**Chapter 3: The Use of Contextual Knowledge in a Digital Society**

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**Abstract**

Recent advancements in Information and Communication Technology (ICT), the expansion of the Internet and big data tools, have come to predominantly determine the way in which we generate, store, communicate or exchange information. This chapter examines ICT-enabled platforms that aid in information aggregation. It contrasts such platforms with a well-known, traditional platform for knowledge aggregation, viz., the market. In doing so, it highlights the relevance of the Socialist Calculation Debate that took place among economists in the past. It argues that ICT-enabled platforms may still face limitations: the aggregation of contextual, tacit knowledge; the lack of effective coordination devices; as well as the lack of criteria to discipline the data generated, among other things. Even if it does not constitute an effective centralised aggregation mechanism, ICT has facilitated the formation of decentralised, non-market platforms (markets without prices), which offer novel ways of utilising dispersed information.

* 1. **Introduction**

How can knowledge that is scattered among millions of individuals in a society be mobilised and utilised in the best possible way? The importance of this question is rather self-evident. However, any reasonable answer to this question would depend on a variety of factors. To start with, the way in which a society is organised at the time of this consideration is an important factor. It may also depend on the state of relevant prevailing technological, institutional factors which govern how information is exchanged in a society. There may be difficulties that arise in unambiguously determining a unique best way to accomplish this monumental task in principle. Instead, one may have to be content with relatively better alternatives that are available in a society.

In the case of our current society, advancements in information and communication technology (ICT) have come to predominate the determination of the way in which we generate, store and communicate or exchange information. The development of the Internet, or more broadly Web 2.0, has enabled millions of individuals to interact, collaborate and share knowledge. These technologies have led to the production of digital data on a massive scale and variety that surpasses levels which existed at any point of time in history. This situation has often been referred to as the beginning of the big data era. In addition, developments in computational intelligence and machine learning have also placed a variety of tools at our disposal that enable us to process these massive volumes of data and synthesise into useful information.

The problem of knowledge or information aggregation is not unique to a digital society. In fact, this has been the subject of an important debate in the history of economic analysis that took place during the first half of the twentieth century, viz., the socialist calculation debate. This debate concerns the possibility of a planned economy performing (replicating) economic calculations (or computations) in relation to a market economy. Such calculations naturally involve a wide variety of information concerning relative scarcities, determining the optimal allocation of resources and prices in the economic system. We focus on an important contribution to this debate by Friedrich Hayek, which recast the fundamental nature of the economic problems facing a society as constituting a knowledge aggregation problem. He focused on the relative merits of markets and the efficacy of price as a coordinating device in aggregating knowledge that is dispersed among different actors. His broad conclusion was that with a centralised mechanism, it would be impossible to aggregate the relevant knowledge for it is often fragmented, incomplete (never available in its entirety to a single person), tacit and often contextual. For him, there was no rival mechanism that would have been effective like the decentralised market that coordinates the actions of individuals through price signals.

However, ICT-enabled technologies are increasingly seen as offering an effective way to mobilise knowledge that is dispersed among individuals. Big data and machine learning together offer individuals the ability to economize from the search of vast, relevant knowledge so that they can make a variety of decisions. Nevertheless, are there limits concerning the extent to which ICT-enabled digital technologies can aid in the utilisation of knowledge? Is this data-driven approach capable of handling all forms of knowledge that exist in a society? To what extent can they augment or replace other forms or modes through which decentralised knowledge has been aggregated in the past? These are questions that we aim to address in this chapter.

The chapter is organised as follows. In Section [2,](#page3) we provide an overview of the socialist calculation debate and focus on Hayek's important contribution to this debate. In Section 3, we outline the developments that govern the way in which knowledge is used and exchanged in a digital society. We sketch how markets and many modes of ICT-enabled platforms can be viewed as information aggregation platforms. Section 4 explores the features that distinguish the ICT-enabled platform and explores some of its limitations, in particular, those that concern lack of disciplining constraints on the data generated by these platforms. Section 5 outlines the new possibilities that are offered by ICT-enabled platforms, such as matching, that constitute non-market coordination devices.

* 1. **Hayek, calculation debate and knowledge**

Friedrich Hayek (1899-1992), considered to be one of the titans of economic theory in the twentieth century, made a seminal contribution to the socialist calculation debate that forms an important backdrop for the themes discussed in this chapter. Hayek advanced the Austrian tradition in economics in several original and important ways, but he is more than just an economist. He was an interdisciplinary scholar with works that inspired many later developments in a variety of areas such as complex systems, neural networks, philosophy, law, and methodological individualism. He was also awarded the Nobel memorial prize in economics in 1974. We will focus on his contribution to the idea of contextuality and knowledge, which are related to the theme of this volume. To understand this better, a brief description of the socialist calculation debate - an important theoretical debate in economic theory - may be apposite at this point.

