Socio-Economic Implications of the Digital Revolution

Dirk Helbing

ETH Zurich, TU Delft, Complexity Science Hub Vienna

Carina I. Hausladen

ETH Zurich

January 28, 2021

Abstract

The digital revolution is reinventing business models, reshaping economic sectors, and changing entire societal institutions. Big Data and Artificial Intelligence, profiling and targeting, and several other technological developments are now fundamentally changing the ways economies work. This contribution discusses opportunities and threats of the "Attention Economy" and "Surveillance Capitalism", with a focus on systemic changes. These are associated with developments such as "more data", "more speed", "more networking". This contribution will also compare two paradigms: one that is based on a data-driven, AI-controlled, and largely centralized vision of society and its optimization, and one that is focused on empowerment, coordination, cooperation, self-organization, self-regulation, co-evolution, and collective intelligence in a distributed framework. It will be illustrated that suitable network effects are critical to a more cooperative and sustainable economy. Based on these insights, the possibility of a new, circular, and synergistic organization of supply chains and a new, symbiotic economy will be highlighted.

Economics is proud of its vast body of literature, particularly its mathematical foundation and formalization, which has accumulated over more than a century. For long, the paradigm of "homo economicus", assuming selfish human decision-makers and profit-maximizing companies, has dominated the theoretical discourse (Persky 1995), until experimental economics emerged and questioned some of the underlying axioms and assumptions (Chamberlin 1948; Smith 1976). Based on lab, online, and real-life experiments, behavioral economics has delivered some surprising discoveries (Camerer, Loewenstein, and Rabin 2004; Mullainathan and Thaler 2000). Among these is the observation that many individuals have fairness preferences (Fehr and Schmidt 1999; Fischbacher, Fong, and Fehr 2003), even under conditions of anonymity (Hoffman, McCabe, and Smith 1996). Therefore, the concept of "homo socialis" was recently proposed as an alternative description of human behavior (Grund, Waloszek, and Helbing 2013). It assumes networked decision-making and conditional cooperation and explains them by a natural evolution of social preferences.

Altogether, people seem to be less selfish than expected (Camerer 2011; Henrich et al. 2001; Hoffman, McCabe, and Smith 1996; Persky 1995), which makes humans more than individuals, namely a social being that cares about others. Adam Smith writes in his book "The Theory of Moral Sentiments" (Smith 1759): "How ever selfish man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it." Nevertheless, coordination and cooperation problems, as famously documented by public goods games (Chaudhuri 2011; Ledyard 1994; Zelmer 2003) and "tragedies of the commons" (Hardin 2009) are quite common. The work of Nobel Prize winner Elinor Ostrom et al. (Ostrom 1990, 1999, 2009, 2010; Ostrom et al. 1994) as well as the body of literature on evolutionary game theory (Gintis 2014) and mechanism design (Roth 2015), has demonstrated that self-regulation and self-organization based on local interactions could often solve these problems and thereby overcome social dilemma situations.

In the meantime, however, the digital revolution has dramatically changed the framework of our economy (Häring and Storbeck 2009; Leydesdorff 2006; Pyka and Hanusch 2006) and society. There is basically no institution that would not be changed or reinvented (Helbing 2021b). This includes administration, governance (Dai 2018), jurisdiction and law enforcement (Fradera 2018), the health system (Topol and Hill 2012) and education system (Collins and Halverson 2018), logistics (Witkowski 2017), trading (Caria 2017), and labor markets (Brynjolfsson and McAfee 2011).

In the following, we will discuss some of the changes that are expected to have a fundamental impact on the dynamics of our economic system. In short, we conclude that economic theory will have to be rewritten in many areas. In times of personalized products and services, we will need an economics 2.0 (Helbing 2013a). Unfortunately, it seems that, while the world has changed, economic theory lags behind. It does not offer a good understanding of the new reality yet.

1 Big Data

We are living in a time of Big Data. Within just one minute, hundreds of thousands of photos are uploaded on Facebook (Salman 2021), and Google queries are of the order of millions (Battelle 2011). Information Technology companies have entered the ranks of the most valuable companies in the world, which were previously held by oil companies. For this reason, people often say "data is the new oil" (Humby 2006). However, data is also collected for other reasons such as "ipsa scientia potestas est" ("knowledge itself is power", (Bacon 1597)), "for security reasons", "to save the world", or "to improve the state of the world".

In the meantime, we have entered a time of "cyberphysical systems" and "ubiquitous computing": The "Internet of Things" (IoT) enables billions of wirelessly connected measurement sensors around the world to collect an increasing amount of data. This includes not only income and consumption data but also highly detailed data about our environment and life. It includes mobility and location (GPS) data, data about our social network, data stored in the cloud, messenger data, data evaluated by ebook readers, data collected by robotic vacuum cleaners and smoke detectors, by Smart TVs and gaming consoles, data from search queries, data from Siri and Alexa engagements, biometric data, and all sorts of metadata derived from the sources mentioned above. These digital footprints enable computers, for example, to judge people's personalities more accurately than judgments made by friends or family (Youyou, Kosinski, and Stillwell 2015).

This system is now often called "Surveillance Capitalism" (Zuboff 2019). Different types of cookies track a person's web activity. It is also possible to identify a person via just a 30-second audio recording of their voice (Malik 2018). Besides, dozens of companies log movement patterns. Connecting these patterns allows one to identify people and to generate logs that resemble the privacy of someone's diary (Thompson and Warzel 2019). A combination of such diverse data sources can even be used to produce something like a digital "crystal ball". The company Palantir , for example, runs a commercial version. It is being claimed that such tools make human behavior predictable (Boerman, Kruikemeier, and Zuiderveen Borgesius 2017; Kosinski, Stillwell, and Graepel 2013; Ruths and Pfeffer 2014; Tufekci 2014) - a fact companies of all kinds are using.

2 Attention Economy

Another important fact of our digital world is that we live in an "attention economy" (Davenport and Beck 2002; Simon 1996). Some people go so far as to state that attention is the digital space's currency (Mandel and Leun 1996), or that attention will eventually replace money altogether (Goldhaber 1997). Firms adapt their business models to capitalize on our attention. Music streaming services such as Spotify demonstrate that there already exists an online market to bid on attention: Users either monetarily pay for ads to disappear or pay with their attention and have to listen to ads (Berkeley Economic Review 2020). Clearly, whoever manages to catch our attention has the opportunity to sell us a product, service, or idea. As we will see later on, it provides – more generally –

also a chance to manipulate our thinking and behavior through the information we are confronted with (Harris 2016).

3 Profiling

A lot of the information people are receiving today is personalized, i.e., tailored to their personality. For this, a detailed picture is being created about every one of us. The collection of personal information is called online behavioral advertising, profiling, or behavioral targeting (Bennett 2010).

The files accumulated about us are getting more and more detailed every day. Google users, for example, can download the data the company collected about them. You should not be surprised if the file exceeds multiple gigabytes (Martin 2019). Other companies such as Axciom specialized in collecting thousands of variables related to economic and social circumstances, personality, and health, often directly link them to email or home addresses (McLaughlin 2013).

4 Personalized Pricing

Such profiling data can be used, for example, for personalized pricing. In this case, the price is typically adjusted in a way that makes a purchase on the internet more likely. For this, information such as the income and spending pattern is exploited. For example, if you are using an expensive laptop or smartphone to buy online, the price will likely be higher. The price can not only be adjusted to a country or region, but also to personal information. For example, if your calendar shows a business or holiday trip, the booking portal might know that you need a flight or overnight stay. Hence, it could charge you more.

Personalized pricing can – to a certain extent – destroy classical markets. While traditionally, it is assumed that prices are determined such that supply and demand are matched, this is less and less the case. Instead of markets of a size "close to infinity", with personalized products, services, and prices, markets may shrink to size one. It probably does not even make much sense to call these markets anymore because supply and demand are not necessarily matched anymore. In many cases, it is more profitable to sell products and services over-priced and to destroy products that could not be sold. In other words, in the worst case, personalization can drive prices up, produce artificial scarcity, and cause adverse environmental impacts.

Moreover, personalized pricing is explicitly based on discrimination (Seele, Dierksmeier, et al. 2019). People are not treated equally, as in a physical shop, where typically the same price is offered to all. Due to a lack of algorithmic and data transparency, certain groups of people may be disadvantaged or offered advantages. In other words, companies using personalization could, in principle, reward or punish people for specific characteristics, including political preferences. The latter may be inferred, e.g., by investigating a single data source, such as Twitter data (Ansari, Siddiqui, and Anas 2020). Such a system would not be much different from the Chinese social credit score system (Liang et al. 2018), with the difference that each company, instead of the government, can decide who gets to see what product, service, offer, or price.

5 Code is Law

As Lawrence Lessig stated, "code is law" (Lessig 1999). In other words, algorithms and their programmers increasingly decide how the world works and thereby often evade or undermine the foundational values of democratic constitutions and established principles of the legal system. Due to this development, actors without political legitimacy have now the possibility to shake up the very foundations of legal, political, and societal systems. Moreover, they can overhaul macroeconomics' fundamental relationships based on market dynamics, where prices are adjusted to match supply and demand. In other words, commonly applied economic theories are not anymore expected to describe the market dynamics adequately.

