Artificial Intelligence Sector: The Next Technology Bubble? A Comparative Analysis with Dotcom Based on Stock Market Data

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Abstract
The main purpose of this research is to present a detailed comparison between the 1996-2001 Dotcom and 2014-2018 AI landscapes, by comparing the evolution of Dotcom and AI through a regression model aimed at testing the relationship between these two phenomena, which have similar characteristics, but also distinct features. In a period when the academic and the business environment discourse is focused on the potential effects of diminishing funding and interest in AI and even a bubble burst, our investigation demonstrates the contrary. Having in mind the strengths of the AI market and its interrelations with significant sectors of the world economy, our paper denies the hypothesis of a potential AI crisis, in spite of some hints that AI companies are in the early stages of high risk. Our paper brings also another novelty element related to a different type of Schumpeterian creative destruction identified in the case of AI. The big players present on the market are able to purchase the firms that Schumpeter suggested would replace the existing firms, therefore the creative destruction occurs in the case of start-ups, which are undertaken by stronger companies present on the market, even survivors of the Dotcom crisis, not vice versa.

Keywords: asset, crisis, data, investment, risk, technology.

JEL Classification: E32, E37, E44

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Introduction

Starting from the experience of the Dotcom crisis and from the assumption that excessive investment in technology is not always profitable, the article tests the hypothesis of a possible financial and economic crash generated by investments in artificial intelligence (AI) companies. In order to achieve this goal, we have proposed a parallel between the evolution of Dotcom and AI through a regression model to test the relationship between these two phenomena, which have similar characteristics, but also many distinct features. With several exceptions, detailed comparisons between the 1996-2001 Dotcom and 2014-2018 AI landscapes have not been identified in the literature. In a period when scholars discuss about a potential reduced funding and interest in AI ("AI winter") and even a bubble burst, our investigation demonstrates the contrary. Our argumentation takes into account not only the distinctive attributes of the AI market but also the relevance of actors "betting" on this sector.

Literature review

Some authors (Crain, 2014) underscored that the Dotcom (or Internet) bubble was driven by risk capital, a form of short-term investment spurred by deployment of funds in search of above-average returns. Risk capital took the form of a two-step mode of investment involving private venture capital (VC) firms (most of them based in Silicon Valley) and the public stock markets of New York through initial public offerings (IPOs). The strategy of "Get Big Fast" had as main goal the e-commerce market dominance by a group of several winners, in order to minimize competition and maximize profits.

Another author (Jarvers, 2018) points to the differences between the AI and Dotcom mechanisms and concludes that as regards the AI, one cannot notice a "Dotcom-like investment or asset bubble": "With almost no IPOs of AI start-ups and no distinct trend in overall VC or stock market indices, there is little evidence for a spread from a VC investment to an asset bubble. Furthermore, the sharp increase in AI-related venture capital is economically backed by projected revenue growth and more patents... As soon as venture-backed start-ups turn out unprofitable, expectations will most likely flatten, and a market cleansing effect appears. Due to the strong stance of big companies and governments' interest in the field, it seems implausible that this downturn results in a sudden stop or AI winter".

Other academics (Pan, 2016) underline that, in spite of the AI ups and downs since 1956, when the concept was coined at Dartmouth College in the US, it is worth noting the recent integration of AI with industrial demands, the increasing

