**TALLINN UNIVERSITY OF TECHNOLOGY**

School of Business and Governance

Ragnar Nurkse Department of Innovation and Governance

# Towards a network theory of value:

*The cases of Backfeed and Sensorica*

Alexandros Pazaitis

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Supervisor: Dr. Vasileios Kostakis

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**Abstract:** The current thesis explores the concept of value in the way it is perceived and interpreted in commons-based peer production. The theoretical investigation begins with a historical review on the concept of value in the history of economic thought to identify the interplay between the perception of value and the dominant mode of production. Next, the article explores how changes in techno-economic conditions influence value production and in this view the context of the information economy is analysed. A theoretical framework is synthesised to explore a new theory of value comprising three layers: (a) production of value; (b) record of value; and (c) actualisation of value. The main research inquiry is illuminated through two case studies, namely Backfeed, a blockchain-based protocol that facilitates operations in decentralised productive communities; and Sensorica, a productive network that develops open hardware solutions utilising sensor technologies. The main findings of the cases are discussed in relation to the formulation of a tentative new theory of value. Finally conclusions are drawn and future research hypotheses are indicated.

**Keywords:** theory of value, network collaboration, commons-based peer production, Backfeed, Sensorica

# 1 Introduction

Value is an ambiguous concept that has various interpretations in different contexts. There is a different type of understanding of value when it's being uttered from a stockbroker, a mathematician or a spiritual thinker. Likewise, there is fundamental difference between the value of a variable in an equation, shareholder value and family values.

The focus of this thesis is placed on perceptions of value in economics, understood as the domain of scholarship dedicated to the study of the aspects that are associated with the requisites for human subsistence and well-being. The point of departure is that value as a concept has no concrete meaning on its own. Rather, it is a process or a mechanism through which 'actions become meaningful to the actors by being incorporated in some larger social totality' (Graeber, 2001: XII).

From this perspective, the aim of this thesis is to identify and analyse perceptions of value as they arise from different techno-economic conditions, which significantly determine the dominant modality of production and economic system. The main motivation has been the emergence of new forms of coordination and value creation that have been first exemplified in Free and Open Source Software (FOSS) and the internet. The wide diffusion of ICT have enabled new productive

capabilities in networks of autonomous agents that cooperate asynchronously and permissionlessly to achieve a common goal. More specifically, this thesis examines the case of 'commons-based peer production (CBPP)' (Benkler, 2006), a new modality of production which relies on voluntary contributions by loosely affiliated individuals, with no pre-defined roles or structure to create collective goods and services that are openly accessible as commons.

Subsequently, the main research question of the current thesis is: How is value conceived and captured in CBPP? In order to answer this question, three sub-questions are formulated: (a) how is value defined by- and in turn influences the techno-economic conditions? (b) how do these conditions evolve and change? And (c) what are the techno-economic conditions that encompass CBPP? These questions are being addressed through a literature review (section 2) and two case studies (section 3).

The three sub-questions are explored in section 2. For the first sub-question, in section 2.1, a historical approach is taken to investigate the evolution of value perceptions in the history of economic thought, from antiquity philosophers to the classical political economists at the turning point of industrialisation. Next, section 2.2, explores the literature on technological change and techno-economic paradigms (Perez, 1983; 2002) to reflect on the second sub-question. Subsequently, the third sub-question is handled in section 2.3, in which the techno-economic conditions of the information economy are analysed, where CBPP has surfaced. Finally, in section 2.4 a synthesis is attempted to compose an analytical framework for the case studies.

Section 3 attempts to shed light to the main research question with two case studies illustrating different mechanisms that aim to capture value in CBPP. The selected cases are Backfeed, a protocol for decentralised cooperation implemented on the blockchain, and Sensorica, a productive network dedicated to the development of open hardware solutions utilising sensor technologies. The main findings of the cases are briefly discussed in relation to the theoretical framework, in an attempt to illustrate the contours of a new theory of value. In the final section of (section 4) the article is briefly summarised and the main conclusions are outlined.

# 2 Theoretical framework

The theoretical approach on value of the current thesis is inspired by the Hegelian thought (1807), understanding that individual action can only become meaningful or concrete as part of a greater whole. Simultaneously, from a Marxist point of view (1867), the focus is narrowed to the

mode of production in order to identify the parts that integrate such concrete systems of action that are primarily related to the creation and distribution of the means of material subsistence.