Therefore, one urgently needs to address the question of how a theory properly describing the economic dynamics in the digital age needs to look like? As we will see, it will require a much better understanding of psychology and cognitive science.

6 Digital Doubles

The digital revolution does not stop at profiling people and at personalizing products, services, offers, and prices. The trend goes towards the creation of "digital doubles". The term is inspired by industry developing "digital twins", virtual copies of physical systems and assets, identifying problems, and increasing efficacy (Tao and Qi 2019). Imagine a computer-based, digital copy of yourself, an avatar that does not only behave like you but also maps the specifics of your body and health. Such a digital double can be created by learning black boxes fed with measurement and surveillance data (Pasquale 2015). It can be used to simulate our behavior to specific environments, circumstances, or information (Strife 2007), and our body's reaction to certain kinds of food and medical treatments. On an even larger scale, those digital doubles are being used for "world simulations" (Chaturvedi, Dolk, and Drnevich 2011), where possible future scenarios are simulated in some of the most powerful supercomputers of the world. Compared to this endeavor, the computational power of most companies is limited. Still, customer profiles certainly get ever more detailed, and simulation methods are increasingly being used to anticipate the impacts of particular marketing and other measures.

7 Targeting

"Targeting" is another development that is becoming increasingly important. The term means that the information provided, products, services, and prices are personalized, i.e., tailored to a particular individual, as mentioned before. Such targeting increases the attractiveness of products and services and the effectiveness of information.

Personalization also increases the manipulative power of advertisement and marketing measures. This can go so far that companies may manipulate the emotions (Kramer, Guillory, and Hancock 2014), interests, minds, and behaviors of people, including their voting behavior (Epstein and Robertson 2015). Even though the Cambridge Analytica approach has been questioned, similar

neuromarketing methods (Ariely and Berns 2010) are common today. The underlying techniques often work subliminally: The target does not recognize the manipulation consciously and has the feeling the decision was self-determined, while it was actually triggered by a sophisticated information system through specific cues.

Experiments with the targets increase the effectiveness of this method. A common approach is A-/B-testing (Kohavi and Longbotham 2016), where targets are exposed to different settings, and the response to various stimuli is evaluated. In this way, people can be conditioned, i.e., "programmed" or "remotely controlled" to a certain extent. Tristan Harris, who has previously worked as a Design Ethicist at Google, even speaks of "mind control" (Harris 2017).

Another frequently used term for this method is "Big Nudging", i.e., combining nudging techniques with Big Data (Helbing, Frey, et al. 2017). Such Big Nudging may systematically exploit "cognitive biases". The "Snowden Files" (The Guardian 2013) have shown that secret services exploit insights by behavioral science for their purposes (Dhami 2011). In other words, character traits, personal weaknesses, positive emotions, and fears may be turned against us (Greenwald 2014). Currently, there is little legal protection against such misuse or even abuse (Solon 2017).

Even though there is no current evidence of a "buy button" in the brain (Stanton, Sinnott-Armstrong, and Huettel 2017), research shows that neuromarketing methods developed with the use of fMRI (Knutson et al. 2007; Soon et al. 2013) and EEG (Telpaz, Webb, and Levy 2015) have the potential to predict a consumer's choice. Furthermore, there is growing evidence that marketing information strongly influences choices on an unconscious level (Ferraro, Bettman, and Chartrand 2009).

Using powerful Artificial Intelligence systems, such "personalized treatments" can now be deployed on a large scale. In other words, they can be applied to millions of people simultaneously. Thereby, digital population control has become conceivable to some extent. This means that market dynamics are increasingly determined by digitally induced psychological effects and decreasingly by macroeconomic relationships between supply and demand. However, the digital revolution does not stop there.

8 Neurocapitalism

Companies make considerable investments in the development of man-machine interfaces. Keywords are "neurotechnologies" or "brain-computer-interfaces". Neuralink (Musk 2019), for example, developed a device that – as of 2020 – was able to wirelessly transmit neural spikes from the snout area of a pig's brain to a computer.

Yet, noninvasive methods already provide deep insights into the human brain. EEG methods, for example, allow for what some scientists call synthetic telepathy (Brigham and Kumar 2010): Measuring electromagnetic fields produced by the brain allows one to identify imagined speech syllables (Brigham and Kumar 2010), perform computer mouse operations (McFarland et al. 2008), or control a robotic hand (Faiz and Al-Hamadani 2019; Tombini et al. 2012).

Furthermore, research on how to use nanotechnologies in neuroscience grows considerably. Nanobots are ultra-small artefacts allowing one to interact re-

motely with body cells. Different research fields investigate how to leverage this to improve brain performance in healthy people and patients suffering from disorders (Opris et al. 2020). Moreover, nanorobotics may allow one to interface the cloud with a human brain (Martins et al. 2019).

Such technology would potentially enable subjects to get direct, instantaneous access to each aspect of human knowledge. In perspective, one could also read a sentence or picture that someone imagines, transmit the content wirelessly, and make another person perceive that content. One day, it might even be possible to watch a TV program without a TV set, just by projecting the content into one's brain, using a combination of nano- and neuro-technology.

So far, such technologies are not yet commercially offered. However, investments into technologies as outlined above are considerable, initiating a new economic era beyond surveillance capitalism, named "neurocapitalism". In this system, companies would not only know our wishes, but they may also manipulate or determine our wishes directly. Of course, this would enable possible misuse such as totalitarian mind control.

In such a system, people may not anymore be able to think freely. Instead, their thoughts may be controlled by an Artificial Intelligence system. Some even seem to envision a "superintelligent system" that acts like a "benevolent dictator". Based on Big Data and the Internet of Things (IoT), AI algorithms, and quantum computers, it might try to optimize the path that life on planet Earth is taking. For example, it may attempt to minimize climate change. To realize this imagined optimal path, however, behavioral control would be imposed. While such a development may sound highly speculative, attempts along these lines have apparently already been made (Cerri and Chaturvedi 2007).

9 Digital Policing

In China, for example, the social credit system rewards and punishes certain kinds of behaviors in an attempt to determine the society's path (Creemers 2018; Kostka 2019; Liang et al. 2018). "Aadhaar" in India registered nearly 99% of its citizens. Western countries, too, deploy predictive and other kinds of digital policing, where interference may not be restricted to crimes or terrorism. The mass surveillance program named "KARMA POLICE", for example, was designed to provide the secret service with "either (a) a web browsing profile for every visible user on the internet, or (b) a user profile for every visible website on the internet." (Gallegati 2018)

10 Cashless Society

"To make our economy more sustainable" or "to save the planet" seems to be a common justification of behavioral control attempts. However, besides behavioral manipulation, there exist further control approaches. One of them is known under the label "cashless society" (Worthington 1995).

Sweden pioneers the shift toward digital payments: Only 9% of Swedish people paid for their purchases in shops by cash in 2020 (Sveriges Riksbank 2020). In India, cash is still the most widely used payment instrument, but

its use declined after the government's demonetisation efforts in 2016 (Reserve Bank of India 2020).

A cashless society may not just replace cash with digital money; it may also record transactions on a blockchain, as it is standard when handling crypto currencies, such as Bitcoin (Nakamoto 2019). While some of the related data may be anonymized, it may still be possible to analyze transactions to fight crime and corruption. Moreover, it is conceivable that certain kinds of transactions would be blocked. Let us assume that one has made a couple of airplane flights this year and that further flights shall be prevented in order to reduce climate change. In such a case, the system may block the booking or take other action to discourage undesired behavior. In principle, this approach would allow for totalitarian control as well. Most likely, however, one would not eliminate all degrees of freedom so that there would be more flexibility than in a system that punishes certain kinds of behaviors altogether.

11 Alternative Approaches

Above, it has been explained why the rapid technological developments, combined with environmental, social, and economic challenges, may lead to increased control not only of production but also of consumption, people, and societies. Other trends, however, promote empowerment and coordination rather than manipulation and control. This applies, for example, to the open-* movement.

11.1 Opening Up for Cooperation

Open access (Laakso et al. 2011; Willinsky 2006), open data (Murray-Rust 2008), open source (Weber 2009), open innovation (Chesbrough and Appleyard 2007; Gassmann, Enkel, and Chesbrough 2010) are just some of the recent developments in this direction. There are also astonishing success stories of "fab labs" and "maker spaces" (Troxler and Wolf 2010; Van Holm 2014): The "De Waag" community in Amsterdam, for example, has developed the "Fairfone" – a digital technology project that has been recognized worldwide (Akemu, Whiteman, and Kennedy 2016). Given such potentials, the United States even wanted to become "A Nation of Makers" (The White House 2015b).

The success story of UNIX/LINUX (Torvalds and Read By-Diamond 2001) has, in a sense, been repeated by public information platforms such as Wikipedia (Kittur, Chi, et al. 2007; Kittur and Kraut 2008) and OpenStreetMap (Chilton 2009). Such platforms are sometimes supported by millions of volunteers but used by a thousand times bigger community of people. These are just some of the examples of digital public goods that have been successfully created.