number of mergers and acquisitions in the sector led by large-scale companies alongside significant influx of capital and its tremendous technological progress. Besides, there are many government initiatives with the goal of accelerating the investment in the AI sector (Shoham et al., 2018, pp. 57-58) not only for the sake of the market, but also having in mind the geopolitical aspects related to AI leadership. According to the Ministry of Science and Technology of the People's Republic of China (MOST) New Generation AI Development Research Centre and the Chinese Academy of Science and Technology for Development (CASTED) - MOST-CASTED (2019), The United States and China are the strongest countries in the field of AI, followed by the United Kingdom, Israel, Japan and South Korea. Villasenor (2018) emphasizes that "geopolitics is determined in large part by many of the same domains that AI is poised to revolutionize… AI will make manufacturing, transportation, and trade more efficient, improve crop yields, open a wealth of new opportunities for technology advances, reshuffle labor markets, and force a fundamental rethinking of approaches to national security and the architecture of modern militaries. In the coming decades, countries that are able to successfully cultivate and harness a culture of AI innovation will be well-positioned for both economic growth and improved national security". Moreover, other authors (Chui et al., 2019) advance even the idea of transforming AI in a "valuable tool in the worldwide efforts to achieve the United Nations' Sustainable Development Goals". Allen (2017) analyzes eight technologies with "a significant impact on the overall technology landscape during its peak" (Desktop Operating Systems, Web Browsers, Networking, Social Networks, Mobile Apps, Internet of Things, Cloud Computing, and Artificial Intelligence) out of which only AI benefits of two determinants for "how far and how fast a technology advances over time". These factors are: a low "barrier to entry for a single developer to create something useful" and the decentralized "development on the core platform" (Figure 1).

In the case of AI, anyone can contribute to the development of the sector (it is highly decentralized) and there are low barriers to entry. In our opinion, the AI plays the role of "activity optimizer" at the level of companies, as suggested by Shoham et al. (2018, p. 38): "Organizations tend to incorporate AI capabilities in functions that provide the most value within their industry. For example, financial services have heavily incorporated AI in Risk, while Automotive has done so in Manufacturing, and Retail has done so in Marketing / sales".

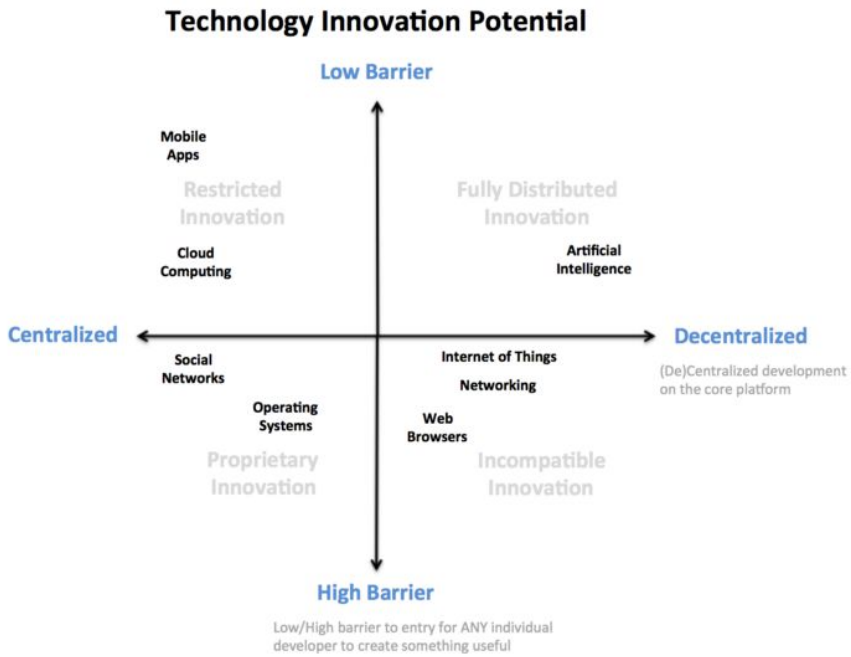

Figure 1. Technology innovation potential according to two main determinants
Source: Allen (2017)

Having in mind the size of the players involved in AI and what is at stake in developing this sector and also the results of our quantitative research, we exclude a potential "AI winter". As long as countries such as the US and China, but also other states (Israel, Japan, South Korea, Germany, France and United Kingdom) have government strategies in the field of AI and this is a tool of geopolitics, no bubble burst can occur.

There are many variables associated with different technology markets, such as: specific market conditions, technological progress as an enabler of entrepreneurship and new business models, behavior of various competitors, specific rules and norms and also financing channels. During the last two decades, start-ups (companies in the first stage of their activities) have played a remarkable role in the technology sector. At the end of 1990s there was recorded a proliferation of the Dotcoms, i.e. companies with activities based on the Internet. Intense speculations led to overvalued assets, with no real support in terms of profitability and consequently the dotcom bubble burst.

