due to a bubble-like speculative dynamics.

As discussed in Sections 2.1 and 2.3, others have suggested the role of the growing supply-demand imbalance and the depreciation of the dollar. For the sake of completeness, we now briefly review another class of explanations, involving geopolitical forces. The hypothesis is that oil prices have appreciated on worries about possible supply disruptions arising from the kind of conflicts that have plagued the Niger Delta region in Nigeria, terrorist attacks by al-Qaeda in the Persian Gulf,

[5] United States Senate Permanent Subcommittee on Investigations, 109th Congress 2nd Session, The Role of Market speculation in Rising Oil and Gas Prices: A Need to Put the Cop Back on the Beat; Staff Report, prepared by the Permanent Subcommittee on Investigations of the Committee on Homeland Security and Governmental Affairs, United States Senate, Washington DC, June 27, 2006. p. 3.

[6] We set t_1 to be the first trading day of January, April, July and October in 2003–2008.

economic or other sanctions against key oil producers, or war. In particular, the rate of bellicose gesticulations between Iran and Israel escalated in May and June 2008, with a growing fear of disruption of oil supply. This was fueled by the statements of the commander of Iran's Islamic Revolutionary Guard Corps, Gen. Mohammed Ali Jafari that "Tehran would definitely act to impose control on the Persian Gulf and Strait of Hormuz", after which, he added, "the oil price will rise very considerably, and this is among the factors deterring the enemies". How much is due to the uncertainty about Iran has been a matter of considerable debate. Many point to the unprecedented $11 one-day spike in oil prices from $128 to $139 a barrel that took place June 6, 2008 after Israel's Deputy Prime Minister Shaul Mofaz warned that an Israeli attack on Tehran's nuclear facilities was "unavoidable" if international pressure did not succeed in persuading it to freeze its uranium enrichment program. While that incident offered the most spectacular suggestion of a relationship between threats against Iran and the price of oil, most analysts believe the effect is somewhat more modest, albeit still quite real. In a congressional testimony in June 2008, Daniel Yergin, a longtime analyst and historian of the oil industry, observed, "You see the Iranians make a bellicose statement, and you see the price of oil go up five or seven dollars".[7]

One should not underestimate the tensions between the USA and the rather unstable Venezuelian regime (Venezuela being a major oil producer), as well as the Russian stance on the missile shield in Poland and the Czech republic during 2007 (Russia being the second largest oil producer after Saudi Arabia), which provide additional geopolitical uncertainties that moved oil prices on a daily time scale.

Given the stochastic and multiple sources of uncertainties resulting from geopolitical events, we conclude that, while volatility has been significantly impacted, the above discussion does not support the causal impact of geopolitical uncertainty on producing the observed quadrupling of oil prices in less than four years, though it may have some minor direct contribution. Rather, our interpretation is that the geopolitical events have participated in raising the level uncertainty, which is often the fertilizer of speculation, leading to oil prices increasingly decoupled from fundamental valuation (the hallmark of a bubble).

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