Industrialisation has been a historical milestone for humanity, providing the means to solve the contemporary agonising issues, including famine and plague. The industrial modality of production has been the foundation of a social form, determining the way in which actions had become meaningful, i.e. valuable for the society. It is arguably to a large extent based on this construct that the price system is justified as the dominant standard for value until today.

Nevertheless, the revolution of Information and Communication Technologies (ICT) has brought about significant changes in the way societies organise their productive capacities. CBPP has been itself part of this transformation, exemplifying some unique productive capabilities. This is not to suggest that the new technological conditions determine a certain social order, but ICT have certainly effectuated unseen possibilities for human communication and coordination. It is in this context that such a transformative process is analysed to examine the information economy, as the new logic of guiding meaningful action. This way, perceptions of value within a certain techno-economic context, are considered as instrumental in unlocking the potential for societies to prosper.

## 2.1 Value in the history of economic thought

This historical approach is aiming to rediscover the roots of the price system, which is understood as the currently dominant system to determine value. For this, the main approaches on value in the economic thought are explored at the turning point of industrialisation, as capitalism started to take off.

Before the establishment of capitalism as the dominant economic system, various philosophical and practical traditions had been elaborating on the concept of value. In antiquity, the Greeks had a normative perspective in relation to wealth focusing on what constitutes a 'good life'. The economy was considered as subordinate to political and ethical issues and economic phenomena were not investigated for their own sake (Sewall, 1901). This, however, did not hinder the development of very sophisticated approaches in economics.

Aristotle in Ethics (1897) suggested that value is expressed almost exclusively in the exchange of two things. However, he implied a distinction between value in use and value in exchange, arguing that the latter is subordinate to the former, as it is the usability of any good that makes someone desire it in an exchange. Aristotle understood people’s demand for each other’s goods or services as a standard of measurement of their value. In turn, representation of demand in

money serves to equate the different types of labour applied to produce different types of things, so that they can be exchanged (Sewall, 1901).

The Christian theologians and the scholastics of the 13th century, led by Albert the Great and Thomas Aquinas, incorporated the Aristotelian theory of justice and economic exchange to crystallise the doctrine of the 'just price', which reflected the true value of commodities in exchange (Baldwin, 1959; Sewall, 1901). Overall, the unifying element of the approaches of antiquity and the medieval philosophy was that value serves a broader social necessity, rather than being a rational economic aim, and was connected to ethical and legal considerations (Sewall, 1901). Analytical approaches were fundamentally normative and economics were considered to be part of justice and moral philosophy (Baldwin, 1959).

The following centuries were marked by the emergence of the nation state and the development of industrialisation and international trade. Smith in the Wealth of Nations (1776) arguably provided the first complete theory of value in modern economics. He explicitly stated and explored the basic dichotomy between 'value in use' and 'value in exchange', but, in contrast to Aristotle, Smith claimed that the first is not a determinant of the latter, neither necessary nor a prerequisite and refers to the famous water/ diamonds paradox to underpin his argument (Smith, 1776: IV). With his interest being in the principles that regulate commodity exchange, he studied the real measure for value in exchange and the real price for all commodities.

A key point for Smith's comprehension for value is the division of labour. In a society with developed division of labour individuals produce only a small fraction of the goods or services that are necessary to satisfy their needs. Therefore, they have to exchange the products of their own labour to those of other people's labour. In this sense, Smith defined the value of any commodity as 'equal to the quantity of labour which it enables [the person who possesses it] to purchase or command' (1776: IV). For Smith the real price of every thing was the toil and trouble of acquiring it, understood as the deposition of a specific portion of one's ease, liberty and his happiness. Subsequently, the real price of every commodity exchanged for another one is the toil and trouble which it can save its possessor and which it can impose on other people (ibid: IV).

Labour thus represents this toil and trouble, 'the first price that was ever paid for all things' and the origin of all the wealth of the world (ibid: V). This price, Smith argued, is always the same, assuming an ordinary physical and mental state and is not varying in its own value. Therefore, labour alone can function as 'the ultimate and real standard by which the value of all commodities

can at all times and places be estimated and compared. It is the real price of commodities; money is their nominal price only' (ibid: IV).