In our opinion, the actual situation of the start-ups in the AI sector is different than that of dotcoms.

• First, the AI technology is a mature one "due to the confluence of seven factors: new algorithms; the availability of training data; specialized hardware; cloud AI services; open-source software resources; greater investment; and increased interest" (MMC Ventures and Barclays, 2019). AI corresponds to a high market demand, as it is a new factor of production able to improve companies' profitability (Purdy & Daugherty, 2017). AI has several key advantages, including: "innovation (new products and services); efficacy (perform tasks more effectively); velocity (complete tasks more quickly); and scalability (free activity from the constraints of human capacity)", all these benefits having deep implications for consumers, companies and societies MMC Ventures and Barclays, 2019). AI applicability does not resume to one main field such as the Internet, but it influences various services and manufacturing industries and can be also seen as a "problem solver" in different fields (banking, healthcare industry, environmental issues, logistics, automotive, education and many others).

• Second, one can remark a different type of Schumpeterian creative destruction in the case of AI, in the sense that strong actors may "swallow" weaker ones, the latter representing significant assets which increase the competitiveness capabilities of the former. After the Dotcom crash of 2000s, the technological progress and eased market access, accompanied by much more diverse private funding sources for unlisted firms generated incomparably more favorable conditions for start-ups (Kenney & Zysman, 2019). Since 2013, one can remark also the presence of "unicorns", start-ups with a market capitalization of over $1 billion. Kenney & Zysman (2019) conclude that "if the flow of private capital slows or is no longer available and the public capital markets are closed, then the start-ups that do have significant potential will be forced to either sell themselves to the platform giants or fail outright". Therefore the other companies present on the market are able to purchase the firms that Schumpeter suggested would replace the existing firms, therefore the creative destruction occurs in the case of start-ups, which are undertaken by stronger companies present on the market (in most cases large ones, such as Alphabet – Google's parent –, Amazon, Apple, Baidu, Facebook, IBM and Microsoft, including also several survivors of the Dotcom crisis) not vice versa.

• Third, Ventura (2002) analyses the connection between asset price bubbles, international capital flows and economic growth. He underscores that: (1) "bubbles tend to appear and expand in countries where productivity is low relative to the rest of the world"; (2) bubbles absorb local savings, eliminate inefficient investments and generate resources that are partially used to invest in high productivity countries; (3) as world allocation of investment is improved and

rate-of-return differentials across countries diminish, "bubbles allow the world economy to operate at a higher level of efficiency". Martin & Ventura (2011) emphasize that "business cycles are driven by two types of shocks: fundamental shocks that affect technology and preferences; and investor sentiment shocks that lead to the appearance and collapse of bubbles in financial markets". Martin & Ventura (2018) refer to rational bubbles, namely the situation in which the agents know that the assets are being overvalued but they support these bubbles taking into account the "wealth effect of bubble creation": "newly created bubbles reallocate resources because they are sold by productive to unproductive agents, either directly or indirectly through the credit market". AI is attracting investment, entrepreneurship and interest (MMC Ventures and Barclays, 2019). Even if a bubble is underway, the reallocation of resources in the presence of critical mass already created will continue to spur a virtuous circle.

While the development and sustainability of AI are proved to be perceived in a positive way by young highly educated people (Gherheş & Obrad, 2018), its transformative power is viewed and studied by Ilie et al. (2019) as a modern tool for forecasting different economic indicators, in strong relationship with sustainable development. After conducting an analysis on 19 European countries, the authors developed a method of using AI in order to forecast possible developments at both micro and macroeconomic level, consequently indicating possible ways of diminishing their negative effects on the national or European economy and on specific companies. In the public sector, AI is mainly applied in environmental issues (including agriculture), security and safety issues, as presented in a comprehensive study (Gomes de Sousa et al., 2019) highlighting the research framework for AI solutions.