By now, hackathons are a common framework to promote quick progress in a setting that combines cooperation with competition, so-called "co-epetition" (Rhaman 2013). More generally, crowd-based approaches have become quite popular. This ranges from crowdsourcing (Howe 2006) to crowdfunding (Mollick 2014). It has even been possible to finance entire skyscrapers utilizing crowd funding (Vogel and Moll 2014). It is conceivable that this model will also be used to develop new medical treatments. Furthermore, citizen science is a further approach that builds on the engagement of volunteers. The success stories range

from astrophysics (Marshall, Lintott, and Fletcher 2015) over environmental studies (Conrad and Hilchey 2011) to protein folding for the development of new medical drugs (Khatib et al. 2011).

11.2 From GovLabs to "Peace Rooms"

In the meantime, there are also GovLabs, which explore new participatory modes of governance. For example, it has been proposed to turn "war rooms" into "peace rooms" (Helbing and Seele 2017). "War rooms" – also known as situation rooms – are being used for strategic management and tactical operations, also in big businesses. Here, all relevant information comes together, and decisions are being taken, which are implemented based on hierarchical principles (e.g., a military command chain).

Such an approach tends to suffer from a narrow perspective: while the military is interested mainly in security and power, a business is typically focused on profit. One-dimensional optimization, however, is not a suitable and sufficient basis for a thriving society. The latter requires the consideration of prosperity, health, education, environment, and culture, to mention just a few of the relevant goals. Therefore, cities and nations are operated differently from businesses: they aim to balance various objectives such as the above. The corresponding survival rates affirm the success of this approach: on average, cities live much longer than businesses. In a sense, cities hedge risks better than businesses.

The novel concept of "peace rooms" aims to overcome the above mentioned weaknesses of "war rooms": they would work more transparently (to increase trust and reduce flaws), be led by interdisciplinary teams of internationally renowned experts (to ensure a multi-perspective approach combining up to date knowledge of various domains), be guided by ethicists (to avoid dual use and undesired side effects), operate in the constitutional framework (to protect the fundamental values of society), and offer opportunities for participation (such that civil society can contribute, e.g., through NGOs, crowdsourcing or citizen science) (Helbing and Seele 2017). Managed this way, "situation rooms" would serve societies better.

The same is expected for businesses. In fact, an unusual experiment of the company Caterpillar Inc. has delivered some surprising insights. It turned out that involving staff, suppliers, buyers, and local people in the decision-making may create solutions that work better for everyone while producing higher profits (Praneo 2016).

At first, it appears to be paradoxical that "making compromises" can lead to more success and higher profits. The observation becomes understandable, however, in the context of literature explaining "conditional cooperativeness" through social preferences (Brandts and Schram 2001; Goeree, Holt, and Laury 2002; Palfrey and Prisbrey 1997) as well as the emergence of "networked thinking" in competitive, social dilemma kinds of situations (Grund, Waloszek, and Helbing 2013), which can promote high levels of emergent cooperation and considerably increased payoffs.

11.3 Informational Self-Determination

One could go a significant step further by creating Big Data infrastructures as a collective good. In many societies today, the agricultural sector is supported by public subsidies; the industrial sector is supported by public roads and infrastructures; the service sector is supported by public libraries, schools, and universities. Therefore, why should the digital sector of society not be backed by tax-payer funded infrastructures and platforms as well?

To give people genuine informational self-determination would not only be appropriate for the sake of human dignity and control over their own lives (i.e., for constitutional and human rights reasons); but it would also be in the interest of the economy, society, and environment. Given that highly detailed digital doubles have been created about all of us (e.g., for the purpose of "world simulation"), it would be easy to give us access to our profile, i.e., the data of our digital double. We could then decide what companies would be allowed to use what data for what purpose and what period of time, to offer us personalized products or services. The uses would be transparently recorded for our inspection. Without our specific consent, it should be forbidden to use our data for other purposes than statistical evaluations for the public good. Digital assistants, i.e., personalized AI systems running locally on our computers or smart devices, could learn our privacy and data sharing preferences, such that they could help us comfortably manage our data.

Such an approach – consistent with the spirit of the GDPR – would create a major benefit for our economy, society, and environment, because then not only big businesses could work with our data and metadata but – assuming that we give our consent – also small and medium-sized companies (SMEs), spin-offs, scientific institutions, NGOs, and other civil society initiatives. Such a setting would establish an information, innovation, production, and service "ecosystem", something like a "digital catalyst", allowing for combinatorial innovation. Therefore, a lot more could be done with the data collected about this world, including new business models, societal and environmental initiatives.

The above approach would also be compatible with the Customer Privacy Bill of Rights Act (The White House 2015a) and the WEF consensus on "Personal Data as A New Asset Class" (World Economic Forum 2011, 2012). The decentralization project "Solid", led by Tim Berners-Lee and developed collaboratively with the MIT (Mansour et al. 2016), is trying to implement a similar system. It would constitute a new way of running the internet and managing personal data contrasting "surveillance capitalism".

Complementary, given the problem of biased or even discriminatory Artificial Intelligence solutions (Caliskan, Bryson, and Narayanan 2017; Hacker 2018; Hacker and Petkova 2017), it would be useful to make progress concerning algorithm transparency (Wachter, Mittelstadt, and Floridi 2017). Here, it has been proposed to publicly share algorithms with a delay (say, of two years). This would correspond to the way we handle other intellectual property such as patents (just that the protection period would be different). Delayed open-sourcing would allow for a reasonable period, during which private profit can be made; thereafter, algorithms would become a public good (if there are no major contradicting security issues) and could, thereby, benefit companies and societies around the world. Given that the world is currently faced with a "climate emergency" and a "pandemic emergency," as well as other existential problems,

such a co-epititive approach appears to be more suitable and responsible than today's exclusively competitive economic approach (Helbing and Seele 2020).

11.4 Co-* Principles

Network interaction can dramatically change the outcome of system dynamics, e.g., from a non-cooperative result such as a "tragedy of the commons" to a highly cooperative outcome (Helbing, Szolnoki, et al. 2010). This applies particularly to mutual symbiotic relationships (Boucher, James, and Keeler 1982). Ecosystems deliver many examples of this. The "microbiome" (Whipps, Lewis, and Cooke 1988) is perhaps one of the most impressive cases. An economic organization could learn a lot from this, e.g., by letting mutualism shape market practice (Lloveras, Warnaby, and Quinn 2020). Nature could certainly deliver many bio-inspired solutions – further scientific terms are biomimicry (Benyus 1997) and biomimetics (Bhushan 2009) – particularly for a circular economy (Helbing, Deutsch, et al. 2009).

Ecosystems are good examples of complex adaptive systems, which can self-organize (Eigen and Schuster 1977). However, similar findings have also been made in financial (May, Levin, and Sugihara 2008) and social systems (Helbing 2012). Self-regulation also works in economic settings, given a suitable organizational framework. Nobel Prize winner Elinor Ostrom, for example, has worked out a couple of success principles for the management of common pool resource (CPR) (Ostrom 1990); these include

1. clearly defined boundaries (effective exclusion of external un-entitled parties);
2. rules regarding the appropriation and provision of common resources that are adapted to local conditions;
3. collective-choice arrangements that allow most resource appropriators to participate in the decision-making process;
4. effective monitoring by representatives who are part of or accountable to the appropriators;
5. a scale of graduated sanctions for resource appropriators who violate community rules;
6. mechanisms of conflict resolution that are cheap and of easy access;
7. self-determination of the community recognized by higher-level authorities;
8. in case of larger common-pool resources, an organization in the form of multiple layers of nested enterprises, with small local CPRs at the base level.

In recent years, people have paid increasing attention to the benefits of co-* principles such as coordination (Seele, Jia, and Helbing 2019), cooperation (Camera and Casari 2009; Friedman and Oprea 2012), co-learning (Shoham and Tennenholtz 1994), co-working (Kojo and Nenonen 2017), co-creation (Payne, Storbacka, and Frow 2008; Prahalad and Ramaswamy 2004; Ramaswamy and Ozcan 2014), co-evolution (Helbing, Yu, and Rauhut 2011), and collective intelligence (Surowiecki 2005; Woolley et al. 2010).

11.5 Collective Intelligence

In the past decades, subjects such as "collective intelligence" (Woolley et al. 2010) and "swarm intelligence" (Beni 2020) or "the wisdom of crowds" (Kittur, Chi, et al. 2007; Kittur and Kraut 2008; Mollick and Nanda 2016; Surowiecki 2005) as well as the opposite, "the madness of crowd" (Mackay 1841), have been intensive research areas. Overall, one can conclude that crowds can often collectively outperform individual experts (Surowiecki 2005). However, the wisdom of the crowd effect can also be undermined, for example, by social influence (Lorenz et al. 2011).

For "collective intelligence" or "social intelligence" to emerge, a sufficient degree of diversity is needed (Page 2008; Woolley et al. 2010). The following four-phase procedure exemplifies how collective intelligence may be supported:

1. Independent exploration: In the first phase, people should collect relevant information and seek possible solution approaches independently. In this phase, it is essential that they are not externally manipulated to favor a particular solution: diversity is key. The process can be improved by suitable incentive schemes such as "minorities report" (Mann and Helbing 2017).