To place this perception into context, Smith's era was not the first time when the practice of exchange and the money economy appeared in human societies. But it was the first time that a certain techno-economic logic, based on the division of labour and industrial production, rationalised the prominence of trade as a crucial function for societies. In turn, the price system institutionalised exchange markets as the determinants of the value of things. Smith, recognised this function of the price system by assuming a 'natural price', at which commodities are sold precisely for what they are worth (ibid: VII). A price that would provide an accurate compensation covering rent for land, wages for labour and profit for capital. Economics started to transform as a scientific discipline and shifted away from the medieval pursue of the 'just price', towards the examination of a divine-like 'natural' order, assumed to be achieved by the efficient and precise function of markets.

Later theories made this relation even clearer. Ricardo developed his theory of value in the third edition of Principles (1821), at first, as a critique on Smith. Ricardo accepted the distinction between use and exchange value, but explicitly regarded the latter as the only one concerning economic analysis, while he was the first one to associate exchange value with scarcity (Hollander, 1904). Ricardo was also the last classical political economist to adhere to the labour theory of value. Mill (1848) completely dismissed the labour theory of value and argued for a measurement of value of any thing as the 'command its possession gives over purchasable commodities in general' (1848: Part III.1.5). Later on, Jevons (1871), building on Ricardo's relation of value and scarcity, developed the concept of marginal utility, giving rise to a whole new generation of economists, including L. Walras, C. Menger, A. Marshall and V. Pareto, as well as M. Friedman and neo-liberal scholars of the 20th century. These views have completed the shift in economic thought. They dismiss any material embodiments of value and overemphasise the efficacy of free markets in coordinating any sort of meaningful action in societies, based on generalised assumptions, such as utility-maximisation and equilibrium (Walras, 1874; Marshall, 1890).

The historical conditions influenced the gradual transformation of the perception of value, so as to efficiently coordinate human sociality towards what has been generally perceived as beneficial. The industrial revolution has effectuated the key factors that distinguish a new economic system, which Sombart (1902) would later call capitalism: 'a particular economic system, recognisable as an organisation of trade, consisting invariably of two collaborating sections of population, the owners of the means of production, who also manage them, and property-less

workers, bound to the markets which they serve' (Sombart, 1902 in Gibson et al, 1996: 3). An economic system that by its definition was increasingly dependent on trade has led to a perception of value as exchange power inevitably dominating the economic thought (Sewall, 1901). Money became the primary commodity acquiring exchange value and the concept of value became almost interchangeable with price. Global governance has been to a large extend focusing on regulation of international trade, with supranational institutions like the General Agreement on Tariffs and Trade (1947) and the European common market initiatives, starting with the European Coal and Steel Community (1951) that evolved to the European Union.

But markets require precision, cost effectiveness and a rational pursue of profit maximisation, aspects that are hard-wired in the capitalist business spirit. The art of systematic bookkeeping, born in the commercial centres of the Italian city states in the 14th century, provided this framework for the advance of trade (Yamey, 1949). Sombart (1902) has eloquently emphasised the role of double-entry bookkeeping in stimulating and intensifying the capitalist spirit (Yamey, 1964). Capitalism and double-entry for Sombart are so intimately connected, that it is difficult to tell which one was the cause and which one the effect. On one hand, capitalism has procured in double-entry bookkeeping a tool which activates its forces, while on the other hand, the latter has accentuated capitalism out of its own spirit.

Double-entry bookkeeping allowed for the standardised quantification of the results of all business activities and the reduction of assets and equities to numerical abstractions. It has thus provided a rational basis for strategic decisions and resource allocation and clarified business aims through a simple representation of win or loss (Yamey, 1964; Gibson et al, 1996). This systematic organisation of all business aims propelled discipline, control, practicality and depersonalisation into the logic of enterprise. The gradual dismissal of the labour theory of value in the evolution of economic though has been only indicative of this abstraction of the social productive relations to the mathematical logic of double-entry bookkeeping.

Elaborating on this element of abstraction, Marx offered a different interpretation on value. In the first volume of The Capital (1867), Marx distinguished the 'capitalist mode of production' from simple commodity production, as studied by classical political economists (King & McLure, 2015). Whereas in pre-capitalist conditions commodities would be valued in exchange according to the labour expended in their production, capitalist production, he argued, 'is not merely the production of commodities, it is essentially the production of surplus-value' (1867:359). In capitalism the fundamental aspect of goods is their quantitative relation with money, which allows them to exchange as commodities (Fuchs, 2010).