**3.2.1 Socialist Calculation Debate**

The socialist calculation debate centered around the feasibility and relative efficiency of the socialist mode of economic organization. This mode relying on central planning and common ownership and its ability to perform (replicate) economic calculation on a par with a society organised in the capitalistic mode was questioned. The relative superiority of central planning vis-à-vis a decentralised market-based mechanism in the allocation of capital, labour and other resources was one of the topics that was intensely debated. It is considered to be one of the most important debates in economic theory, the debate broadly between Austrian economists, neoclassical economists and market socialists.[[1]](#footnote-1)

The calculation debate started with Ludvig von Mises’ essay (von Mises [1920)](#page21) entitled ‘Economic Calculation in the Socialist Commonwealth’, in which he challenged the feasibility of rational economic planning within socialism in the absence of private ownership. Among the responses, Oscar Lange in his essay ‘On the Economic Theory of Socialism’ (Lange 1936, [1937)](#page20) claimed that once the same set of information available to a theoretical market economy is presented to a central planning board, the latter will be able to devise mechanisms that replicate and achieve the optimum allocation of resources. In doing so, Lange in fact utilised the Walrasian general equilibrium analysis, a benchmark theoretical model of the market-based economy, in making his case for such a possibility. Under the original Walrasian formulation, an economy can be seen as a set of equations. Thus, there should be no need for prices. Once the information about available resources and people’s preferences are given, it should be possible to calculate the optimal solution for resource allocation. Lange even went on to propose a procedure in the form of an actual computing algorithm through which allocation could be accomplished by a centrally planned economy. In other words, his proposal was meant to be a non-market based alternative that would be able to achieve the optimal allocation of resources in an economy.

Among the many scholarly exchanges on this topic, Hayek later made an important contribution that is often regarded as the most ‘influential single article in the debate’ (Levy and Peart 2008). A remarkable aspect of Hayek's contribution lies in placing the crucial role of knowledge, in particular, contextual knowledge, at the centre of this debate. His paper is considered to be a classic even today and featured as one of the 20 most important articles in the American Economic Review in the 100 years since its inception (Arrow et al. 2011). This article (Hayek 1945) has since been constantly re-examined in light of the subsequent advancements in information technology and computing (Cockshott and Cottrell 1997; Lavoie [1985)](#page20). In the following subsection, we provide an overview of this article to set the stage for our later analysis.

**3.2.2 The use of knowledge in a society**

In departing from the dominant theoretical outlook concerning the functioning of a decentralised market economy that underpinned the socialist calculation debate, Hayek ventured to completely reformulate the focus of the problem at hand. For him, there was a wedge and the economic problem that faced the society was quite different from the manner in which it was conceived within neoclassical economic theory. The problem was perceived by many who were participating in the debate as that of finding the best available use of the resources available in a society and the conditions under which this could be accomplished. Although the goal in itself may not have been impediment, the problem formulation was severely mistaken according to Hayek. It assumed that a problem solver was presented with all of the relevant information, the knowledge regarding all of the available means and starts with a given system of preferences. Conditional on this being available in its entirety to a single mind, the problem was to find the best possible use of the available means in a society.

Hayek argued that the actual economic problem was not the one above, but that it was instead a problem of the effective utilisation of the knowledge in a society. If so, what might be the nature of this knowledge? Hayek pointed out that the data concerning the availability of resources, preferences, associated and relevant knowledge is never available to a single mind to perform the economic calculation outlined earlier. Hayek argued that, by its very nature, such knowledge is dispersed among a multitude of individuals in an economy, where everyone knows only bits and pieces, but never the knowledge in its entirety.

The peculiar character of the problem of a rational economic order is determined precisely by the fact that the *knowledge of the circumstances of which we must make use* never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society… is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. (Hayek 1945, p.519-520, italics added)

Hayek asked which of the available arrangements - market-based or a centrally planned economy - is better disposed to solving the knowledge problem. The answer to this question, of course, will depend on the kind of knowledge (scientific, contextual, tacit and so on) that we are talking about. In particular, when analysing at the level of the whole society, the relative importance of different forms of knowledge becomes important. He argued that a substantial part of the knowledge that is relevant in this context is subjective, tacit (Polanyi 1966) and often unorganised. Consequently, it would be infeasible for individuals to make all of this knowledge readily available to a planner to carry out computations. For him, ‘the knowledge of the circumstances’ is a crucial element to be confronted with when one tries to understand the economic problems facing the society. In our view, it is straightforward to interpret unorganised or dispersed knowledge - knowledge of the particular circumstances of time and place - as contextual knowledge. Hayek went on further to add that this form of knowledge cannot be easily summarised in an aggregate, statistical form since it is highly contextual and these important differences associated with context are necessarily obscured in trying to summarise them as statistical aggregates.

... I should briefly mention the fact that the sort of knowledge with which I have been concerned is knowledge of the kind which by its nature cannot enter into statistics and therefore cannot be conveyed to any central authority in statistical form. The statistics which such a central authority would have to use would have to be arrived at precisely by abstracting from minor differences between the things, by lumping together, as resources of one kind, items which differ as regards location, quality, and other particulars, in a way which may be very significant for the specific decision. **It follows from this that central planning based on statistical information by its nature cannot take direct account of these circumstances of time and place, and that the central planner will have to find some way or other in which the decisions depending on them can be left to the “man on the spot.”** (Hayek 1945, p.524, emphasis added)

If knowledge is in fact dispersed, contextual and often tacit as Hayek points out, then how does society tackle this problem of economic calculation - i.e., the efficient (at least reasonably) allocation of the available resources? To understand this, one can view the market as an institutional arrangement, which attempts to pool together or aggregate the ‘knowledge of the particular circumstances of time and place’ that is dispersed among many interdependent agents across space. This interdependence can be interpreted as a *distributed network* in modern parlance.