The Organisation for Economic Co-operation and Development – OECD (2018) indicates an accelerated growing global interest in AI technologies starting with 2016, especially in start-ups, that have attracted approximately "12% of all worldwide private equity investments in the first half of 2018", with most of the start-ups located mainly in the United States and China, the European Union covering only 8% of global AI equity investments, as reported for 2017. Starting with 2010, China and USA are leading in terms of AI, considering the number of patents and scientific publications, but other emerging economies should also be taken into account, such as India and Brazil (Perez et al., 2018). An in-depth study conducted by Ernst & Young (2018) shows that in terms of AI, private equity and venture capital firms are the most active investors, as compared to corporates, covering three quarters of the deal volume for the past decade, this being "an indication that AI companies are in the early stages of high risk/high growth

dynamics". The worldwide AI market was estimated at approximately 260 billion USD in 2016, the forecasts indicating an exponential growth, to more than 3 trillion by 2024 (Perez et al., 2018).

By applying a method developed by Leybourne, Kim and Taylor in 2007 (LKT method, cited by Leone & Ribeiro de Medeiros, 2015) on monthly data of the NASDAQ divided-price ratio and NASDAQ composite price index since 1973 until the end of 2014, Leone & Ribeiro de Medeiros (2015) have empirically demonstrated a negative bubble in the NASDAQ starting from February 1973 until June 1992 for the dividend-price ratio series, followed by a positive bubble starting from December 1998 until July 2001. As a result, this method is argued to be useful for identifying warning signals of the beginning of a bubble, with implications in several markets. Other authors (Ravisankar et al., 2010) empirically predicted the failure of Dotcom companies by using another method – neural network-genetic programming hybrids –. Shifting towards the existence of an AI bubble, taking into account the decline in productivity registered in the US in the past 10 years, while innovation and technological progress have recorded a tremendous growth, there are authors (Perez et al., 2018) arguing that this might be due to the fact that policy frameworks and security standards cannot ensure an efficient application of AI in significant sectors of activity.

Methodology

The Reuters database was used to select a total of 228 companies that were active in Dotcom in the period from January 1st, 1996 to December 31, 2001. The selection criteria were: companies listing on US NASDAQ and NYSE markets and the availability of prices obtained for the entire period analyzed.

Similarly, there were selected 426 AI companies, listed on the American NASDAQ and NYSE markets from January 1st, 2014 to December 31, 2018. The criterion of price availability obtained throughout the analyzed period was also applied.

For the Dotcom data series, from January 1st 1996 to 31 December 2001, an index was calculated based on the closing prices of the shares of the selected companies, each share having a weight equal to the share of its stock market capitalization in the total stock market capitalization for all 228 companies.

For the AI dataset, from January 1st 2014 to 31 December 2018, similarly, using the closing prices of the shares of the selected companies, an index was calculated in which each share has a weight equal to the share of its stock market capitalization in the total stock market capitalization of the all 426 companies.

Between the two data periods analyzed, the period from January 1, 2002 to December 31, 2013 is not relevant for the research subject: between 2002 and 2013 it wasn't noticed important crowding of investments in a specific sector; after the DotCom Bubble, the real estate investments have influenced the world economy, which later generated the economic crisis, followed later by recovery until 2012/2013.

Results

The evolution of the two time series is highlighted in the chart below (Figure 2):

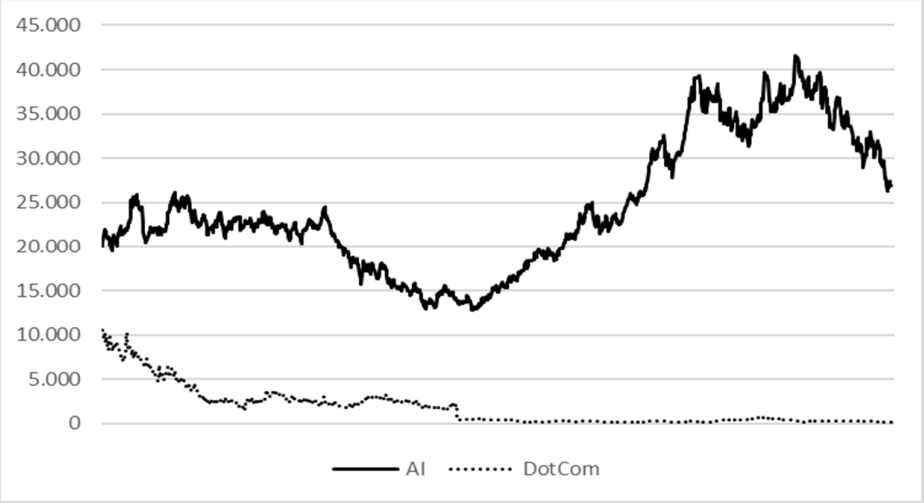

Figure 2. The evolution of the AI index (2014-2018) and the DotCom index (1996-2001), index value