In this sense, for Marx exchange value in capitalism is rather a manifestation of the structural relations than a direct result of labour. It is a property that the products of labour acquire, which is only actualised in the market through their exchangeability as commodities (Milios et al, 2002). Therefore, the production for exchange and profit in capitalism leads to an expression of value as a product of 'homogenised labour processes', what Marx encapsulated to the concept of ‘abstract labour’ (1867:39).

Marx, much like the classical economists, distinguished use value and exchange value. However, he identified a qualitative and quantitative element in the two forms. He held that in capitalist production there are two processes of labour identified: First, concrete labour, which produces use values, the qualitative element of goods, representing 'the everlasting nature-imposed condition of human existence' (Marx, 1867:130); and second, abstract labour, which creates exchange value expressed in a quantitative relation with money (Milios et al, 2002; Fuchs, 2010; 2012). Hence, for Marx the value of commodities does not hold any connection with their material substance or usability.

Moreover, Marx’s breakthrough in his theory of value was his analysis of money. He went beyond the understanding of money as a measure and medium of value and drew attention to the function of money as value within itself (Graeber, 2001). From this perspective, money is not simply a tool facilitating economic activities, but rather becomes their final end: ‘the very embodiment of value, the ultimate object of desire’ (Graeber, 2001: 66). Money thus, for Marx, measures not only the value of commodities, but the value of any type of social action.

It becomes evident how a particular modality of production has organically transformed the perception of value, in the sense of defining meaningful action within a broader social totality (Graeber, 2001). The production processes in the capitalist mode of production have shifted away from the production of goods that have actual usability, towards the production of goods that can create surplus after being exchanged for other ones. Subsequently, the system of value has to fulfil the purpose of making commodities commensurable, as they embody different types and amounts of labour, so that the exchange could take place.

The classical political economists, even though they acknowledged the problem of incommensurability of labours, assumed a natural order imposed by market mechanisms that would achieve the type of precision required for exchange (Meikle, 1995). Marx, on the contrary, argued that resolving incommensurability in exchange results in stripping the products of labour of their

qualitative characteristics. The value of things is divorced from their usability and the labour they embody turns to 'labour of equal quality' (abstract labour) (Marx, 1867:40; Milios et al, 2002).

It may be argued that this process had been fulfilling a practical necessity in capitalism, enabling the system to reproduce itself and expand. However, this development has not been seamless and unhampered. Throughout the history of capitalism there have been many occasions where the economy was impeded and crises burst, many of which had similar characteristics with the contemporary crisis of 2008. The exploration of such occasions is the subject of the following section.

## 2.2 Technical change and Techno-Economic Paradigms

It has become widely acknowledged that the current on-going crisis represents a turning point in the global economy. However it is neither the first and, most probably, nor the last of these moments in history. In fact such decisive moments tend to appear every five to six decades, following a recurrence of cyclical progressions, which Kondratieff (1935) statistically presented in his "long waves". Schumpeter (1939), building on the analysis of the long waves further discussed the cyclical behaviour of the capitalist economy, provoked by surges of technological innovation.

Departing from the Schumpeterian understanding of the economy, Perez (1983) postulated that those recursive patterns are not explicitly an economic phenomenon. They are rather explained as a result of a dynamic harmony and disharmony of the techno-economic sphere, on one hand, and the socio-institutional, on the other. The root is conceived within the first sphere, where technological revolutions cause discontinuities in the trajectory of technical change, leading to mismatches with the established institutional framework. This process eventually results in a shift of the 'techno-economic paradigm', i.e. the 'common sense' or the set of best practice principles that guide engineering and economic behaviour (Perez, 2002; 2004). Each techno-economic challenge has a socio-institutional solution and once a match with the new paradigm is achieved, the potential for a period of prosperity and development opens up.

This process of 'creative destruction', as it is often described in the Schumpeterian tradition, exposits the powerful dynamic of technological advance in re-shaping the world. Long periods of prosperity throughout the history of capitalism are characterised by and named after the core industries which had become the propellers of development of the time. From the Industrial Revolution to the Railway Era and from the Age of Electricity to the Age of the Automobile (Perez, 2004). Likewise, the contemporary ICT revolution has triggered a growing discussion over the Information Age (Castells, 2010).