Even if we adopt the view that the market is an interdependent, institutional arrangement or a network of individuals, economising knowledge (and resources) in a society involves a continuous, dynamic coordination of the actions of the various individuals who supply and demand these resources and products. Therefore, what the market eventually does with this pooled dispersed knowledge is important. Hayek, along the lines of von Mises, argues that markets generate prices (which are symbols, signals or indicators) that aid in economising on the amount of knowledge required by any one agent. Prices, therefore, *emerge* as a result of the market activity that pools together the dispersed knowledge in an economy. They are *emergent* in the following sense: as Hayek states, these prices as numerical or quantitative indices “cannot be derived from any property possessed by that particular thing, but which reflects, or in which is condensed, its significance in view of the whole means-end structure.” (Ibid, p. 525). A market can be viewed as playing the role of aggregating information and generating “sufficient statistics” in the form of prices. These emergent prices, in turn, act as coordination devices that help actors to economise on the amount of knowledge that any particular individual needs to possess or know to make market decisions.

Which of the events which happen beyond the horizon of his immediate knowledge are of relevance to his immediate decision, and *how much of them need he know*? (Ibid, p. 525; Italics added)

The most significant fact about this system is the economy of knowledge with which it operates, or *how little the individual participants need to know* to be able to take the right action. (Ibid, pp. 526-527; Italics added)

For instance, a decision maker or an entrepreneur in any one place does not have to concern himself with all of the potential causes that can alter the demand elsewhere and to seek the relevant knowledge on this. In Hayek’s view, he will simply have to look at prices since they reflect the underlying scarcity in an economy. Although Hayek was writing at a time when ideas concerning network science were not readily available, he nevertheless incorporated some of these concepts implicitly. For example, the amount of search that an individual has to undertake can be seen as the network distance that exists between the ‘man on the spot’ and all of the knowledge that is relevant (and required) to make his decision. In a market economy, this involves only a single degree of separation. The dramatic shortening of network distance is due to the existence of emergent prices, indices or sufficient statistics (Fig. 3.1). With prices, each decision maker “will have to consider only these *quantitative indices (or ‘values’) in which all the relevant information is concentrated*.” (Ibid, p. 525; Italics added) These indices incorporate all of the relevant knowledge, including contextual and tacit knowledge. Using this concept, Hayek advanced the argument that a free market system is well-equipped to solve the knowledge problem, while a centrally planned system is not.

[Place Fig. 3.1 about here]

We can interpret the entire system of prices as a second-level knowledge network that emerges from the underlying network (as shown in Fig. 3.1). The first-level network can thus be seen as network of agents from which a second-level network of symbols emerge. These symbols compress relevant knowledge and help agents to deal with the dispersed, contextual knowledge and with it in a way to reckon with the complexity of the system in which they operate. However, the efficacy of this mechanism in this network formulation is contingent on whether there is a sufficient overlap among the agents in the first-level network. Leaving that aside, the idea that these symbols “can act to coordinate the separate actions of different people in the same way as subjective values help the individual to coordinate the parts of his plan.” (Ibid, p. 526). This referred to as the Hayek hypothesis, which has received considerable attention in the field of experimental economics (Smith 1982).

In sum, Hayek’s argument that markets pool contextual knowledge efficiently to generate prices and help to coordinate the actions of individuals is an important insight. For Hayek, there has not been an alternative or rival mechanism that effectively coordinates actions in the way that markets and prices do.

All that we can say is that nobody has yet succeeded in designing an alternative system in which certain features of the existing one can be preserved which are dear even to those who most violently assail it - such as particularly the extent to which the individual can choose his pursuits and consequently freely use his own knowledge and skill. (Hayek 1945, p. 528)

However, are prices the only exclusive symbols that exist in a society? What has not been addressed in [Hayek (1945)](#page19) is the role and significance of non-price symbols, and how these non-price symbols interact with a ‘man on the spot’. There are other coordination devices that exist in an economy which help align the actions of individuals (Manzini, Sadrieh and Vriend [2009)](#page20). On the other hand, several advancements in information technology have enabled us to re-conceptualise what we traditionally think of as data. In the next section, we will investigate the relevance of Hayek’s view in the context of the socialist calculation debate to a society that is increasingly becoming digital and in which information access has advanced dramatically.

3.3. **Knowledge and the digital society**

A remarkable change in the society in which we currently live concerns the way in which information is stored, exchanged and utilised for making a variety of day-to-day decisions. Formidable developments in computational tools, information and communication technology have revolutionised the way in which we generate and exchange information, notably with the increasing penetration of the Internet throughout the world. Its increasing penetration has extended to various aspects of social life, ranging across the devices that we use, such as phones, watches, cars, washing machines, televisions, and personal assistants, among others. Computing information is no longer restricted to desktops alone; it has become ubiquitous across devices and space. This ubiquitous or pervasive computing has been partly facilitated by the rapid increase in the use of various hand-held devices and the growing popularity of social media. These developments have resulted in an information-rich environment where human beings now operate. Consequently, more and more aspects of our lives are being recorded and quantified in ways that were impossible to conceive of a few decades ago.