2. Information exchange: In the second phase, relevant information and promising solution approaches should be shared. Here, the different arguments and how they relate to each other should be systematically mapped out in an argument graph that shows the different perspectives on the problem that is to be solved.

3. Integration: In the third stage, through a round table setting, representatives of the different perspectives should try to develop integrated views and solutions based on a deliberative approach. Only integrated approaches that take different perspectives and interests on board are expected to perform well for a great majority of people.

4. Voting: In the fourth stage, people affected by the problem at hand should vote for the best integrated solution. Here, it is advised to use not a simple majority voting approach but a more sophisticated method such as "quadratic voting" (Posner and Weyl 2017) or "preferential voting" (Hare 1873).

In favor of reaching better solutions to complex problems in a world that is faced with various existential threats, it would be desirable to build new kinds of social media that are based on such principles promoting constructive dialogue and collective decision-making. The approach outlined above could be a blueprint for a digital upgrade of democracies towards "digital democracies" (Helbing and Pournaras 2015; Hindman 2008). However, they are expected to deliver better business solutions as well (see, for example, the previously mentioned experiment by Caterpillar).

11.6 Collective Goods, Private Services

Economists are often critical about collective goods because they may suffer from an erosion of cooperation, resulting in a tragedy of the commons. But

what about creating collective goods and maintaining them through private services?

In the meantime, new collaborative approaches such as "hackathons" and "making" have reached the city level and beyond. Think, for example, of the "We versus Virus" hackathon in response to COVID-19 (Menger 2020) and the "Make City" festival in Berlin (MakeCity 2018). In times, where it is possible to produce houses with 3D construction printers within three weeks (Carlson 2020), some have gone so far as to promote open architecture (Koren et al. 2013) and open source urbanism (Bradley 2015; Finn 2014; Jiménez 2014; Sassen 2011). Others argue for design as a service (Wu et al. 2012).

It has also been proposed to run the "Make City" festival competitively, as City Olympics / City Challenges / City Cups would do (Bloomberg Philanthropies 2019; Cup 2019; European Investment Bank 2019; European Week of Regions and Cities 2019; World Wide Fund For Nature 2020). The idea is as follows: Neither nation states nor global corporations have managed to solve existential challenges such as lack of sustainability on time. Therefore, we need a third pillar, cities and regions, where civil society is mobilized in a bottom-up way to address global challenges. The disciplines of this friendly competition could, for example, include lowering energy consumption, improving air quality, reducing climate change, increasing sustainability, and improving resilience. Local politics, media, businesses, research institutions, NGOs, and citizen initiatives could all contribute to finding better solutions. The activities and developments would be paid for by taxes and donations. Results would be open source and fall under a creative commons license.

Why would this be beneficial? Because every city could pick the best fitting solutions that have been developed around the world. It would also be possible to combine solutions and develop them further. In this way, the best ideas around the planet could be combined – thereby unleashing the power of collective intelligence worldwide. All this would offer plenty of opportunities for businesses around the globe, which would bring various solutions together, develop them further, and offer related services. This could give rise to novel, networked platforms and a global, participatory, symbiotic information, innovation, service, and product "ecosystem".

However, it does not stop there. Mass innovation can be digitally supported. Suppose you would want to learn how to cook. Then, you could now use augmented reality to guide you. You would not have to study it for long. The same applies to a lot of other activities. Augmented reality could lift people to a semi-professional level. This would make it a lot easier to establish a project or business, to find and recruit the right people, to make business plans, to schedule activities, to raise money, to do the budgeting and spending. Digital tools could help us to be a lot more creative and entrepreneurial, not just in an economic way. We could also be a lot more effective in contributing to social, environmental, and cultural activities.

11.7 Participatory Budgeting, Sustainability, Resilience

One would, of course, need to have better access to resources as well. This can be reached by going a step beyond "participatory budgeting" (Helbing 2021a), which is increasingly popular in many cities to improve urban settings. The next step could be an investment premium – i.e., a particular, new kind of money

that you cannot spend for yourself but would be provided to invest in projects you consider essential (Blackstock, Kelly, and Horsey 2007; Helbing, Frey, et al. 2017). In this way, the best local activities would get the needed resources to make a positive difference. Thereby, citizens and civil society could make a much more significant contribution to the transformation towards a digital and sustainable society.

Such approaches also play an increasing role in connection with concepts such as "participatory sustainability" (Walker et al. 2002) and "participatory resilience" (Helbing 2021b). They would give environmental movements co-creative opportunities to shape the future. "Participatory resilience" would build, in particular, on concepts such as redundancy, diverse solutions, decentralized organization, solidarity, and digital assistance (Taleb 2012). In such a way, socio-economic systems can be made resistant to shocks and surprises, disasters, and crises, by increasing systemic adaptability and strengthening the social fabric (Wright 2001).

11.8 The Digital World Is Not A Zero-Sum Game

However, why should we do all this? It has become increasingly clear that the world is not a zero-sum game (Friedman and Kahn Jr. 2003). Digitally assisted, participatory approaches prepare us better for the challenges of the future. They are also much better suited to achieve the Sustainable Development Goals (SDGs) than the economic system of today and well compatible with a modern "design for values" perspective (Farmer et al. 2012), making our future economy more compatible with democratic principles and constitutional values such as human rights, including human dignity and informational self-determination. Importantly, the approach also promotes economic prosperity by offering catalytic, symbiotic economic opportunities. Remember that digital goods and services are not limited, like material resources are.

Sharing information does not just redistribute value. It can increase the overall value and benefit several parties simultaneously. Hence, in contrast to the "old", material economy we have been raised in, we can benefit from combinatorial innovation and the unlimited opportunities that the digital age is offering us – if we just decide to manage resources not as we used to (based on scarcity and self-centered competition). The digital revolution has not only the possibility of human-machine symbiosis on stock – but it can also enhance social behavior ("social enhancement").

11.9 A Socio-Ecological Finance System (FIN4)

Stock markets, the economy, and societies are known to be complex adaptive systems (Gallegati 2018; Helbing 2013b; Kirman 2010). In such systems, strong interactions between its components may lead to unexpected side effects, feedback effects, or cascading effects, which cannot be simply controlled in a top-down way (Ashby 1961). However, complex adaptive systems tend to self-organize, i.e., to develop characteristic structures, properties, and functions. By changing the interactions, one can change the emergent outcomes. That is, complex adaptive systems can often be improved by feedback effects that modify interactions among the system's components or by adding or removing network

links. These are research areas of cybernetics (Fiedler 1973) as well as connectivity science (Barabási 2016), network science (Phelan 2001), complexity science (Global Climate Forum e.V. 2021), and global systems science (Dapp, Helbing, and Klauser (eds.) 2021).

Such feedbacks can be based on real-time measurements, which may now be cheaply realized with the Internet of Things (IoT). For example, CO2, noise, temperature, humidity, radiation, and many other externalities can be measured using wirelessly communicating sensors. This also concerns positive externalities such as social cooperation, education, or the reuse of different kinds of waste. Such diverse measurements can be used as inputs to define new kinds of money and new incentive systems.

While classical economics suggests to attribute to each externality a value or price in Dollars, say, it has been recently proposed to introduce various hardly convertible currencies instead. This enables differentiated, multi-dimensional feedbacks, as they are needed to manage complex adaptive systems or to build self-organizing or self-regulating systems.

Such a multi-dimensional approach facilitates a new, socio-ecological finance system called "Finance 4.0" (Helbing 2014), which allows introducing additional social and ecological incentives into the economic system, thereby supporting the co-evolution towards a sustainable, circular economy based on symbiotic interactions. For the sake of illustration, imagine one would introduce "black", "red", "blue", "green", "yellow" and all sorts of "differently colored" eCoins to price different kinds of externalities. These different eCoins could, for example, be implemented utilizing Blockchain technology.

In other words, the Finance 4.0 system would combine the Internet of Things and Blockchain technology to define multiple new currencies enabling real-time feedback and incentives. This multi-dimensional incentive system could be used to reward desirable externalities while discouraging undesirable ones. Such a differentiated reward system would be much more suitable to manage complex systems such as our economy and society than the effectively one-dimensional money system we have today.

The present economic system is, in principle, based on a utilitarian approach that judges the entire world using a one-dimensional scale (such as profit). This one-dimensional approach oversimplifies many complex problems. It creates a hierarchy and power structure, which, however, is not well enough suited to establish a sustainable and resilient coordination system and organizational framework for today's complex world.

To illustrate the multi-dimensional approach a bit better, let us consider our human body, which is also a complex adaptive system. It is mainly self-organized, and many of its processes are not centrally controlled by the brain. Clearly, the body cannot thrive by varying just one variable, such as the amount of water we drink. We rather need various substances such as water, proteins, fats, carbohydrates, vitamins, and minerals. For each of these substances, there are separate feedback loops. They are certainly not controlled by a single quantity analogous to money. Why should we manage the economy with one-dimensional money if we can learn a lot from the circular economy that nature has established over millions of years of multi-dimensional (co-)evolution rather than one-dimensional optimization?