Nevertheless, it must be emphasised that technological revolutions, as in fact any type of revolution in the wider sense, do not necessarily lead to one inevitable social outcome. Much like, social revolutions, they are organic and often destructive events, that do not fall within the control of any particular social force. At the same time, the key role that technologies play in societal evolution has to be recognised. Technology should be viewed as a moving frontier, which expands the sphere of the feasible, creating new possibilities for certain social groups that are able to deploy them.

Therefore, technology is itself a field of social struggle, as different social forces invest in the new opportunities to benefit from them (Feenberg, 2002). When social groups take control of a certain technology, then social, political and economic systems can effectively be transformed. In the neo-Schumpeterian tradition (Freeman, 1974; 1996; Perez, 2002) crises, which are some of the basic functions of capitalism, are considered to be windows of opportunity for institutional change that rejuvenate the system. From a different perspective, Kostakis & Bauwens (2014) point out that crises, similar to the current crisis, can tentatively lead to something more than a socio-institutional regeneration of the dominant system. New modes of social production and new models of value creation and distribution emerge from radical socio-technical transformations, which, in the long term, have the potential to transcend the system as a whole. These aspects can bring about deep political and social change; a transition in the main modality by which humanity allocates its resources.

Such transitions are made apparent within two moments in history, where there are significant fundamental differences in the dominant productive relations and processes (Bauwens, 2015). From the slave-based system of the Roman Empire to the feudal order, and from the latter to capitalism, fundamental changes can be observed in the most vital aspects of human societies, including key raw materials and energy resources; technologies; types of territorial exploitation and financial systems. Above all changes occur in the global political dominance and the type of social contract and governance.

Whether or not the so-called Information Age entails the premises for such a transformation is to be argued and is also beyond the objectives of the current thesis. Nevertheless, the transformative dynamics that have been effectuated by the ICT-driven techno-economic paradigm pose certainly numerous challenges to the established business and institutional environment. In the next section the focus is placed on some of these challenges that are associated with CBPP and the emerging forms of organisation.

## 2.3 The information economy

The term 'information economy' generally connotes an economy in which production is associated with knowledge, communication and information, as opposed to other kinds of activities (Porat, 1977). The term has been elsewhere referred as 'post-industrial economy' or 'knowledge economy' (Machlup, 1962; Bell, 1973; Drucker, 1968), which alludes to a deeper transformation, than a simple protrusion of information in the productive processes. Information, in its broader sense, has been an important element in the development of all societies. However, in the information economy the difference lies in the new technological conditions that have effectuated a new form of social organisation, where 'information generation, processing, and transmission become the fundamental sources of productivity and power (Castells, 2010: 21). As discussed earlier, those ICT-driven conditions have brought about a wider reformation that sparkled a series of riddles that have 'techno-economic origin and socio-institutional solution' (Perez, 2004: 1).

The first riddle concerns the transformation of work and the nature of labour. Wealth creation in the information economy depends on socialised productive processes (Rullani, 2004; Arvidsson & Colleoni, 2012). Value is increasingly created in collaborative processes by a 'multitude' (Hardt & Negri, 2004) of diverse actors, and thus labour is less susceptible to control and measurement. Labour becomes immaterial (Hardt & Negri, 2000), that is more qualitative and ever more complex, while intangible assets gain significance in corporate value assessment (Arvidsson & Colleoni, 2012).

The immeasurability of value (Hardt & Negri, 2000) poses strong challenges for the conventional practices of management and accounting (Toms, 2008). The rationality of the price system is decreasing. This 'value beyond measure' (Hardt & Negri, 2000: 355) is more or less directly channelled to financial markets, whereas the latter 'are not so much rational as they are affective' (Arvidsson & Colleoni, 2012:141). The importance of financial markets in the information economy is associated with an evaluation system based on sentimental projections of future earnings.

The second riddle concerns the nature of information as a product of human sociality. Rigi & Prey (2015) advocate that informational content alone does not possess any exchange value, as it is non-rivalrous and it can be reproduced at negligible cost and time. The value of commodities has been traditionally associated with scarcity, while information production operates in the logic of abundance. Hence, the produced information does not classify as a commodity but rather as universal commons. Bollier (2014) defines the commons as a shared resource, co-governed by its

community of users according to their rules and norms. Information production refers to the digital commons of software, knowledge, design and culture. Nonetheless, as Castells' (2010) definition implies, the information commons represents mutualised productive resources that are central to the capacity for any kind of production, including physical goods.