The manner in which information is exchanged and used within this larger framework has been succinctly synthesised in Figure 3.2. The left panel summarises the way in which information or data is collected or pooled from a variety of electronic digital devices that individuals own, such as a computers, watches, tablets or smart phones. These devices are connected to a common platform via the Internet. However, information flow in this case is not just unidirectional since the data pooled from other agents can be aggregated or processed. This synthesised or processed information can be accessed by other individuals who might need it for their decisions. Some of the examples include the United Nations’ project on Global Pulse, Google Flu Trends, Google Glass, and Street Bump (Table 3.1). In some cases, the information relayed back to the agent is merely informative as in the case of on-line restaurant reviews. In some other cases such as Environmental Teapot, BinCam, and smart mirror (Table 3.1), information signals are used to actively persuade or ‘nudge’ agents to behave or make decisions in a specific way.[[2]](#footnote-2)

[Place Fig. 3.2 about here]

In addition to ubiquitous computing, we find that the various physical digital devices constitute a network over which they routinely interact with each other and the individual (Figure 3.2, the right panel). Typically, stationary or mobile objects are endowed with a digital sensor that enables these objects to continuously collect information regarding their environment, ranging from temperature, humidity and suspended matter in the air to pedestrian intensity and even conversations. All of this information can be pooled into a platform that in turn is a source of very rich information.[[3]](#footnote-3) This is popularly referred to as the Internet of Things [(IoT)(Westerlund,](#page21) Leminen, and Rajahonka 2014). It facilitates real-time information sharing between agents and devices and this could be useful for increasing the quality of decision-making in a variety of ways. Some examples include BinCam, Environmental Teapot, smart mirror, smart carpet or smart belt, as well as intelligent personal assistants (Table 3.1).

Table 3.1 New Data Collection Device

|  |  |
| --- | --- |
| Description | Related Research |
|  |  |
| Global Pulse | [Kirkpatrick (2014)](#page20) |
| Google Flu Trends | [Ginsberg et al. (2009)](#page19) |
| Google Glass | [Ackerman (2013)](#page18) |
| Street Bump | [Schwartz (2012)](#page21) |
| Traffic D4V | [Picone, Amoretti and Zanichelli (2012)](#page20) |
| BinCam | [Comber and Thieme (2013)](#page19) |
| Environmental Teapot | [Marres (2012)](#page20) |
| Smart Mirror | [Pantano and Nacarato (2010)](#page20) |
| Smart Carpet | [Aud et al. (2010)](#page18) |
| Smart Belt | [Shieh, Guu, and Liu (2013)](#page21) |
|  |  |

**3.3.1 Big data**

Another distinguishing feature related to increasing digitisation in our society concerns the vastness of data in regard to the diverse domains of human activities that are available for analysis. This situation has to with advancements in data-collection and archiving processes. It can be referred to as the big-data phenomenon.[[4]](#footnote-4) The amount of data available for academic and commercial research has seen an exponential growth in the past decade that has opened many new possibilities and avenues for rich data analysis. In addition to its commercial use, the popularity of this big data phenomenon has been significant across diverse academic disciplines such as computer science, epidemiology, economics, history, particle physics and sociology [(Einav](#page19) and Levin 2014; Varian 2014; Howe et al. 2008). The vastness of this data has increased the hope that a purely data-driven science is possible and that it is well within our reach.

A clear definition of what exactly is big data continues to be hotly de-bated. A widely accepted definition of big data focuses on the 3Vs: volume, velocity and variety. This definition supposedly characterises and distinguishes big data from other forms of data.[[5]](#footnote-5) The volume aspect in the 3V definition captures the continuously increasing magnitude of big data over time. Velocity points us to the high frequency at which the data is being generated and the remarkable increases in the speed at which we are able to process and analyse such data. Variety captures the immense diversity in the types of data that are available today. The idea of data is no longer limited to the structured, tabular or rectangular form as in the past. Data in the form of text, images, video, audio and other types of metadata are increasingly being considered on a par with traditional forms of data. Such non-traditional, semi-structured and unstructured data and parallel developments in computational techniques to analyse such data in terms of machine learning tools have facilitated unprecedented access to studying and understanding big data phenomena that was not possible before.

However, the 3V definition suffers from context specificity in that all of these dimensions stated are relative to a certain time and state of technology. [Chen and Venkatachalam (2017b)](#page19) alternatively provide a process-based definition of big data and argue that it is to be ‘perceived as a continuous, unstructured and unprocessed dynamics of primitives, rather than as points (snapshots) or summaries (aggregates) of an underlying phenomenon’. In view of this definition, big data can be seen, in a given spatio-temporal domain, to be the archive of whatever people said, people did and even people thought. In other words, it is a microscopic, dynamic view of human activities. This view can also be found in [Kirkpatrick (2014,](#page20) p.4):

Global Pulse is interested in trends that reveal something about human well-being, which can be revealed from data produced by people as they go about their daily lives (sometimes known as “data exhaust”). Broadly speaking, we have been exploring two types of data in the Pulse Labs. The first is data that reflects “*what people say*,” which includes publicly available content from the open web, such as tweets, blog posts, news stories, and so forth. The second is data that reflects “*what people do*,” which can include information routinely generated for business intelligence and to optimize sales in a private sector company. An example of “what people do” data is anonymised mobile phone traffic information, which can reveal everything from footfall in a shopping district during rush hour to how a population migrates after a natural catastrophe.