Source: authors, Eviews output

Using the Eviews 9 software, the link between the two time series was analyzed to obtain a Pearson correlation coefficient of 0.58, indicating the possibility of a linear relationship between the two time series. The coefficient of 0.58 is moderate, according the literature (Asuero et al., 2006).The stationarity of the two time series has also been tested, finding that they are non-stationary. Next, the time series were stationarized and they were tested on whether they are co-integrated, pre-conditions for the regression. An order of 1 co-integration (with lag 1) was obtained.

Consequently, an ARDL model of the type was used:

$$AI = a0 + a1*AIt-2 + a2*AIt-1 + a3*DOTCOM + a4*DOTCOMt-1 \quad (1)$$

where:

- AI is the index-based index series built on the prices of companies operating in the field of artificial intelligence;
- AI t-1 and AI t-2 are derived from AI by one or two lags;
- DOTCOM is the index-based index series built on DOTCOM's prices;
- DOTCOM t-1 is the previous series of DOTCOM.

The two series contained data on the share prices of dotcom companies in the period 1996-2000 for the first index and share price data for the period 2014-2018 for the second index. Results were obtained confirming the regression model, as can be seen in the following table (Table 1).

Table 1. Regression model output

Dependent Variable: AI				
Method: ARDL				
Date: 07/12/19 Time: 11:21				
Sample (adjusted): 3 1258				
Included observations: 1256 after adjustments				
Maximum dependent lags: 4 (Automatic selection)				
Model selection method: Akaike info criterion (AIC)				
Dynamic regressors (4 lags, automatic): DOTCOM				
Fixed regressors: C				
Number of models evaluated: 20				
Selected Model: ARDL(2, 1)				
Note: final equation sample is larger than selection sample				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
AI(-1)	0.957984	0.028231	33.93359	0.0000
AI(-2)	0.039454	0.028230	1.397589	0.1625
DOTCOM	0.115270	0.086344	1.335001	0.1821
DOTCOM(-1)	-0.117165	0.085789	-1.365739	0.1723
C	72.51728	56.89288	1.274628	0.2027
R-squared	0.995266	Mean dependent var		24512.59
Adjusted R-squared	0.995251	S.D. dependent var		7493.998
S.E. of regression	516.4305	Akaike info criterion		15.33573
Sum squared resid	3.34E+08	Schwarz criterion		15.35618
Log likelihood	-9625.839	Hannan-Quinn criterion		15.34342
F-statistic	65754.63	Durbin-Watson stat		2.002348
Prob (F-statistic)	0.000000			

Source: Eviews output

The regression model is valid: f statistical probability is 0, the Durbin-Watson statistic close to 2, and R-squared and Adjusted R-squared have a value greater than 95%.

We assume that the lag_1 variable is dominating the model, because the DotCom Index and AI Index were built on stock market prices, which depends in a considerable extend by themselves. Also, as the model comprise lag_1 variable, we consider that is not necessary to perform the analysis on stationary data.

As the regression model is valid, the evolution of the AI has been predicted, as can be seen in the graph below (Figure 3, showing both the real values of the AI index for the period 2014-2018 and the estimate values after 02.01.2019, outlined by the dotted right):

Figure 3. AI index evolution and forecast
Source: authors, Eviews output

The forecast for a period of about two years indicates a slightly increasing evolution of the AI index, but almost linear and with a very moderate slope. Stock market prices drivers, both in DotCom (1999-2000) and in AI (2013-2018) are dominated by the phenomenon of agglomeration of investments in "fashion" sectors, which characterize the markets in a quasi-similar way – eg. the appearance of redundancies, profits lower than the expectations of investors. However, Stock prices are greatly influenced by a large number of factors that are not specific to the company/sector, as are the economic general conditions.