The interest in the commons is not restrained on the management of the resources, but it also concerns the accompanying social practice of working together on equal footing for a common purpose, referred to as 'commoning' (Bollier, 2016). Commoning goes beyond the management of 'common-pool resources' (Ostrom, 1990). Rather it is also connected to new forms of governance and provisioning of goods and services. In the information economy, the commoning dynamic is exemplified by the myriads of Free and Open-Source Software projects or the free encyclopaedia Wikipedia. It is related to a new mode of production, different from private for-profit or public state-owned production, which Benkler (2006) called commons-based peer production (CBPP). Its product primarily possesses use value for a community of users/producers. Those are self-organised in highly networked productive structures, beyond traditional hierarchy and central coordination, and deploy common property regimes to make use value freely accessible (Bauwens, 2005).

However, the socio-institutional arrangements that govern today's economy are still to a large extent associated with the capitalist mode of production. Marx (1867) unveiled an antagonistic relation of use value and exchange value in capitalist production: The first serves the collective social interest, whereas the second the individual private objectives. This relation is further eradicated in the context of information, due to its non-rivalry form. With exchange value being the one dominating economic affairs, it is imposed on the information commons through artificial scarcity and enclosure. In turn, the market value extracted constitutes a form of monopoly rent (Rigi & Prey, 2015).

Therefore, the Marxist analysis of concrete and abstract labour remains relevant in the information economy (Fuchs, 2012). For instance, the activity of Facebook users is concrete labour that produces 'informational content' that embodies use value (Fuchs, 2012:187). This content is then commodified and exchanged to media advertisers, and the control of this process is in the hands of the owners of the infrastructure (Kostakis & Bauwens, 2014). The users are also the audience for advertising and their attention is also commodity that is actually measurable in terms of aggregated time of social labour (Fuchs, 2012).

Clearly, CBPP unseals a political economy that goes beyond the Marxian framework of critique and negates the conventional canons of value altogether (Rigi & Prey, 2015). It inaugurates

forms of governance indigenous to the information economy that encapsulate its transformative dynamics. Nevertheless, as long as CBPP remains subsumed under the rules of the markets and the abstracted logic of capitalism, it will still fall within the reach of Marx's analysis (Rigi & Prey, 2015). Admittedly, the best possible development in the Marxian theory of value is to be made obsolete by a radical change in the productive relations beyond capitalism.

The commons could function as the fabric of such a transformation. Helfrich offers an interpretation of the commons as 'an important form of transpersonal rationality and coordination; a new category that describes the individual-in-relation-with-others' (in Bollier, 2016: 20). Commoning thus encapsulates a different form of coordination of human sociality that makes sense within a certain techno-economic context and is in turn solidified as meaningful action. The same way that the industrial economy and the capitalist mode of production relates to production for exchange, the information economy and CBPP relates to the circulation of the commons.

In this perception, the information economy infers something more than information gaining fundamental significance in economic practice. It portrays a new system of value in economic affairs, in which the information commons become the logic that guides human behaviour towards what is perceived as the greater good. For the first time in modern economic history it can be abundance rather than scarcity that can set the boundaries of analysis of economic activities.

## 2.4 Synthesis and framework of analysis: towards a new theory of value

Value is understood as an abstraction of human relations. It is a coordination mechanism that operates on a cognitive level, guiding individual and collective behaviour. It only becomes real at the end of this process, when the effect of this collective intelligence becomes evident. A theory of value thus stipulates the locus of this process, providing an interpretation of how human action is formed, motivated and scaled.

This thesis suggests that this relation can be observed in three interwoven layers: (a) production of value; (b) record of value; and (c) actualisation of value.

The first one refers to the modality of production, which rationalises a particular form of action as a meaningful contribution to the societal needs. The capitalist mode of production has been associated with exclusive ownership and control of the means of production, hierarchical command of labour and the production of surplus value in exchange. Respectively, CBPP is

characterised by collective ownership and management of resources, network-based coordination, self-identified and permissionless contributions and the production of social value in use.