This view of big data helps us to see what is ontologically different about the nature of data available in this information era. On the one hand, data emanating from wearable devices, developments relating to Web 2.0, ubiquitous computing and social media provide unprecedented access to dynamic, organised and unorganised information on human beings at an individual level. On the other hand, advances in machine learning, ICT and artificial intelligence gives us ways to process the data gathered above. For instance, text mining and sentiment analysis are used in an attempt to discover patterns in non-conventional, user-generated forms of data and to aid in extracting useful information from them. According to Aggarwal and Zhai (2012, p.2), “[T]ext mining can be regarded as going beyond information access to further help users analyze and digest information and facilitate decision making.” This is accomplished by a combination of tools and insights from natural language processing and computational linguistics with the aid of computational intelligence. In the case of sentiment analysis, user-generated data has been employed to understand shifts in the sentiments of the agents which could impact economic outcomes and indicators in the aggregate.

Together, these two, i.e., big data and computational intelligence tools, can be seen as accomplishing the function of *information aggregation* in a digital society. Take the example of Google Flu Trends. This pooled information uses a search engine that helps to collect unstructured posts, messages, searches, updates and tweets that are user-generated. This data is in turn used to predict influenza patterns ahead of the Centers for Disease Control and Prevention (CDC) which could potentially help in tackling of issues related to public health. Similarly, the Street Bump app (Table 3.1) relies on motion detectors that are available in our phones to trace the potholes in a city without having to rely on workers to patrol all of the streets. In other words, these applications can be seen as gathering important information possessed by the “man on the spot” (Hayek 1945, p. 524) which is then made available to a health official or a town planner.

In light of this, we can see a potential connection between the issues that Hayek raised for the role of markets in facilitating an effective use of knowledge in a society and the developments related to ICT in the big data era outlined above. They both perform the role of an information aggregation mechanism that is, in particular, related to the case in which information is distributed among many individuals in a society. Both of them feed information back to the society for the individuals who rely on it to make their decisions. This begs the question of the relation and relevance of Hayek’s insight regarding the impossibility of socialist calculation to the digital society. This question will be discussed in the following section.

**3.4 Calculation debate in a digital society?**

In the previous section, we argued that markets and aspects of digital society facilitated by ICT can both be viewed as platforms that aggregate information. Consequently, the digital society may be seen as introducing several non-market information aggregation mechanisms. It may be useful to sketch the process of information aggregation between traditional markets and ICT-enabled platforms. Although both deal with largely unstructured and unorganised, even contradictory, data, there are some essential differences. First, knowledge (or information) is not physically pooled in the case of traditional markets, even while it is placed in a concentrated form on the ICT platforms in one place that can be accessed. Second, in the case of markets, the available dispersed information is acted upon or processed by various ‘men on the spot’. On the other hand, the pooled information can be processed by both human beings and intelligent algorithms in the case of ICT-enabled platforms. Third, the complex, decentralised act of processing dispersed information generates prices, which can be seen as an emergent phenomenon in the case of markets. ICT-enabled platforms, on the other hand, generate a variety of indexes and symbols (for instance, restaurant and movie ratings), but they are not necessarily price equivalents.

We therefore ask whether these ICT-enabled platforms together constitute a credible alternative to the conventional market mechanism? If this is answered in the affirmative, we further ask whether it can perform better than the market in the area of knowledge utilisation and in aiding dynamic coordination among agents? Broadening the scope of the earlier calculation debate, we ask whether information aggregation can be effective enough to achieve the best possible resource allocation, bridging all gaps in supply and demand misalignments, and even avoiding accidents and traffic jams altogether? The relation between ICT and Hayek’s insights on the socialist calculation debate can be investigated in the following ways:

* First, from the digital-society side, if ICT can enable the non-market platforms to aggregate information as markets do, then so would the unique ability of the market mechanism be challenged.
* Second, from the other side, if the socialist calculation debate is fundamentally ICT-irrelevant, i.e., the limitations pointed out by Hayek in this debate are independent of possible advancements in information and communication technology, then this debate can shed light on the future prospects of the digital society. Consequently, it can guide us regarding the natural limitations concerning the role of ICT and the expectations that we can reasonably hold.

**3.4.1 Data discipline**

In order to explore these connections, we need to consider the quality of information aggregation in these modes. [Sunstein (2008)](#page21) made an important observation concerning the quality of information aggregation in the context of blogs that is relevant here. In response to the claim by Posner ([2004)](#page20) that blogs have the ‘potential to reveal dispersed bits of information’, Sunstein argued that there are natural limitations to this mode of information aggregation. It is important to realise that the opinions shared in social media, blogs, and on Twitter are subjective and their contextual or tacit dimension of this knowledge cannot be truly overcome. Furthermore, Sunstein argued, unlike the case of Hayek, there are no price equivalents that perform the role of a coordination device in the case of blogs or other instances of text mining. The lack of effectiveness stems from the fact that price as a coordinating device aligns incentives and guides actions. On the other hand, ICT-enabled information aggregation does not necessarily guarantee that the incentives and actions of the players are always appropriately aligned in a dynamic context. This renders a natural weakness in the quality of knowledge aggregation and its efficacy is severely limited in terms of its role in disciplining adaptive agents.

