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Ups and downs of economics and econophysics — Facebook forecast

Nenad Gajic *, Ljuba Budinski-Petkovic

Faculty of Engineering, Trg D. Obradovića 6, 21000 Novi Sad, Serbia

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ABSTRACT

What is econophysics and its relationship with economics? What is the state of economics after the global economic crisis, and is there a future for the paradigm of market equilibrium, with imaginary perfect competition and rational agents? Can the next paradigm of economics adopt important assumptions derived from econophysics models: that markets are chaotic systems, striving to extremes as bubbles and crashes show, with psychologically motivated, statistically predictable individual behaviors? Is the future of econophysics, as predicted here, to disappear and become a part of economics? A good test of the current state of econophysics and its methods is the valuation of Facebook immediately after the initial public offering — this forecast indicates that Facebook is highly overvalued, and its IPO valuation of 104 billion dollars is mostly the new financial bubble based on the expectations of unlimited growth, although it's easy to prove that Facebook is close to the upper limit of its users.

1. Introduction

Econophysics is a new paradigm [1], specialty, or even the youngest branch of modern science that economists are largely ignoring, but it is accepted by most physicists. It deals with solving problems in the economy, especially those related to financial markets and their behavior. The name was first used as a paper title in 1996 [2]. Econophysics is an interdisciplinary field of research, a branch of physics that attempts to describe the dynamics of financial markets [3] and other problems in the economy [4] and finds the universal laws for their description by applying ideas, concepts, techniques and methods of statistical physics. Illustrative examples of the breadth of topics range from the models of wealth distribution [5] and variations in the growth rate of companies [6] or the GDP of different countries [7], through the distribution of scientific discoveries [8], to modeling the winning strategies for web sites [9] or methods of their realistic valuations [10]. A review of methods can be found in the book by the author of the term "Econophysics" [11], and it is important to emphasize that econophysicists insist on developing models that are based on real data (*a posteriori*), in contrast to economists that usually interpret the data in accordance with prevailing theories (*a priori*), which led to the impossibility of identifying the major crises that are simply not consistent with the neoclassical theory of market equilibrium.

Each abstract model developed by neoclassical economists supports the equilibrium paradigm. Even the results of analysis are adjusted to these *a priori* models to identify the expected principles — for example, when Sharpe developed his known capital asset pricing model [12], he explained that this should be accepted although "there are highly and undoubtedly unrealistic assumptions... since the proper test of a theory is not the realism of its assumptions but the acceptability of its implications... these assumptions imply the equilibrium conditions which form a major part of classical financial doctrine". Models used in econophysics, by contrast, are primarily driven by data, not theories [13].

* Corresponding author. Tel.: +381 216350770; fax: +381 216350770.
E-mail address: nenad.gajicc@gmail.com (N. Gajic).

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Recent papers increasingly suggest that financial economics and econophysics are two disciplines that may be complementary [1], because the economy is a good example of a "complex system with a large ensemble of interacting units" [14], as studied by econophysicists in accordance with the development of so-called "complexity science" that emerged in the 1990s [15]. Physicists are trained to see connections between seemingly unrelated phenomena, to try to look at the big picture and present it with the simplest possible mathematical description which includes as many links as necessary, but no more than that [16].

However, communication between economists and econophysicists is difficult, as suggested by "Nature" back in 2006 [17]. Economists criticize (econo)physicists [18] especially on their contempt and ignorance towards historical achievements of economics, which is also true vice versa [19]. Ignorant relations contributed to the work of econophysicists being published mainly in mathematical and physical (rather than economic) journals, partly because of the complexity of the mathematics on which they are based. However, the current economic crisis reminds us of the old prophetic sentence by Friedrich Hayek, Nobel laureate: "An economist who is only an economist cannot be a good economist".

