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Is the force awakening?

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ABSTRACT

Scientific and technological progress over the centuries was very strong in some fields, much weaker in others and even virtually absent in a few so far. For the future, there are a series of areas where new breakthroughs can be expected to occur. However, there is some evidence that such breakthroughs seem to be increasingly difficult to achieve. The paper reviews these discussions, maps scientific and technological progress over the centuries and presents new ideas on how to foster and accelerate scientific and technological advancement.

Since Johannes Kepler with “Somnium” (Kepler, 1634) wrote the world's first science fiction novel (encompassing a travel to the moon), science fiction has remained a source of inspiration for scientists and the public, as convincingly demonstrated for example with the Star Wars movie “The Force Awakens” which broke box-office records all over the world (http://www.boxofficemojo.com/alltime/). Experiencing the impressive visualization of advanced technologies leaves us wondering whether mankind will ever be able to achieve such technological progress. Beyond science fiction, there are predictions made in the frame of serious future foresight activities. Throughout the entire 20th century, the year 2000 often served as a time on which such predictions for advancement were projected, as for example nicely summarized by Davis (2012). Retrospectively, these predictions now seem over-optimistic and have largely not been fulfilled, progress unfortunately having been much slower than initially anticipated (Humphrey, 1967; Kahn and Wiener, 1967). Predictions for example included: Elimination of bacterial and viral diseases, large-scale ocean farming, weather control, establishment of space colonies (e.g. the ring-shaped “Taurus” was envisioned as a colony that could house 10,000 people for the purpose of mining ore from the moon) etc. If you would transfer someone from 1967 to 2017 and tell him this is the future, most likely he would be very disappointed. Looking out of the window, the world today looks quite similar to how it looked in the 60s. At first sight, it seems that not much has changed except the design of cars and the smartphones in our hands. How can it be that technological progress overall was much slower than predicted? In fact, efforts to look back on what has been achieved so far and what can be expected from the future have triggered an intense debate on whether technological progress is overall accelerating as usually claimed or whether it might even have decelerated in recent decades.

Key examples of proponents for the optimistic position are Vinge (1993), Kurzweil (2006) and Erik Brynjolfsson/Andrew McAfee (Brynjolfsson and McAfee, 2011, 2014), mostly based on already achieved and projected future breakthroughs in IT and communication technologies - enabling cognitive computing, big data analysis and artificial intelligence which are supposed to catalyze progress in diverse areas (Chen and Butte, 2015). In fact, the rise of computers has become publicly apparent with key events such as the victory of Deep Blue over the chess world champion Gary Kasparov (Weber, 1997) under official tournament conditions in 1997 or the winning of the quiz jeopardy! by the IBM Watson system in 2011 (Markoff, 2011). Machine learning algorithms have already reached an impressive level of sophistication and Google's Deep Q-Network (DQN) has been able to master a diverse range of Atari 2600 games superior to a professional human game tester (Mnih et al., 2015). The fact that Google Deep Mind was able to beat Lee Sedol, one of the world's top players in 2016, was another key milestone, as this game due to its high number of variations is exponentially more complex than chess and requires a certain degree of intuition (Gibney, 2016). The list of achievements was just recently topped by Deep Stack, an algorithm for imperfect-information settings, which was able to defeat with statistical significance professional poker players (Moravcik et al., 2017). Even the occurrence of an event called technological singularity is projected, the generation of artificial intelligence capable of recursive self-improvement whereby smart machines would design successive generations of increasingly powerful machines, creating intelligence far exceeding human intellectual capability (Kurzweil, 2006; Vinge, 1993), basically the last invention humanity would ever have to make. Kurzweil has more generally summarized this as the law of accelerating returns and predicted that paradigm shifts have and will continue to become increasingly common, leading to “technological change so rapid and profound it represents a rupture in the fabric of human history” (Kurzweil, 2011).

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He even arrived at the prediction that already the generation of humans living today will live forever (Goldman, 2013). Amazingly, just recently a series of discoveries have brought a breakthrough in anti-aging research (Castellano et al., 2017).

On the other end of the spectrum, however, several proponents have argued that technological progress in the past decades has decelerated. This is, for example, claimed by Michael Mandel (Mandell, 2000), Peter Thiel with Gary Kasparow (Thiel and Kasparow, 2011), David Graeber (Thiel and Graeber, 2014), Cowen, 2011a, b, 2016, Gordon, 2012, 2016, Hanlon, 2014, Fredrick Erixon with Bjorn Weigel (Erixon and Weigel, 2016a, b) and summarized by Rotman (2016), Graeber (2012), Karlgaard (2012), Pfeiffer (2016), several articles in The Economist (Economist, 2013a, 2013b; The Economist, 2015), Buchanan, 2015 and Fry, 2016 but heavily contradicted by others such as Gates (2014) or Mokyr (2014) just to mention a few.