Participants in the blogosphere usually lack an economic incentive. They are not involved in any kind of trade, and most of the time they have little to gain or to lose. If they spread false-hoods, or simply offer their opinion, it may well be that they sacrifice little or nothing. Perhaps their reputation will suffer, but perhaps not; perhaps the most dramatic falsehoods or at least distortions will draw attention and hence readers. Most bloggers do not have the economic stake of those who trade on markets. (Sunstein 2008, p. 90)

This phenomenon is not limited to blogs alone. It extends to other non-market information aggregation cases such as online reviews, where a lack of robust incentives and possibilities for adverse reinforcement and persistence of sub-optimal options exist (Vriend 2002; Chen and Venkatachalam [2017a,b)](#page19). One way to evaluate the efficiency of information aggregation arising from markets and non-market platforms would be to compare and contrast the success of the predictions, where possible. Let us turn to prediction markets, which provide a relevant example.[[6]](#footnote-6) Prediction markets for electoral outcomes is a case in which information is often private. Agents in such prediction markets trade contracts for which the associated pay-offs typically depend on the future outcomes that are currently unknown (say, election results). The price of trading options is, in a perfect scenario, supposed to act as an aggregate indicator of all of the private information, knowledge or preferences dispersed among different individuals (Berg et al. [2008;](#page18) Rothschild 2015). Note that this is a market for information aggregation with a built-in coordination device.

In addition to prediction markets, we have traditional methods of information aggregation such as opinion polls. The success of their respective predictions of different outcomes give us one way to evaluate the efficiency of information aggregation of these different modes. Prediction markets are seen to increase the accuracy of forecasts concerning diverse social phenomena vis-a-vis traditional forecasting methods. However, these prediction markets are not infallible and there have been several instances in the past where they have proved to be inaccurate. There are perhaps natural limits to both these cases; therefore, it could be argued that their *relative* efficiency in information aggregation should be judged and not their absolute efficiency in relation to actual outcomes. Since our focus here is on ICT-enabled non-market platforms, in particular, the possibility of overcoming the shortcomings of traditional opinion polls (platforms) becomes important. In this case, the expanding, near-universal penetration of social media can provide a way to aggregate opinion in real-time. However, the lack of a credible coordination device pointed out by [Sunstein (2008)](#page21) equally plagues ICT-enabled platforms as well. [Huberty (2015)](#page19) casted doubt on the ability of ICT-enabled platforms such as social media to meaningfully aggregate information to forecast accurately given their nature.

In addition to providing incentives, the prices and other statistics emanating from the markets are subject to several implicit disciplining mechanisms. Some instances of such discipline exerted by markets on the data generated take the form of budget constraints and stock-flow consistencies, which cannot be violated. For instance, let us consider an economy underpinned by agents who have a specific distribution of beliefs and wealth, possess certain learning behaviours and are embedded in a social network of a specific kind, all of which are assumed to be approximated by actual observable data. Let these agents interact in an actual financial market and we can then observe them and generate several statistics concerning prices, their volatility, spread, volume of transactions and so on. A theory of information aggregation starting with the same underlying assumptions about agents and attempting to relate to actual aggregate data and statistics must necessarily be constrained by these disciplining mechanisms of the market on the generated data. Therefore, it is possible to identify the checks and balances while building such a theory. Although ICT-enabled platforms generate various sentiment indices, statistics and non-price symbols, whether they impose discipline on the data that they generate is unclear.[[7]](#footnote-7) Even if such mechanisms were to exist in principle, they do not seem to be readily discernible.

* 1. **Information aggregation and non-market alternatives**

We have seen that the power of markets in knowledge aggregation is intimately tied to the presence of an in-built coordination device, namely a price signal, which aligns incentives. It also successfully matches participants with different needs, who possess different knowledge or expertise in ways that may be mutually beneficial. A question that then arises is whether it is possible to ‘calculate’ or compute without prices, instead of through other symbols. In the big-data era, we do see that some symbols are successfully used as the ‘equivalent’ of price. Similarly, they also help in matching different individuals across space who are unified in their need to connect, with a potential for exchange. We will examine these possibilities in this section.

Let us take the example of the environmental teapot [(Marres, 2012)](#page20). This presents a case of augmented technology that connects an everyday object like a teapot to the electricity grid. The pooled information takes into account the real-time surge in electricity consumption and gives signals as to when it is a good time to brew one’s tea. Here, the green and red lights act as non-price signals that help to coordinate the actions of the individuals who are sensitive to the overall, collective demand that prevails at any given point in time. A similar example can be found in the case of the BinCam (Comber and Thieme 2013). This is another persuasive technology which enables the possibility to record and share images of waste that is thrown away onto a network consisting of other individuals. This signal, which can be seen as a disciplining device, leads to self-reflection and a re-evaluation of the actions by those who are concerned about the environment.

The idea behind these two experiments is to combine the use of social norms and persuasive technology. Instead of solely relying on prices to reflect the composition of preferences or the supply and demand of various resources, the norms and technology allow preferences to be modified or changed to be consistent with prices through the use of persuasive technology. There are surely some ethical concerns about the use of these or variants of these technologies in manipulating behaviour. However, they highlight the potential for the use of digitally-enabled persuasive technology to help facilitate the economic calculations traditionally left to prices and the market. In doing so, it is not simply an economic calculation, given preferences, as in the case of the economic calculation as seen in the socialist calculation debate that Hayek was criticising. Instead, it resorts to the active formation or evolution of preferences mediated by social norms and social influences that is even paternalistic in a sense. Our intention here is not to justify such paternalism or to reject it outright, but instead, to highlight the role of non-price equivalents in shaping behaviour that influences resource utilisation.