11.10 A New Economy Is Born

Altogether, it appears that we are currently seeing the formation of a new economy (Helbing 2014): an economy that is not anymore determined by matching supply and demand, by psychological manipulation, or AI-enabled centralized control but an economy that is more differentiated and diverse, more participatory, more sustainable and resilient, and more value sensitive. Using suitable real-time feedback, as they become cheaply possible with the Internet of Things, the digital revolution offers us new opportunities. This includes the chance to learn how to make Adam Smith's dream of the "invisible hand" work for us – locally and for societies at large. By means of mechanism design and computational social science, one can now create complex adaptive systems that show desired behaviors as a result of self-organization. At the same time, the approach is robust to small perturbations, which offers freedom for creativity and innovation.

Acknowledgments

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 833168).

References

Akemu, Ona, Gail Whiteman, and Steve Kennedy (2016). "Social Enterprise Emergence from Social Movement Activism: The Fairphone Case". In: *Journal of Management Studies* 53.5, pp. 846–877. DOI: 10.1111/joms.12208.

Ansari, Mohd Zeeshan, Areesha Fatima Siddiqui, and Mohammad Anas (2020). "Inferring Political Preferences from Twitter". In: *International Conference on Emerging Technologies in Data Mining and Information Security IEMIS 2020*. URL: https://arxiv.org/abs/2007.10604.

Ariely, Dan and Gregory S. Berns (2010). "Neuromarketing: The Hope and Hype of Neuroimaging in Business". In: *Nature Reviews Neuroscience* 11.4, pp. 284–292. DOI: 10.1038/nrn2795.

Ashby, W. Ross (1961). *An Introduction to Cybernetics*. London: Chapman & Hall.

Bacon, Francis (1597). *Meditationes Sacrae*. De Haeresibus.

Barabási, Albert-László (2016). *Network Science*. Cambridge, MA: Cambridge University Press.

Battelle, John (2011). *The Search: How Google and its Rivals Rewrote the Rules of Business and Transformed our Culture*. New York: Penguin Books, Limited.

Beni, Gerardo (2020). "Complex Social and Behavioral Systems". In: *Complex Social and Behavioral Systems*, pp. 791–818. DOI: 10.1007/978-1-0716-0368-0.

Bennett, Steven C. (2010). "Regulating Online Behavioral Advertising". In: *The John Marshall Law Review* 44, p. 899.

Benyus, Janine M. (1997). *Biomimicry: Innovation Inspired by Nature*. New York: Quill–William Morrow.

Berkeley Economic Review (2020). *Paying Attention: The Attention Economy*. URL: https://econreview.berkeley.edu/paying-attention-the-attention-economy/.

Bhushan, Bharat (2009). "Biomimetics: Lessons From Nature — An Overview". In: *Philosophical Transactions of the Royal Society A* 367, pp. 1445–1486. DOI: http://doi.org/10.1098/rsta.2009.0011.

Blackstock, Kirsty Ll, Gail J. Kelly, and Browyn L. Horsey (2007). "Developing and Applying a Framework to Evaluate Participatory Research for Sustainability". In: *Ecological Economics* 60.4, pp. 726–742.

Bloomberg Philanthropies (2019). *American Cities Climate Challenge*. URL: https://www.bloomberg.org/program/environment/climatechallenge/#overview.

Boerman, Sophie C, Sanne Kruikemeier, and Frederik J Zuiderveen Borgesius (2017). "Online Behavioral Advertising: A Literature Review and Research Agenda". In: *Journal of Advertising* 46.3, pp. 363–376.

Boucher, Douglas H, Sam James, and Kathleen H Keeler (1982). "The Ecology of Mutualism". In: *Annual Review of Ecology and Systematics* 13.1, pp. 315–347.

Bradley, Karin (2015). "Open-Source Urbanism: Creating, Multiplying and Managing Urban Commons". In: *Footprint*, pp. 91–107.

Brandts, Jordi and Arthur Schram (2001). "Cooperation and Noise in Public Goods Experiments: Applying the Contribution Function Approach". In: *Journal of Public Economics* 79.2, pp. 399–427.

Brigham, Katharine and B. V. K. Vijaya Kumar (2010). "Imagined Speech Classification with EEG Signals for Silent Communication: A Preliminary Investigation Into Synthetic Telepathy". In: *4th International Conference on Bioinformatics and Biomedical Engineering*, pp. 10–13. DOI: 10.1109/ICBBE.2010.5515807.

Brynjolfsson, Erik and Andrew McAfee (2011). *Race Against the Machine*. Lexington, Mass.: Digital Frontier Press.

Caliskan, Aylin, Joanna J. Bryson, and Arvind Narayanan (2017). "Semantics Derived Automatically from Language Corpora Contain Human-Like Biases". In: *Science* 356.6334, pp. 183–186.

Camera, Gabriele and Marco Casari (2009). "Cooperation Among Strangers Under The Shadow of the Future". In: *American Economic Review* 99.3, pp. 979–1005.

Camerer, Colin F. (2011). *Behavioral Game Theory: Experiments in Strategic Interaction*. Princeton: Princeton University Press.

Camerer, Colin F., George Loewenstein, and Matthew Rabin (2004). *Advances in Behavioral Economics*. Princeton: Princeton University Press.

Caria, Riccardo de (2017). "A Digital Revolution in International Trade? The International Legal Framework for Blockchain Technologies, Virtual Currencies and Smart Contracts: Challenges and Opportunities". In: *Modernizing International Trade Law to Support Innovation and Sustainable Development. UNCITRAL 50th Anniversary Congress*. United Nations, pp. 105–117.

Carlson, Cajsa (2020). *Kamp C Completes Two-Storey House 3D-Printed in one Piece in Situ*. URL: https://www.dezeen.com/2020/12/22/kamp-c-completes-two-storey-house-3d-printed-one-piece-onsite/.

Cerri, Tony and Alok Chaturvedi (2007). *Sentient World Simulation (SWS): A Continuously Running Model of the Real World*. URL: https://www.krannert.purdue.edu/academics/mis/workshop/ac2_100606.pdf%20https://emerj.com/ai-future-outlook/nsa-surveillance-and-sentient-world-simulation-exploiting-privacy-to-predict-the-future/.

Chamberlin, Edward H. (1948). "An Experimental Imperfect Market". In: *Journal of Political Economy* 56.2, pp. 95–108.

Chaturvedi, Alok R., Daniel R. Dolk, and Paul L. Drnevich (2011). "Design Principles for Virtual Worlds". In: *MIS Quarterly: Management Information Systems* 35.3, pp. 673–684. DOI: 10.2307/23042803.

Chaudhuri, Ananish (2011). "Sustaining Cooperation in Laboratory Public Goods Experiments: A Selective Survey of the Literature". In: *Experimental Economics* 14.1, pp. 47–83.

Chesbrough, Henry W. and Melissa M. Appleyard (2007). "Open Innovation and Strategy". In: *California Management Review* 50.1, pp. 57–76.

Chilton, Steve (2009). "Crowdsourcing is Radically Changing the Geodata Landscape: Case Study of OpenStreetMap". In: *Proceedings of the UK 24th International Cartography Conference*. Santiago, Chile, p. 6.

Collins, Allan and Richard Halverson (2018). *Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America*. New York: Teachers College Press.

Conrad, Cathy C. and Krista G. Hilchey (2011). "A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportuni-

ties". In: *Environmental Monitoring and Assessment* 176.1-4, pp. 273–291. DOI: 10.1007/s10661-010-1582-5.

Creemers, Rogier (2018). "China's Social Credit System: An Evolving Practice of Control". In: *SSRN Electronic Journal*. DOI: 10.2139/ssrn.3175792.

Cup, The Climate City (2019). *The Climate City Cup*. URL: https://climatecitycup.org/%20https://www.kidapawancity.gov.ph/climate/.

Dai, Xiudian (2018). *The Digital Revolution and Governance*. New York: Routledge, pp. 1–270. DOI: 10.4324/9781315182155.

Dapp, Marcus, Dirk Helbing, and Stefan Klauser (eds.) (2021). *Finance 4.0: Towards a Socio-Ecological Finance System*. Springer.

Davenport, Thomas H. and John C. Beck (2002). *The Attention Economy: Understanding the New Currency of Business*. May. Cambridge, MA: Harvard Business School Press. DOI: 10.1145/376625.376626.

Dhami, Mandeep K. (2011). *Behavioural Science Support for JTRIG's (Joint Threat Research and Intelligence Group's) Effects and Online HUMINT Operations*. URL: https://www.statewatch.org/media/documents/news/2015/jun/behavioural-science-support-for-jtrigs-effects.pdf.

Eigen, Manfred and Peter Schuster (1977). "A Principle of Natural Self-Organization". In: *Die Naturwissenschaften* 64.11, pp. 541–565.

Epstein, Robert and Ronald E. Robertson (2015). "The Search Engine Manipulation Effect (SEME) and Its Possible Impact on the Outcomes of Elections". In: *Proceedings of the National Academy of Sciences of the United States of America* 112.33, e4512–e4521. DOI: 10.1073/pnas.1419828112.

European Investment Bank (2019). *Global Climate City Challenge: 5 Cities Selected as Climate Leaders*. URL: https://www.eib.org/en/press/all/2019-349-global-climate-city-challenge-5-cities-selected-as-climate-leaders.

European Week of Regions and Cities (2019). *Intelligent Cities Challenge: A Strategy for Cities in the 21st Century*. URL: https://europa.eu/regions-and-cities/programme/sessions/575_en.