2. Theory and real-life application

The tools economists have today are not good enough to explain the current situation and enable the prediction and prevention of economic crises. The solution may be in sight, and the historical breakthrough in relations with econophysics started, quite unexpectedly, with the negative criticism [18] which made an example of one paper to show how: "'log-periodic' business had been exaggerated into doomsday speculations published in serious journals". The exemplified paper [20] explained historical anomalously large returns with the possibility that "a major still untriggered crash is looming over us". The same author soon published a book on stock market crashes [21] and a prediction that the US stock market would reach a lower turning point in early 2004 [22]. As this prophecy failed to come true two years after the publication, "the bubble of log-periodicity" [14] burst and put an end to numerous publications on the paradigm.

Developments continue, and the ScienceDaily article [23] from May 2010 claims that econophysics is good at predicting the economic crisis, because physicists have better tools than economists or financial experts. The same name is mentioned again in the story how already in 2005 Didier Sornette, a physicist, earthquake scientist, and financial expert at ETH Zurich (Swiss Federal Institute of Technology in Zurich, one of the most recognized technical and engineering universities in the world), predicted bubbles in the US real estate markets. His prediction turned out to be accurate, although it was criticized by many economists stating that such bubbles cannot exist or be predicted (such optimistic predictions about the future growth of the stock exchange happened also a few days before "Black Tuesday", as two main economic institutions failed to recognize the collapse in 1929 that marked the beginning of the "Great Depression"). The same physicist and his colleagues have since predicted the bursting of "many other bubbles", for example, in the oil market [24] and Asian financial markets.

The financial crisis was also commented on by Nobel laureates in economics, as Paul Krugman publicly asks: "How did economists get it so wrong?" [25]. Too few economists foresaw the coming crisis, and the profession itself was completely blind "to the very possibility of catastrophic failures in a market economy" due to a renewed romanticized belief that individual investors behave rationally in perfect markets that should be trusted (although the Nobel prize in economics for 2001 and 2002 was awarded for works that recognize the limitations of agents and markets, i.e. that conflict with the neoclassical idea of "market equilibrium"). Paul Krugman in his retrospective article repeatedly talks about "ketchup economists" to explain the state of mind in the economics profession immediately before the crisis – as "two-quart bottles of ketchup invariably sell for exactly twice as much as one-quart bottles of ketchup"; financial theorists conclude from this that the ketchup market is perfectly efficient, failing to observe the emergence of the biggest financial bubble in history – when the undiagnosed bubble burst, US households have seen $13 trillion in wealth evaporate and more than 6 million jobs have been lost!

Econophysicists repeatedly say that bubbles are created by unrealistic expectations for some growth to continue in the same (unsustainable) pace to infinity, and this psychological "pumping of valuation" by the expected (unrealistic) income at some point leads to a bursting of the overblown bubble — this happens while known economic signals are suggesting that all is well and never better (growth is faster than exponential), and that's why the consequences of such unexpected crashes are dramatic.

However, the emergence of bubbles, their growth and burst can be predicted, but only if we reject the idea of a market that seeks equilibrium. Is it possible to predict the behavior of chaotic systems? Models of such estimates have been used in econophysics, like the self-organized criticality models [26] and models that describe earthquakes [27]. These models were created to explain the phenomena that the "naked eye" can observe in nature. The most famous examples of self-organized criticality are visible on sand dunes in the desert, as seen in Fig. 1 — these regular forms unpredictably change under the onslaught of windy sand storms, and yet each period of rest after the storm is greeted with unexpected regularity. Models describing earthquakes can also be used to predict the stock market recovery after a crash, describing the chaos that is created and new small earthquakes that occur less frequently until the situation is completely stabilized.

Awareness of the relationship between the various research fields is gradually growing, and papers are more inclined to multi-disciplinarity to better clarify the achievements of different branches of the same field, such as the book "Classical Econophysics" written by economists, IT specialists and a physicist [28], or like a big pan-European research initiative FuturICT [29], which gathers scientists from physics, economics, social, engineering and computer science to jointly respond to major challenges of the future.

Fig. 1. Self-organized criticality in nature — sand dunes in the desert.