**3.5.1 Matching**

If one takes a slightly broader view of markets, one quickly realises that some of the markets that we encounter today do not in fact observe prices as co-ordination devices. This brings us to the idea of matching. At least since [Gale](#page19) [and Shapley (1962),](#page19) an impressive literature has developed on matching and market design. There are applications of this idea to marriage, dating platforms, school admission, college admissions, organ exchange and donation (Roth and Sotomayo 1992; Abdulkadiroglu and Sonmez 2013). In these markets, there are no explicit prices that are available to coordinate and solve the ‘economic calculation’ and they may not even be necessary. Instead, these platforms work by relying on other signals to achieve successful pairing between those who seek and those who are willing to supply an item in question. Even though many ICT-enabled information aggregation platforms cannot generate prices, they may still be very helpful in enhancing and widening these ‘markets without a price’ by providing a platform to achieve productive matching.

In addition, there are also examples of matching which bring together people with common goals. This knowledge concerning individuals with such common goals or interests is highly contextual and dispersed, and is typically not mediated through price signals. These arrangements often help achieve common goals that are not possible with individual effort alone. Examples of such arrangements include peer production, crowdsourcing and crowd funding. In peer production, individuals voluntarily get together, collaborate and produce goods, services and knowledge. Crowdsourcing involves pro-social behaviour and is also a collaborative model of production that brings together services and knowledge from dispersed people across space. Crowd funding mobilises resources and investors in novel ways to search, communicate and reach out to people across space. These modes of interaction, facilitated by ICT and the World Wide Web, are increasingly popular.[[8]](#footnote-8)

Overall, the digital society allows a wide variety of matching processes to proceed at a finer level through web data crawling and mining. This fine granularity enhances the matches among crowds that may extend the boundary of traditional markets and thereby increase our reliance on non-market activities. In these activities, the fine granularity that implies a lower effort or threshold for engagements that makes it easier for any agent with a minimal or reasonable level of intrinsic motivation to act or engage. These platforms do not simply pool information and compute, but they do something more. They bring together an intrinsic motivation for contributing to public goods and efficient channels to respond to extrinsic motivating factors.

* 1. **Conclusion**

In the years since Hayek’s famous work of 1945 was published, society has changed in many remarkable ways, especially in the way that agents connect, communicate and share information. In particular, developments in digital technology and computing have altered the mediums and ways in which knowledge sharing occurs among people. Given these developments, this chapter has examined the relevance of Hayek’s classic contribution to the digital society. Insights concerning the impossibility of the socialist economic calculations and the superiority of market-based solutions have been used as a framework to understand the possibilities and limitations of ICT-enabled technologies and computational tools in knowledge aggregation.

In addition to the technological aspects, the discipline of economics has also changed in many ways since Hayek’s paper was published. Ideas such as pro-social behaviour, fairness, reciprocity and tools like social network analysis and complex systems have garnered a lot of attention in economic research. Furthermore, advances in behavioural economics have focused on the importance of context in decision-making. Despite these developments, Hayek's creative reformulation of the economic problem facing our society still has immense relevance.

We have systematically contrasted the differences between markets, ICT-enabled information platforms, prices and non-price coordination devices. Based on this contrast, we have argued that the developments in computational intelligence digital technology and ICT have the potential to help or enhance knowledge or information aggregation in novel ways. They have facilitated the formation of a variety of information platforms as alternative decentralised mechanisms (markets without prices). However, ICT alone will not be able to surpass the limitations pointed out by Hayek. The problem of contextual, subjective knowledge and tacit information still cannot be completely solved. Furthermore, increased effectiveness in knowledge utilisation depends on the combination of technology and the ability to tap ICT-enabled intrinsic motivation through effective matching. These technologies and recent developments in economics together present new and interesting windows to understand and appreciate Hayek’s important insights.

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**References**

Abdulkadiroglu, A. and T.Sönmez, T., 2013. Matching markets: Theory and practice. In *Advances in Economics and Econometrics*, vol. 1, 3-47.

Ackerman, E. 2013. Google gets in your face. *IEEE Spectrum* 50(1): 26-29.

Aggarwal, C. and C. Zhai. 2012. In: Aggarwal C, Zhai C (eds.), *Mining Text Data*, Chapter 1. New York: Springer.

Arrow, K. et al. 2008. The Promise of Prediction Markets, *Science,* 320, 5878, pp. 877-878

Arrow, K. et al. 2011. 100 years of the American Economic Review: The top 20 articles. *American Economic Review* 101(1):1-8.

Aud, M. et al. 2010. Developing a sensor system to detect falls and summon assistance. *Journal of Gerontological Nursing* 36(7): 8-12.

Berg, J., R. Forsythe, F. Nelson and T. Rietz. 2008. Results from a dozen years of election futures markets research. *Handbook of Experimental Economics Results*, 1, 742-751.

Boettke, P. 2000. *Socialism and the Market: The Socialist Calculation Debate Revisited*. edited. 9 volumes. New York: Routledge.

Chen, S. H., B.T, Chie and C.C. Tai. 2017. Smart societies. In R. Frantz, S.-H. Chen, K. Dopfer, F. Heukelom, and S. Mousavi (Eds*.), Routledge Handbook of Behavioral Economics*. New York, NY: Routledge. 250-265.

Chen, S. H. and R. Venkatachalam. 2017a. Information aggregation and computational intelligence. *Evolutionary and Institutional Economics Review*, 14, 231?252.

Chen, S.H. and R. Venkatachalam. 2017b. Agent-based modelling as a foundation for big data. *Journal of Economic Methodology*, 24(4), 362-383.