Faiz, Mohammed Zeki Al and Ammar A. Al-Hamadani (2019). "Online Brain Computer Interface Based Five Classes EEG to Control Humanoid Robotic Hand". In: *42nd International Conference on Telecommunications and Signal Processing*, pp. 406–410. DOI: 10.1109/TSP.2019.8769072.

Farmer, J. Doyne et al. (2012). "A Complex Systems Approach to Constructing Better Models for Managing Financial Markets and the Economy". In: *The European Physical Journal Special Topics* 214.1, pp. 295–324.

Fehr, Ernst and Klaus M. Schmidt (1999). "A Theory of Fairness, Competition, and Cooperation". In: *The Quarterly Journal of Economics* 114.3, pp. 817–868.

Ferraro, Rosellina, James R. Bettman, and Tanya L. Chartrand (2009). "The Power of Strangers: The Effect of Incidental Consumer Brand Encounters on Brand Choice". In: *Journal of Consumer Research* 35.5, pp. 729–741.

Fiedler, Miroslav (1973). "Algebraic Connectivity of Graphs". In: *Czechoslovak Mathematical Journal* 23.2, pp. 298–305.

Finn, Donovan (2014). "DIY Urbanism: Implications for Cities". In: *Journal of Urbanism: International Research on Placemaking and Urban Sustainability* 7.4, pp. 381–398.

Fischbacher, Urs, Christina M. Fong, and Ernst Fehr (2003). *Fairness and the Power of Competition*. Zurich: University of Zurich. URL: https://doi.org/10.3929/ethz-a-004491953.

Fradera, Francesc (2018). "Conference Report on 'Digital Revolution: Data Protection, Artificial Intelligence, Smart Products, BlockchainTechnology and Virtual Currencies. Challenges for Law in Practice'". In: *European Review of Private Law* 26.5.

Friedman, Batya and Peter H. Kahn Jr. (2003). "Human Values, Ethics, and Design". In: *The Human-Computer Interaction Handbook*. Mahwah, NJ: Lawrence Erlbaum Associates, pp. 1177–1201.

Friedman, Daniel and Ryan Oprea (2012). "A Continuous Dilemma". In: *American Economic Review* 102.1, pp. 337–363.

Gallegati, Mauro (2018). *Complex Agent-Based Models*. Springer.

Gassmann, Oliver, Ellen Enkel, and Henry Chesbrough (2010). "The Future of Open Innovation". In: *R&D Management* 40.3, pp. 213–221.

Gintis, Herbert (2014). *The Bounds of Reason: Game Theory and the Unification of the Behavioral Sciences-Revised Edition*. Princeton: Princeton University Press.

Global Climate Forum e.V. (2021). *The Global Systems Science Blog*. URL: http://global-systems-science.org/.

Goeree, Jacob K., Charles A. Holt, and Susan K. Laury (Feb. 2002). "Private Costs and Public Benefits: Unraveling the Effects of Altruism and Noisy Behavior". In: *Journal of Public Economics* 83.2, pp. 255–276. DOI: 10.1016/S0047-2727(00)00160-2.

Goldhaber, Michael H. (1997). *Attention Shoppers! The Currency of the New Economy won't be Money, but Attention — A Radical Theory of Value*. URL: https://www.wired.com/1997/12/es-attention/.

Greenwald, Glenn (Feb. 2014). *How Covert Agents Infiltrate the Internet to Manipulate, Deceive, and Destroy Reputations*. URL: https://theintercept.com/2014/02/24/jtrig-manipulation/.

Grund, Thomas, Christian Waloszek, and Dirk Helbing (2013). "How Natural Selection Can Create Both Self- and Other-Regarding Preferences and Networked Minds". In: *Scientific Reports* 3.1, pp. 1–5.

Hacker, Philipp (2018). "Teaching Fairness to Artificial Intelligence: Existing and Novel Strategies against Algorithmic Discrimination under EU Law". In: *55 Common Market Law Review*, pp. 1143–1186. URL: https://ssrn.com/abstract=3164973.

Hacker, Philipp and Bilyana Petkova (2017). "Reining in the Big Promise of Big Data: Transparency, Inequality, and New Regulatory Frontiers". In: *Northwestern Journal of Technology and Intellectual Property* 15.1. DOI: 10.2139/ssrn.2773527.

Hardin, Garrett (2009). "The Tragedy of the Commons". In: *Journal of Natural Resources Policy Research* 1.3, pp. 243–253.

Hare, Thomas (1873). *The Election of Representatives, Parliamentary and Municipal*. London: Longmans, Green, Reader, and Dyer.

Häring, Norbert and Olaf Storbeck (2009). *Economics 2.0: What the Best Minds in Economics can Teach You About Business and Life*. New York: Palgrave Macmillan.

Harris, Tom (2017). *How a Handful of Tech Companies Control Billions of Minds Every Day*. URL: https://www.ted.com/talks/tristan_harris_

how_a_handful_of_tech_companies_control_billions_of_minds_every_day.
Harris, Tristan (May 2016). *How Technology is Hijacking Your Mind — From a Magician and Google Design Ethicist*. URL: https://medium.com/thrive-global/how-technology-hijacks-peoples-minds-from-a-magician-and-google-s-design-ethicist-56d62ef5edf3.
Helbing, Dirk (2012). *Social Self-Organization: Agent-Based Simulations and Experiments to Study Emergent Social Behavior*. Springer.
— (2013a). "Economics 2.0: The Natural Step Towards a Self-Regulating, Participatory Market Society". In: *Evolutionary and Institutional Economics Review* 10.1, pp. 3–41.
— (2013b). "Globally Networked Risks and How to Respond". In: *Nature* 497.7447, pp. 51–59.
— (2014). "Economy 4.0 and Digital Society: The Participatory Market Society is Born (Chapter 8 of Digital Society)". In: *SSRN Electronic Journal*. DOI: 10.2139/ssrn.2539330.
— (2021a). "Democratic Capitalism — Why not give it a Try?" In: *Next Civilization*. Springer.
— (2021b). *Next Civilization*. Springer.
Helbing, Dirk, Andreas Deutsch, et al. (2009). "Biologistics and the Struggle for Efficiency: Concepts and Perspectives". In: *Advances in Complex Systems* 12.6, pp. 533–548. DOI: 10.1142/S0219525909002374.
Helbing, Dirk, Bruno S. Frey, et al. (2017). *Will Democracy Survive Big Data and Artificial Intelligence?* URL: https://www.scientificamerican.com/article/will-democracy-survive-big-data-and-artificial-intelligence/.
Helbing, Dirk and Evangelos Pournaras (2015). "Society: Build Digital Democracy". In: *Nature* 527.7576, pp. 33–34.
Helbing, Dirk and Peter Seele (2017). "Turn War Rooms into Peace Rooms". In: *Nature* 549.7673, p. 458. DOI: 10.1038/549458c.
— (Sept. 2020). *Digital ID, Global Resilience, and Human Dignity Blog Archive FuturICT Hubs*. URL: https://www.project-syndicate.org/commentary/digital-id-covid19-human-rights-surveillance-technology-by-dirk-helbing-and-peter-seele-2020-09?barrier=accesspaylog.
Helbing, Dirk, Attila Szolnoki, et al. (2010). "Evolutionary Establishment of Moral and Double Moral Standards through Spatial Interactions". In: *PLoS Computational Biology* 6.4, e1000758.
Helbing, Dirk, Wenjian Yu, and Heiko Rauhut (2011). "Self-Organization and Emergence in Social Systems: Modeling the Coevolution of Social Environments and Cooperative Behavior". In: *Journal of Mathematical Sociology* 35.1-3, pp. 177–208. DOI: 10.1080/0022250X.2010.532258.
Henrich, Joseph et al. (2001). "In Search of Homo Economicus: Behavioral Experiments in 15 Small-Scale Societies". In: *American Economic Review* 91.2, pp. 73–78.
Hindman, Matthew (2008). *The Myth of Digital Democracy*. Princeton: Princeton University Press.
Hoffman, Elizabeth, Kevin McCabe, and Vernon L. Smith (1996). "Social Distance and Other-Regarding Behavior in Dictator Games". In: *The American Economic Review* 86.3, pp. 653–660.
Howe, Jeff (2006). "The Rise of Crowdsourcing". In: *Wired Magazine* 14.6, pp. 1–4. URL: https://www.wired.com/2006/06/crowds/.

Humby, Clive (2006). *Data is the New Oil*. URL: https://ana.blogs.com/maestros/2006/11/data_is_the_new.html.

Jiménez, Alberto Corsín (2014). "The Right to Infrastructure: A Prototype for Open Source Urbanism". In: *Environment and Planning D: Society and Space* 32.2, pp. 342–362.

Khatib, Firas et al. (2011). "Crystal Structure of a Monomeric Retroviral Protease Solved by Protein Folding Game Players". In: *Nature Structural & Molecular Biology* 18.10, pp. 1175–1177.

Kirman, Alan (2010). *Complex Economics: Individual and Collective Rationality*. Routledge, London: The Graz Schumpeter Lectures.