And the argument for a slowdown at first sight really seems ridiculous, as conventional wisdom is that the world is moving faster and faster and that the pace of innovation is constantly accelerating. Since 2007, when the first i-phone was released, we experience a digital surge that has had a visible impact on the way we live our lives. Driverless cars are arriving on our roads, drones will soon fly over our heads delivering goods, advanced surgery can be done by robots and modern medicine will soon have made significant impact on cancer (Erixon and Weigel, 2016a, b). For the first time in history, more people die today from eating too much than from eating too little; more people die from old age than from infectious diseases; and more people commit suicide than are killed by soldiers, terrorists and criminals combined (Harari, 2015). The argument of an innovation slowdown is mainly based on the thought that the 1870 to 1970 period had experienced a technological revolution - unique in human history in its tremendous impact on daily lives (e.g. electricity, cars, antibiotics, telephone etc.). According to the proponents, such an impact on our lives has not been achieved by the digital technologies since then. Gordon describes in his book, “The rise and fall of American growth” (Gordon, 2016), the century between 1870 and 1970 as a special century, a period of unprecedented economic growth and improvements in health and standard of living. He stated that this economic revolution was unique in human history and by 1970 lives had totally changed in the developed world. The introduction of fundamentally new classes of technology seems rarer now than it was in the past. Information technology has certainly transformed the present day, but railways, telephony, automobiles and the chemical and steel industries each brought transformations as big as anything IT has wrought so far (The Economist, 2015). Indeed, it seems that the genuine progress in IT from the 1970s up to the 2000s has masked the relative stagnation of energy, transportation, space, materials, agriculture and medicine, at least when the advancement factors described above are taken as key performance indicators. Our ability to do basic things such as protect ourselves from earthquakes and hurricanes, to travel and to extend our lifespans is barely increasing. Many technologies that are considered modern are actually already quite old, Augustin Mouchot wrote the first book on solar energy in 1869, John Ericson designed an engine powered by the sun a few years later, Robert Anderson designed the first electric car in 1831.

Looking at the pure numbers in a non-biased way it has to be noted that the GDP growth has in fact slowed down in western countries (e.g. 2.82% 1920–1970 and 1.62% 1970–2014 for the U.S.) (Rotman, 2016). Productivity growth actually had slowed down in many OECD countries already before the financial crisis, which only amplified the phenomenon (OECD, 2015). Since the start of the financial crisis none of the Western economies have so far returned to the pre-crises trend of GDP growth (Erixon and Weigel, 2016a, b). The real median wage earned by men in the United States is lower today than it was in 1969 and median household income adjusted for inflation is now lower than it was in 1999 (Cowen, 2016). Rates of absolute upward income mobility, children's prospects of earning more than their parents in the U.S. have fallen sharply from ~90% for children born in 1940 to ~50% for children entering the labor market today (Chetty et al., 2017), largely due to lower GDP growth rates and greater inequality in the distribution of growth (Goldin and Katz, 2008). It has been argued that this slowdown would be the best available evidence that the third industrial revolution (mainly digital, post 1972) was a mere shadow of the second industrial revolution (1875–1972) (Gordon, 2012). Another interesting phenomenon signaling a decrease in dynamism is that the share of start-up firms declined from 2001 to 2011, a trend which has continued in recent years (OECD, 2015). The aging of firms at the global frontier was suggested by the OECD to foreshadow a slowdown in the arrival of radical innovations and productivity growth (Andrews et al., 2015). Most indices agree that in most of the world's regions an excess of funds is chasing too few growth investment opportunities and even companies considered to be innovation pioneers are sitting on huge cash piles rather than investing them (Riley, 2015).

Against this view it was convincingly argued that the digitalization and IT revolution produces great benefits that are not reflected in an immediate GDP increase (e.g. free access to knowledge and digital assets) such that the GDP may no longer be the right measure of progress (The Economist, 2016). In addition, rather than indicating a slow-down of science and technology, the lack of GDP growth could originate from the fact that humanity on earth is inevitably facing the limits of growth, as first published in the famous Club of Rome report in 1972 (Meadows et al., 1972). Despite a lot of criticism that the first book has received, recent analysis has demonstrated that the essential points of the report are correct (Meadows and Randers, 2004). It could be shown that the “business-as-usual scenario” described in the Limits to Growth report in 1972 unfortunately aligns well with historical data so far. Going on unchanged, this would finally result in collapse of the global economy and environment around 2020 with signs of decline becoming visible earlier (Turner, 2014, Turner and Alexander, 2014).

Beyond GDP, looking at the healthcare sector as an example to determine whether technological progress is accelerating or decelerating, it is evident that the most important sources of higher life expectancy in the 20th century were achieved in the first half of that century, when life expectancy rose at twice the rate of the last half (Cutler and Miller, 2005). Just recently, for the first time since 1993, Americans' life expectancy has even decreased (Xu et al., 2016). The fact that life expectancy in developing countries is increasing to levels seen in the Western countries is an argument of improved development and technology distribution but not of top technology advancement.

Looking specifically at achieved breakthroughs in science and technology, Dong et al. have found that the last science and technology productivity surge begins around the middle of the 16th century, peaks at the early 20th century but declines since then (Dong et al., 2016). Likewise, the Pentagon physicist Jonathan Huebner (Hübner, 2005) using a list of important technological discovery landmarks, has calculated the global rate of innovation vs. population and has found that the curve peaked around 1870 and has decreased since then. Interestingly, Ray Kurzweil using a similar methodology has reached the opposite conclusion of Huebner: namely that technological progress has been accelerating throughout all of Earth's history, and he predicted that it will continue to do so (Kurzweil, 2006). It is important to note that in such assessments, the level of technology that was already reached in the past and lost later should not be underestimated, such as e.g. indicated in recent discoveries around the ancient Greek Antikythera mechanism which is an analog computer designed by Greek scientists in 205 BCE (Marchant, 2006). A similar Archimedes sphere has been described by Cicero (Marchant, 2015). Another striking example is nanotechnology operated already by the ancient Romans. A historic glass chalice, known as the Lycurgus Cup, appears green when lit from the front and red when lit from behind, a characteristic that puzzled scientists for decades. The mystery wasn't solved until 1990 when researchers discovered that the Roman artisans were nanotechnology pioneers that had impregnated the glass with particles of silver and gold, ground down until they were as small as 50 nm in diameter (Merali, 2013).