Cockshott, W. and A. Cottrell. 1997. Information and economics: A critique of Hayek. *Research in Political Economy* 18(1):177-202.

Kirkpatrick, R. 2014. A conversation with Robert Kirkpatrick, Director of United Nations Global Pulse. *SAIS Review of International Affairs* 34(1): 3-8.

Kitchin, R. and G. McArdle (2016). What makes Big Data, Big Data? Exploring the ontological characteristics of 26 datasets*. Big Data & Society*, 3(1), 1-10

Lange, O. 1936. On the economic theory of socialism: Part one. *Review of Economic Studies*. 4(1):53-71.

Lange, O. 1937. On the economic theory of socialism: Part two. *Review of Economic Studies*. 4(2): 123-142.

Lavoie, D. 1985. *Rivalry and Central Planning: The Socialist Calculation Debate Reconsidered*. Cambridge: Cambridge University Press.

Levy, D M. and S. J. Peart 2008. Socialist Calculation Debate. In Steven N. Durlauf and Lawrence E. Blume, eds., *The New Palgrave Dictionary of Economics*, second edition. London: Palgrave Macmillan.

Manzini, P., A. Sadrieh and N.J. Vriend. 2009. On smiles, winks and hand-shakes as coordination devices. *Economic Journal*, 119(537), pp.826-854.

Marres, N. 2012. The environmental teapot and other loaded household objects: Reconnecting the politics of technology, issues and things. In: Harvey P, Casella E, Evans G, Knox H, McLean C, Silva E, Thoburn N, Woodward K (eds), *Objects and Materials: A Routledge Companion*. London: Routledge.

Pantano, E. and G. Nacarato. 2010. Entertainment in retailing: The influences of advanced technologies. *Journal of Retailing and Consumer Services* 17(3): 200-204.

Picone, M., M. Amoretti and F. Zanichelli, 2012. A decentralized smartphone-based traffic information system. In *IEEE Intelligent Vehicles Symposium* (IV), pp. 523-528.

Polanyi, M. 1966. *The Tacit Dimension*. Chicago: University of Chicago Press.

Posner, R. 2004. Introduction to the Becker-Posner blog. http://www.becker-posner-blog.com/archives/2004/12/introduction to 1.html, December.

Roth, A.E. and M. Sotomayor. 1992. Two-sided matching. In *Handbook of Game Theory with Economic Applications*, vol. 1, 485-541.

Rothschild, D. 2015. Combining forecasts for elections: Accurate, relevant, and timely. *International Journal of Forecasting*. 31(3), 952-964.

Schwartz, A. 2012, *Street Bump: An app that automatically tells the city when you drive over potholes*. Fast Company.

Shieh, W-Y, T-T Guu, A-P Liu. 2013. A portable smart belt design for home-based gait parameter collection. In: *Proceedings of IEEE Conference on Computational Problem-Solving* (ICCP), pp. 16-19. IEEE Press.

Smith, V. 1982. Markets as economizers of information: Experimental examination of the Hayek Hypothesis. *Economic Inquiry* 20(2): 165-179.

Sunstein, C.R. 2008. Neither Hayek nor Habermas. *Public Choice*, 134(12), 87-95.

Varian, H.R. 2014. Big data: New tricks for econometrics. *Journal of Economic Perspectives*. 28(2), 3-27.

von Mises, L.E. 1920. Economic calculation in the socialist commonwealth. Translated. S. Adler. In *Collectivist Economic Planning*, ed. F.A. Hayek. London: Routledge, 1935.

Vriend, N. 2002. Was Hayek an ACE*? Southern Economic Journal* 68(4):811-840.

Westerlund, M., S. Leminen and M. Rajahonka 2014. Designing business models for the internet of things. *Technology Innovation Management Review* 4(7): 5-14.

Wolfers, J. and E. Zitzewitz. 2004. Prediction markets. *Journal of Economic Perspectives*, 18(2), 107-126.

Wolfers, J. and E. Zitzewitz. 2006. Interpreting prediction market prices as probabilities. *National Bureau of Economic Research,* No. w12200.

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1. For more on the Socialist Calculation Debate, see Levy and Peart 2008; [Boettke](#page18) 2000. [↑](#footnote-ref-1)
2. This sort of technology is often referred to as persuasive technology (Fogg 2002; Hamari, Koivisto, and Pakkanen 2014) [↑](#footnote-ref-2)
3. It is important to acknowledge that there are obvious and serious ethical issues when such information is gathered without the active consent of the individual involved. [↑](#footnote-ref-3)
4. The origins of the term Big Data can be traced back to the turn of the twenty- first century (Diebold 2012). [↑](#footnote-ref-4)
5. Some scholars argue for including more Vs in broadening this characterisation such as veracity, vincularity, and value, etc. See [Kitchin and McArdle (2016)](#page20) for a survey. [↑](#footnote-ref-5)
6. For more on prediction markets, see [Arrow et al. (2008);](#page18) [Wolfers and Zitzewitz (2004,](#page21) [2006)](#page21). [↑](#footnote-ref-6)
7. See [Chen and Venkatachalam (2017a)](#page19) for a discussion on the limitations of sentiment analysis and text mining tools in the context of knowledge aggregation. [↑](#footnote-ref-7)
8. See [Chen, Chie and Tai (2017)](#page19) for a detailed discussion [↑](#footnote-ref-8)