Kittur, Aniket, Ed Chi, et al. (2007). "Power of the Few vs. Wisdom of the Crowd: Wikipedia and the Rise of the Bourgeoisie". In: *Alt.CHI*. San Jose, CA.

Kittur, Aniket and Robert E. Kraut (2008). "Harnessing the Wisdom of Crowds in Wikipedia: Quality through Coordination". In: *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work*, pp. 37–46.

Knutson, Brian et al. (2007). "Neural Predictors of Purchases". In: *Neuron* 53.1, pp. 147–156.

Kohavi, Ron and Roger Longbotham (2016). "Online Controlled Experiments and A/B Testing". In: *Encyclopedia of Machine Learning and Data Mining*. New York: Springer, pp. 1–8. DOI: 10.1007/978-1-4899-7687-1.

Kojo, Inka and Suvi Nenonen (2017). "Evolution of Co-Working Places: Drivers and Possibilities". In: *Intelligent Buildings International* 9.3, pp. 164–175.

Koren, Y. et al. (2013). "Open-Architecture Products". In: *CIRP Annals* 62.2, pp. 719–729. URL: https://www.sciencedirect.com/science/article/pii/S0007850613002023#!.

Kosinski, Michal, David Stillwell, and Thore Graepel (2013). "Private Traits and Attributes are Predictable from Digital Records of Human Behavior". In: *Proceedings of the National Academy of Sciences* 110.15, pp. 5802–5805.

Kostka, Genia (2019). "China's Social Credit Systems and Public Opinion: Explaining High Levels of Approval". In: *New Media & Society* 21.7, pp. 1565–1593. URL: https://journals.sagepub.com/doi/full/10.1177/1461444819826402#articleCitationDownloadContainer.

Kramer, Adam D. I., Jamie E. Guillory, and Jeffrey T. Hancock (2014). "Experimental Evidence of Massive-scale Emotional Contagion through Social Networks". In: *Proceedings of the National Academy of Sciences* 111.24, pp. 8788–8790.

Laakso, Mikael et al. (2011). "The Development of Open Access Journal Publishing from 1993 to 2009". In: *PloS ONE* 6.6, e20961. DOI: https://doi.org/10.1371/journal.pone.0020961.

Ledyard, John O. (1994). "Public Goods: A Survey of Experimental Research". Pasadena, CA.

Lessig, Lawrence (1999). *Code: And other Laws of Cyberspace*. New York: Basic Books.

Leydesdorff, Loet (2006). *The Knowledge-Based Economy: Modeled, Measured, Simulated*. Boca Raton, FL: Universal Publishers.

Liang, Fan et al. (2018). "Constructing a Data-Driven Society: China's Social Credit System as a State Surveillance Infrastructure". In: *Policy & Internet* 10.4, pp. 415–453.

Lloveras, Javier, Gary Warnaby, and Lee Quinn (2020). "Mutualism as Market Practice: An Examination of Market Performativity in the Context of Anarchism and its Implications for Post-Capitalist Politics". In: *Marketing Theory* 20.3, pp. 229–249. DOI: 10.1177/1470593119885172.

Lorenz, Jan et al. (2011). "How Social Influence can Undermine the Wisdom of Crowd Effect". In: *Proceedings of the National Academy of Sciences of the United States of America* 108.22, pp. 9020–9025. DOI: 10.1073/pnas.1008636108.

Mackay, Charles (1841). *Extraordinary Popular Delusions and The Madness of Crowds*. Original E. London: Farrar, Straus and Giroux.

MakeCity (2018). *Make City — A Festival for Architecture and Urban Alternatives*. URL: https://makecity.berlin/%20http://makecity.berlin/.

Malik, Sahil (2018). *Identify Voices with Microsoft Cognitive Services*. URL: https://www.codemag.com/article/1807031/Identify-Voices-with-Microsoft-Cognitive-Services.

Mandel, Thomas and Gerard Van Der Leun (1996). *Rules of the Net: Online Operating Instructions for Human Beings*. New York: Hyperion Press.

Mann, Richard P. and Dirk Helbing (2017). "Optimal Incentives for Collective Intelligence". In: *Proceedings of the National Academy of Sciences* 114.20, pp. 5077–5082.

Mansour, Essam et al. (2016). "A Demonstration of the Solid Platform for Social Web Applications". In: *Proceedings of the 25th International Conference Companion on World Wide Web*, pp. 223–226.

Marshall, Philip J., Chris J. Lintott, and Leigh N. Fletcher (2015). "Ideas for Citizen Science in Astronomy". In: *Annual Review of Astronomy and Astrophysics* 53, pp. 247–278.

Martin, Nicole (2019). *How Much does Google Really Know About You? A Lot.* URL: https://www.forbes.com/sites/nicolemartin1/2019/03/11/how-much-does-google-really-know-about-you-a-lot/?sh=55f44697f5d1.

Martins, Nuno R. B. et al. (2019). "Human Brain/Cloud Interface". In: *Frontiers in Neuroscience* 13.3. DOI: 10.3389/fnins.2019.00112.

May, Robert M., Simon A. Levin, and George Sugihara (2008). "Ecology for Bankers". In: *Nature* 451.7181, pp. 893–894.

McFarland, Dennis J. et al. (2008). "Emulation of computer mouse control with a noninvasive brain-computer interface". In: *Journal of Neural Engineering* 5.2, pp. 101–110. DOI: 10.1088/1741-2560/5/2/001.

McLaughlin, Catriona (2013). *Acxiom: Die Besserwisser*. URL: https://www.zeit.de/2013/28/acxiom.

Menger, Marie-Eve (2020). ""WirVsVirus" — Erfahrungen beim Hackathon". In: *Information-Wissenschaft & Praxis* 71.4, pp. 236–238. DOI: https://doi.org/10.1515/iwp-2020-2097. URL: https://www.degruyter.com/view/journals/iwp/71/4/article-p236.xml.

Mollick, Ethan (2014). "The dynamics of Crowdfunding: An Exploratory Study". In: *Journal of Business Venturing* 29.1, pp. 1–16.

Mollick, Ethan and Ramana Nanda (2016). "Wisdom or Madness? Comparing Crowds with Expert Evaluation in Funding the Arts". In: *Management Science* 62.6, pp. 1533–1553. DOI: 10.1287/mnsc.2015.2207.

Mullainathan, Sendhil and Richard H. Thaler (2000). *Behavioral Economics*. Tech. rep. DOI: 10.3386/w7948.

Murray-Rust, Peter (2008). "Open Data in Science". In: *Nature Precedings*. DOI: https://doi.org/10.1038/npre.2008.1526.1.

Musk, Elon (Oct. 2019). "An Integrated Brain-Machine Interface Platform With Thousands of Channels". In: *Journal of Medical Internet Research* 21.10. DOI: 10.2196/16194.

Nakamoto, Satoshi (2019). *Bitcoin: A Peer-to-Peer Electronic Cash System*. URL: https://bitcoin.org/bitcoin.pdf.

Opris, Ioan et al. (2020). "Editorial: Nanotechnologies in Neuroscience and Neuroengineering". In: *Frontiers in Neuroscience* 14.2, pp. 12–15. DOI: 10.3389/fnins.2020.00033.

Ostrom, Elinor (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge, UK: Cambridge University Press.

— (1999). "Institutional Rational Choice". In: *Theories of the policy process*, pp. 35–72.

— (2009). *Understanding Institutional Diversity*. Princeton: Princeton University Press.

— (2010). "Beyond Markets and States: Polycentric Governance of Complex Economic Systems". In: *American Economic Review* 100.3, pp. 641–672.

Ostrom, Elinor et al. (1994). *Rules, Games, and Common-Pool Resources*. Michigan: University of Michigan Press.

Page, Scott E. (2008). *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*. Princeton: Princeton University Press.

Palfrey, Thomas R. and Jeffrey E. Prisbrey (1997). "Anomalous Behavior in Public Goods Experiments: How Much and Why?" In: *The American Economic Review* 87.5, pp. 829–846.

Pasquale, Frank (2015). *The Black Box Society*. Cambridge, MA: Harvard University Press. URL: https://www.amazon.de/Black-Box-Society-Algorithms-Information/dp/0674368274.

Payne, Adrian F., Kaj Storbacka, and Pennie Frow (2008). "Managing the Co-creation of Value". In: *Journal of the Academy of Marketing Science* 36.1, pp. 83–96.

Persky, Joseph (1995). "The Ethology of Homo Economicus". In: *Journal of Economic Perspectives* 9.2, pp. 221–231.

Phelan, Steven E. (2001). "What is Complexity Science, Really?" In: *Emergence, A Journal of Complexity Issues in Organizations and Management* 3.1, pp. 120–136.

Posner, Eric A. and E. Glen Weyl (2017). "Quadratic Voting and the Public Good: Introduction". In: *Public Choice* 172.1-2. DOI: 10.1007/s11127-017-0404-5.

Prahalad, Coimbatore K. and Venkat Ramaswamy (2004). "Co-creation Experiences: The Next Practice in Value Creation". In: *Journal of Interactive Marketing* 18.3, pp. 5–14.

Praneo (2016). *Caterpillar Business Case*.

Pyka, Andreas and Horst Hanusch (2006). *Applied Evolutionary Economics and the Knowledge-Based Economy*. Cheltenham, UK: Edward Elgar Publishing.