Conclusions

The Dotcom crisis has been caused by very high investments that have proven to be irrational, with the profitability of companies in the industry being below the expectations of investors. The investment situation in AI seems to be somewhat similar to Dotcom, but it differs by at least two specific characteristics:

- The variety of domains (compared to the previous limitation - to tech equipment and websites), which determines that financial results, cannot be quantified and evaluated in such a short timeframe;
- Lower returns than other sectors, which can be regarded as unsatisfactory by investors, which can identify more profitable areas. It is worth underlining that the AI is only adopted when the expected revenues exceed the adoption costs (Frontier Economics, 2018).

These differences do not seem to suggest a possible crash generated by investments in AI, similar to that recorded in the Dotcom period. Our built and tested model supports this fact, so the hypothesis of a new similar crisis is denied.
As underlined by relevant literature (Pan, 2016; Shoham et al., 2018; MOST CASTED, 2019; Villasenor, 2018; Allen, 2017; MMC Ventures and Barclays, 2019; Purdy & Daugherty, 2017), there are many attributes pointing to the strengths of the AI sector:

(1) intrinsic characteristics of the AI sector, as, on the one hand, it is highly decentralized and there are low entry barriers, and on the other hand, it spurs innovation, efficacy, velocity and scalability;

(2) its utility as a new factor of production able to improve companies' profitability;

(3) integration of AI with demands in services and manufacturing industries;

(4) the increasing number of mergers and acquisitions in the sector led by large-scale companies alongside significant influx of capital and tremendous technological progress;

(5) the wealth effect of potential bubbles from the perspective of relocating resources;

(6) governmental initiatives supporting a strong AI sector having in mind the correlations with economic growth, sustainable development and increased national security, but also the geopolitical perspective.

From the standpoint of start-ups, which play a major role in the AI sector, we have identified a different type of Schumpeterian creative destruction than in the case of the Internet companies. The large companies present on the market have the capacity to purchase the firms that Schumpeter suggested would replace the

existing firms, therefore the creative destruction occurs in the case of start-ups, which are undertaken by stronger companies present on the market not vice versa. Even if a bubble is underway, the reallocation of resources in the presence of critical mass already created will continue to spur a virtuous circle.

The analysis has a series of limits, the most important limit of the model being that it is built only based on companies listed on stock exchanges. There are many other companies, as venture capital ones, which are not listed on the stock exchange, that would give more significance to the model. AI index forecast the model is based on the Dotcom index price movements, and the authors only consider bubble dynamic as the main similarity. Finally, the model only takes into consideration the dynamics of a single sample of companies from a different time period, but still offers valuable results for future research. Starting from the above mentioned limits, it would be interesting to analyze the evolution of unlisted companies, but access to these data is very difficult because they are not public. Such a study would be even more valuable, as most companies in this field are not listed on the stock market until they are successful. That is why, in this scenario, a better profitability calculation could be made than for listed companies, and the results could provide additional important conclusions. Also, as future research, a panel data analysis on AI and DotCom could be made, in order to compare identical models used on data from early 2000 and recent data. The small number of specialized studies on this topic reflects the opacity of data, which represents a significant barrier to any detailed investigation. Nevertheless our argumentation fully supports the idea that an "AI winter" is excluded. AI technology is already a mature one and there are many enablers of this sector development. The actual process of digitalization is one of them. The utility of the AI for sectors such as banking, healthcare industry, environmental issues, logistics, automotive, education and many others as well as the complex and far-reaching governmental initiatives interrelated to the AI emphasize the continuing potential of this field. Even diminishing returns on the medium and long term will not prevent strong and healthy investments in the AI.

We consider our research being useful both, scientifically and practically – the results show a pattern that could be followed and tested further. In this regard, for the continuity of research, the authors intend to identify other sectors which attract investments and may be at risk of crowding. Practically, this agglomeration could promote sectorial crises, even affecting the entire economy, fact which could thus be prevented.

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