3. Facebook prediction — results and discussion

The model for realistic valuation of Internet sites and companies in the field of social networks [10] is explained in the article concluding that "Facebook is vastly overvalued" [30], which is a good example of a forecast that can be monitored in the future; it is based primarily on the upper limit of the potential number of users that neither media estimates nor IPO valuation of the company have taken into account, emphasizing that Facebook is worth more because of the large growth potential. Here we explain the most important conclusions of this work, accepted for publication 6 months before the company's IPO, and we refresh the forecast with the latest information — predicting future results before they occur is what makes a research program progressive, while stagnant programs mainly deal with the subsequent analysis of things that have already occurred. With this example we'll soon be able to assess the maturity of econophysics methods.

Announcements in popular business media said Facebook will go public (from a closed to an open public limited company, with new co-owners and significant capital resources for further development) in May 2012 or later [31,32]. Expectations for the initial public offering were high and rising. Rough estimates ranged from "more than $66.5bn" [33], to over "roughly $80 billion" [34], to "north of $100 billion" [35]. In March 2012 we saw more confirmations of the $100 billion value, after "the social network said in a new disclosure document that it added 25 underwriters to an original group of six for its IPO" [36] (underwriters purchase shares of the issuer at an agreed price, then sell them at higher to profit on the price difference). The conclusion announced "biggest-ever U.S. Web IPO". None of the given references specify how the valuation was reached or which methodology was used. The value of $104bn was the highest company valuation after the last auction on the secondary market, which was the last pre-IPO trading. Offers in the final minutes have raised the price over the previous record of $41 to over $44 per share [37]. As the next trade occurs when Facebook is a public company, it's important to note a very unusual move when the last day of trading on the secondary market was moved from Monday 2nd April to Friday 30th March [38] — the reasons for this unusual move are unclear, but afterwards the stock prices in the secondary market could not respond to unofficial reports for Q1 2012, although sellers on the secondary market are often the company's insiders with quick access to unpublished information. Indeed, soon the earnings report showed that Facebook's profit for Q1 2012 (205 million dollars) is 12% lower than the profit in the first quarter of 2011 [39].

Facebook's valuation is based on the rapid growth that all estimates certainly took into account, because profit is simply not high enough to justify the forecasts. According to official data provided in February 2012 [40], the net income (profit) for 2011 was $1bn (see Fig. 2). According to the IPO valuation of $104 billion, Facebook has a P-E ratio (price–earnings) of 104 — this means that if annual profit remains the same and fully paid to shareholders who never sell their shares, the investment in Facebook would turn a profit after more than a century. In comparison, at the time of writing Google had a P-E of about 22, Apple about 18, and Microsoft (with yearly net income of over $23 billion) had a P-E of 12 — with a price–earnings ratio of 104, it would be worth almost 2400 billion USD!

Profit margin is obtained by dividing net incomes (profits) with total revenues (presented in Fig. 3). Analyzed prediction sets the average profit margin of Facebook to 29% for the three year period 2009–2011. True, although calculated according to rumors that have circulated in financial media in time without official reports. The final result is the same, but estimated profit margins for each chronological year (26%–30%–31%) are individually different from the officially reported (29%–31%–27%) — the profit margin of Facebook in 2011 was 27% and is actually lower than in previous years.

While many think that Facebook has a high potential for further growth, and this was used to justify high estimates of its value, it's easy to provide quantitative evidence that this is not so. Evidence of maturity begins with the analysis of Facebook users, which we show in detail here. Part of this information was published by Facebook, until 500 million users, and the recent SEC report of the company shows changes in the number of users in the past three years as shown in Fig. 4.

This is very important information. The manner of the official report indicates an attempt to present numbers as an exponential growth. The growth of the graphics made up according to official data can be extrapolated as a straight line, constant and proportional growth suggesting it to be unlimited. Unlimited growth of users means unlimited growth in revenues and profits. This assumption is unrealistic, indicated by extending the line into the future, so that the number of FB users, with this kind of growth, in the not too distant future exceeds the total population of the planet!