Ramaswamy, Venkat and Kerimcan Ozcan (2014). *The Co-creation Paradigm*. Stanford, California: Stanford University Press.

Reserve Bank of India (2020). *Assessment of the Progress of Digitisation from Cash to Electronic*. URL: https://www.rbi.org.in/Scripts/PublicationsView.

aspx?id=19417%20https://m.rbi.org.in/Scripts/PublicationsView.aspx?id=18745.

Rhaman, Shibley (2013). *"Co-epetition" — How Collaborative Competition Might Ultimately Benefit the Patient*. URL: http://shibleyrahman.com/tag/co-epetition/.

Roth, Alvin E. (2015). *Who gets What — and Why: The New Economics of Matchmaking and Market Design*. Boston: Houghton Mifflin Harcourt.

Ruths, Derek and Jürgen Pfeffer (2014). "Social Media for Large Studies of Behavior". In: *Science* 346.6213, pp. 1063–1064.

Salman, Aslam (2021). *Facebook by the Numbers: Stats, Demographics & Fun Facts*. URL: https://www.omnicoreagency.com/facebook-statistics/.

Sassen, Saskia (June 2011). *Open Source Urbanism*. URL: https://www.domusweb.it/en/opinion/2011/06/29/open-source-urbanism.html.

Seele, Peter, Claus Dierksmeier, et al. (2019). "Mapping the Ethicality of Algorithmic Pricing: A Review of Dynamic and Personalized Pricing". In: *Journal of Business Ethics*, pp. 1–23. DOI: https://doi.org/10.1007/s10551-019-04371-w. URL: https://link.springer.com/article/10.1007/s10551-019-04371-w#citeas.

Seele, Peter, Christoph D. Jia, and Dirk Helbing (2019). "The New Silk Road and its Potential for Sustainable Development: How Open Digital Participation could make BRI a Role Model for Sustainable Businesses and Markets". In: *Asian Journal of Sustainability and Social Responsibility* 4.1. DOI: https://doi.org/10.1186/s41180-018-0021-3.

Shoham, Yoav and Moshe Tennenholtz (1994). *Co-Learning and the Evolution of Social Activity*. Tech. rep. Department of Computer Science, Stanford University.

Simon, Herbert A (1996). "Designing Organizations for an Information-Rich World". In: *International Library of Critical Writings in Economics* 70, pp. 187–202.

Smith, Adam (1759). *The Theory of Moral Sentiments*. London: A. Miller.

Smith, Vernon L. (1976). "Experimental Economics: Induced Value Theory". In: *The American Economic Review* 66.2, pp. 274–279.

Solon, Olivia (Nov. 2017). *Ex-Facebook President Sean Parker: Site Made to Exploit Human 'Vulnerability'*. URL: https://www.theguardian.com/technology/2017/nov/09/facebook-sean-parker-vulnerability-brain-psychology.

Soon, Chun Siong et al. (2013). "Predicting Free Choices for Abstract Intentions". In: *Proceedings of the National Academy of Sciences* 110.15, pp. 6217–6222.

Stanton, Steven J., Walter Sinnott-Armstrong, and Scott A. Huettel (Sept. 2017). "Neuromarketing: Ethical Implications of its Use and Potential Misuse". In: *Journal of Business Ethics* 144.4, pp. 799–811. DOI: 10.1007/s10551-016-3059-0.

Strife, Sim (2007). *Sentient World: War Games on the Grandest Scale*. URL: https://www.theregister.com/2007/06/23/sentient_worlds/.

Surowiecki, James (2005). *The Wisdom of Crowds*. New York: Anchor Books.

Sveriges Riksbank (2020). *The Payment Behaviour of the Swedish Population*. URL: https://www.riksbank.se/en-gb/statistics/statistics-on-payments-banknotes-and-coins/payment-patterns/.

Taleb, Nassim Nicholas (2012). *Antifragile: How to Live in a World we don't Understand*. London: Penguin Books, Limited.

Tao, Fei and Qinglin Qi (Sept. 2019). "Make More Digital Twins". In: *Nature* 573.7775, pp. 490–491. DOI: 10.1038/d41586-019-02849-1. URL: https://www.nature.com/articles/d41586-019-02849-1.

Telpaz, Ariel, Ryan Webb, and Dino J. Levy (2015). "Using EEG to Predict Consumers' Future Choices". In: *Journal of Marketing Research* 52.4, pp. 511–529.

The Guardian (2013). *"The NSA Files", Collection of Articles*. URL: https://www.theguardian.com/us-news/the-nsa-files.

The White House (2015a). *Administration Discussion Draft: Consumer Privacy Bill of Rights Act of 2015*.

— (2015b). *Nation of Makers*. URL: https://obamawhitehouse.archives.gov/nation-of-makers.

Thompson, Stuart A. and Charlie Warzel (2019). *Twelve Million Phones, One Dataset, Zero Privacy*. URL: https://www.nytimes.com/interactive/2019/12/19/opinion/location-tracking-cell-phone.html.

Tombini, Mario et al. (2012). "Combined Analysis of Cortical (EEG) and Nerve Stump Signals Improves Robotic Hand Control". In: *Neurorehabilitation and Neural Repair* 26.3, pp. 275–281. DOI: 10.1177/1545968311408919.

Topol, Eric J. and Dick Hill (2012). *The Creative Destruction of Medicine: How the Digital Revolution Will Create Better Health Care*. New York: Basic Books.

Torvalds, Linus and David Read By-Diamond (2001). *Just for Fun: The Story of an Accidental Revolutionary*. New York: Harper Collins.

Troxler, Peter and Patricia Wolf (2010). "Bending the Rules: The Fab Lab Innovation Ecology". In: *11th International CINet Conference*. Zurich, Switzerland, pp. 5–7.

Tufekci, Zeynep (2014). "Engineering the Public: Big Data, Surveillance and Computational Politics". In: *First Monday* 19.7. DOI: https://doi.org/10.5210/fm.v19i7.4901.

Van Holm, Eric (2014). "What are Makerspaces, Hackerspaces, and Fab Labs?" In: *SSRN Electric Journal*. DOI: http://dx.doi.org/10.2139/ssrn.2548211.

Vogel, John H. and Benjamin S. Moll (2014). "Crowdfunding for Real Estate". In: *The Real Estate Finance Journal* 30.1, pp. 5–16.

Wachter, Sandra, Brent Mittelstadt, and Luciano Floridi (2017). "Transparent, Explainable, and Accountable AI for Robotics". In: *Science Robotics* 2.6.

Walker, Brian et al. (2002). "Resilience Management in Social-Ecological Systems: A Working Hypothesis for a Participatory Approach". In: *Ecology and Society* 6.1. DOI: 10.5751/es-00356-060114.

Weber, Steve (2009). *The Success of Open Source*. Cambridge, MA: Harvard University Press.

Whipps, J. M., K. Lewis, and R. C. Cooke (1988). "Mycoparasitism and Plant Disease Control". In: *Fungi in Biological Control Systems*. Manchester: Manchester University Press, pp. 161–187.

Willinsky, John (2006). *The Access Principle: The Case for Open Access to Research and Scholarship*. Cambridge, MA: MIT Press.

Witkowski, Krzysztof (2017). "Internet of Things, Big Data, Industry 4.0 — Innovative Solutions in Logistics and Supply Chains Management". In: *Procedia Engineering* 182, pp. 763–769.

Woolley, Anita Williams et al. (2010). "Evidence for a Collective Intelligence Factor in the Performance of Human Groups". In: *Science* 330.6004, pp. 686–688.

World Economic Forum (2011). *Personal Data: The Emergence of a New Asset Class*. URL: http://www3.weforum.org/docs/WEF_ITTC_PersonalDataNewAsset_Report_2011.pdf.

— (2012). *Rethinking Personal Data: Strengthening Trust*. Tech. rep. Davos.

World Wide Fund For Nature (2020). *One Planet City Challenge*. URL: https://wwf.panda.org/projects/one_planet_cities/one_planet_city_challenge/%20http://wwf.panda.org/our_work/projects/one_planet_cities/one_planet_city_challenge/.

Worthington, Steve (1995). "The Cashless Society". In: *International Journal of Retail & Distribution Management* 23.7, pp. 31–40.

Wright, Robert (2001). *Nonzero: The Logic of Human Destiny*. New York: Vintage.

Wu, Dazhong et al. (2012). "Towards a Cloud-Based Design and Manufacturing Paradigm: Looking Backward, Looking Forward". In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference*. Vol. 45011. American Society of Mechanical Engineers, pp. 315–328.

Youyou, Wu, Michal Kosinski, and David Stillwell (2015). "Computer-Based Personality Judgments are More Accurate than those Made by Humans". In: *Proceedings of the National Academy of Sciences* 112.4, pp. 1036–1040.

Zelmer, Jennifer (2003). "Linear Public Goods Experiments: A Meta-Analysis". In: *Experimental Economics* 6.3, pp. 299–310. DOI: 10.1023/A:1026277420119. URL: http://link.springer.com/10.1023/A:1026277420119.

Zuboff, Shoshana (2019). *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*. New York: Hatchett.