The growth of Facebook can't be unlimited, because it's limited by the total human population (7 billion [41]) and the number of Internet users (2.3 billion [42]). The official data is, presumably, just presented in a way that will appeal to most investors; this is facilitated by the lack of updating the official info after 500 million customers, and now the official

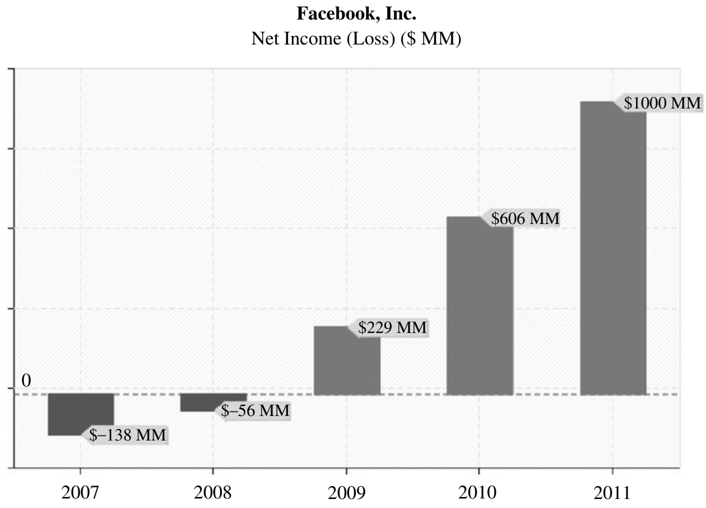

Fig. 2. Officially reported net incomes of Facebook.

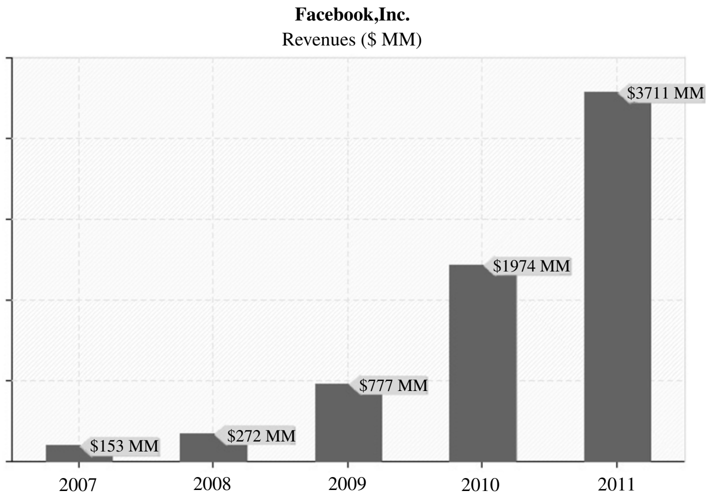

Fig. 3. Officially reported revenues of Facebook.

Facebook's timeline [43] only shows the user numbers in December each year, which is consistent with the officially reported numbers of users. However, long before the SEC report the total number of users wasn't updated, and Fig. 5 may show why.

Fig. 5 is taken from a site which is in no way affiliated with this research [44], and the graph was refreshed since 2010 with "leaked" information about Facebook breaking certain barriers in millions of users (this information is now confirmed by officially reported numbers, although precise moments in time do not match). Eight years after launch, Facebook has largely passed from the exponential (unlimited) growth phase to a logistic function growth phase, when growth slows and the number of users is stabilizing, gradually reaching a maximum possible limit after which the only possible growth is systemic (e.g., general population growth or internet users' growth). No wonder that this moment is chosen for the capitalization of the company, nor that the information coming from the company was presented in a way that maximizes its perceived value for investors, but this looks like the pumping of a new financial bubble.

Models in biology to describe the growth in competition include the so-called "S-curve". An example of what they describe is simple and very clear: the rabbit population in a fenced grass field first multiplies exponentially, but later multiplying is slowed down because the available food is limited. The population eventually stabilizes at the level where the S-curve reaches a "ceiling". Such an S-curve is generally predictable because each niche (ecological, market, etc) eventually becomes filled, so this model is used to predict various things, from the sale of newly launched products, diffusion of technology or ideas, to the life-long achievement of an artist's creativity [45]. Facebook shows the change of regime in 2010 (disjointed point with 450 million users in Figs. 5 and 6), indicating a shift from a purely exponential growth behavior (the paradigm for unlimited growth) to a logistic function with asymptotic plateau (the paradigm for growth in competition), and all forecasts of further growth that do not consider this are too optimistic.

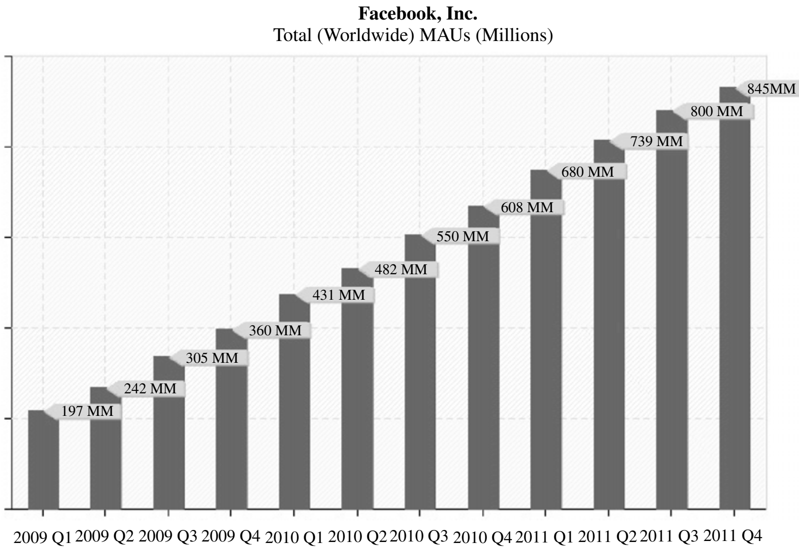

Fig. 4. Officially reported numbers of monthly active users of Facebook.

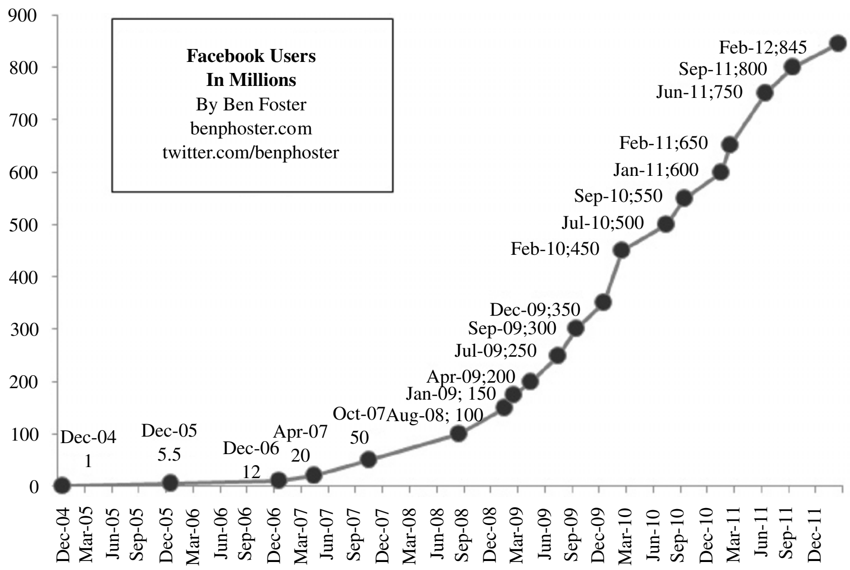

Fig. 5. Facebook users by first report of achievement (officially or externally).

Fitting the data by the logistic function and extending the "unfinished" (Fig. 6) S-curve into the future, one can visualize the forecast of a slowdown in the growth of users over the next few years, which is a slightly more optimistic forecast than the one introducing the methodology [10] — our forecast corresponds approximately to the middle "high growth" scenario due to newly published data from Facebook. Based on the functions for fitting the data, here are the numbers we predict that the official Facebook timeline will be refreshed with during the next four Decembers: 960 million users in 2012 — to 1034 million users in 2013 — to 1074 million users in 2014 — to 1096 million users in 2015. In comparison, if the number of users grows linearly, Facebook will have approximately 1750 million users in December 2015.

Sornette and Cauwels, who at the time of writing had fewer data (Facebook had not yet issued official statements), introduced three S-curves (for base, high and extreme growth) through complex calculations. Their paper proposes a new methodology that enables realistic valuation of companies like Facebook, based on the unique properties of social networks that their "value products" are their users (and their personal data), and that therefore revenues and profits of such companies, and hence their value, are directly related to the customer base. We must emphasize that at the valuation of $ 104bn every Facebook user increases the value of the company by about 115 USD! The maximum possible number of Facebook users was set between 840 and 1820 million users, the lowest value being most likely. The realistic value toward which Facebook will weigh on the stock exchange was set (using a discount factor of 5%, a profit margin of 29% and annual

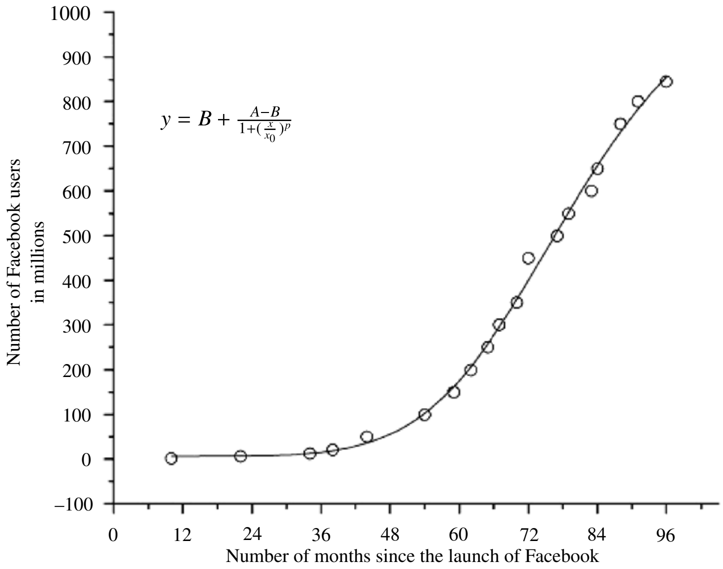

Fig. 6. Number of Facebook users fitted to unfinished S-curve ($A = 6.00$, $B = 1128.3$, $X_0 = 79.685$, $p = 6.07094$).

revenue per user of $3.5) to $15.3 billion in the base case, $20.2 billion in case of high growth and only $32.9 billion in the scenario of extreme growth (with approximately 5% probability). Everything above that is a financial bubble.

Much of what econophysicists do has yet to be confirmed in practice, but it's very likely that the complex relationship between economics and physics will continue in the future, with ups and downs (and unexpected affairs with biology). Until the time when econophysics, according to theories of the development of scientific methods described by all the major philosophers of science (Popper [46], Kuhn [47], Lakatos [48], etc), finally takes its place, which is unlikely to be in physics (because it deals with economic problems) or independency, but most likely in the integration of econophysics and its main principles in economics. Increased interdisciplinarity and mutual cooperation of physics and economics was predicted even before the global economic crisis [49], and in the aftermath it's almost certain.

4. Conclusion

There is the dilemma whether anyone can truly model an economic/financial system/phenomena meaningfully, but the strength of econophysics is in its interdisciplinarity. It offers different perspectives and approaches to studying and modeling economic systems, improving and enhancing the mainstream economic analysis. Post hoc data analyzing/interpreting and ad hoc predicting of economic phenomena are the two approaches that are complementary to each other, with the later more potently influencing the state and acceptance of econophysics and its methods, bringing them closer to becoming essential parts of economics (adopted paradigm or research program). The prediction that we presented, analyzed and supplemented by the latest info says that Facebook may not be worth $104 billion, but in the best (and least likely) case only a third of that value, while the rest is the "speculative bubble". This prediction can easily be monitored in the future as we can already track another prediction from the same article, which pointed out how overpriced Groupon was. The valuation of the company was done to test the methodology, prior to Groupon IPO in November 2011 — after the initial jump from $20 to $31, the price of shares gradually fell to below $10 at the time of revisions in this paper (4 May 2012). The tendency of the decrease in the price of Groupon corresponds to the methodology that indicates that the IPO value of the company was approximately doubled.

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The authors declare no competing financial interests nor any other conflict of interest.

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