The second layer concerns a systematic representation of economic affairs, which provides the means to assess, motivate and nourish meaningful action, allowing the system to scale and become sustainable. This layer contains the method used to track and record the produced value, which to a large extent crystallises the logic of the established economic system. The role of double-entry bookkeeping was discussed in unleashing and stimulating the business activities of capitalism. Double-entry bookkeeping had conveyed the logic of mathematical precision and abstraction to business operations and hard-wired it into the price system. It had been born as a practice of merchants and has been thus endemic to trade, the engine of the capitalist mode of production. Likewise, the value media apt to represent CBPP are expected to stem from the domain of ICT, as the enabling set of technologies of the information economy to effectively support polycentricity, fluid coordination and multiplicity of contributions.

The third layer includes the development of a common sense that rationalises meaningful action within the logic of an economic system. It is where value becomes real justifying people's choices and struggles. In capitalism, as discussed earlier, the value of commodities is a property that they carry on from their production, but is only actualised in markets, through their exchange for other commodities. This value is interpreted through a nominal representation in monetary units, determining both the means and the ends of the productive process. Accordingly, in CBPP, it's the practice of commoning and sharing of use values representing the type of social relations that make value perceptible. It is where an economic system can be materialised, one which rationalises people's capacity to organise their productive efforts based on the commons, encapsulating both the relevant resources, as well as the associated practices and governance models.

The following section attempts to palpate those elements by exploring two illustrative cases. Two types of enabling technologies are briefly analysed, namely the blockchain and the Resources-Events-Agents (REA) model, while two cases demonstrate respectively a potential application.

# 3 Case studies

In this section the main research question is addressed through two case studies. Both cases illustrate a different approach in the production and capturing of value in CBPP communities and offer interlocking interpretations of how value is conceived in CBPP.

## 3.1 Methods and justification

The two selected cases illustrate different perspectives in relation to the envisioned organisational patterns and the role of technology, but have similar understanding of value and share a common motivation to solve one specific challenge: how to capture value that is created in collaborative processes and distribute it fairly to the contributors.

As discussed earlier, the past decades have marked the emergence of numerous online and offline CBPP communities that cooperate in a peer-to-peer manner to create common value, like in Free and Open Source Software, Wikipedia, OpenStreetMaps, CouchSurfing or WikiHouse. Even though many of these communities offer useful products and services to a significant number of users, only a few of them have been able to become self-sustainable. The majority of them operates on a very small scale, often on a local territory or in a niche area. They usually comprise a small handful of highly motivated contributors and a larger number of people who contribute on an ad hoc voluntary basis (Fuster Morell et al, 2014). The lack of resources and material incentives often impedes them from attracting new contributors beyond the intrinsically motivated individuals (Arvidsson et al, 2016). Above all, contributors face constant precariousness and often cannot sustain their active participation for a long period of time, regardless of their motivation.

Hence, scaling up for these communities usually means formalising into a more rigid hierarchical structure and adopting a market-oriented approach. The community starts to turn into a company or other legal entity to accumulate necessary funds and reward contributors with economic returns. This approach often conflicts with the original intentions of the community, which is generally focused on social relations and meaningful scooperation, rather than profit-oriented activities. This issue was very well illustrated by the shift of CouchSurfing from a non-profit to a for-profit corporation, which led to the gradual dissipation of the community members, who no longer could reflect themselves into the value proposition of the new entity (Johnson, 2011; Bauwens, 2011).

The selected cases arguably represent potential solutions to these challenges. On one hand, Backfeed offers a consensus protocol implemented on blockchain technology that allows community members to make evaluations of each other's contributions and distribute the rewards based on their reputation. On the other hand, Sensorica has developed a distributed value accounting system that logs all contributions and distributes revenues accordingly. Both projects enable types of governance that reflect the patterns observed in peer-to-peer communities. They intend to support a dynamic structure that does not rely on a set of predefined roles and tasks, but

rather on open collaboration, where everyone has equal potential and access to knowledge and basic means to contribute in a self-identified fashion. In return they can receive a fair slice of the pie that also reflects their influence in the community.

In terms of methods, both cases are approached from the standpoint of intrinsic case study research (Stake, 1994). The main motivation is to develop a deeper understanding of the cases for their own sake, as they are of particular interest with regard to the main research question of the current thesis. Moreover, due to the topicality and distinct characteristics of the investigated phenomena, they can only be approached within their real-life context and therefore case study research is the most appropriate method (Yin, 1981). Both cases present different challenges and therefore the approach in relation to data gathering has been adapted accordingly.

The Backfeed model is mostly theoretical and based on a superficial understanding of how it would apply in practice to real-world communities. Given the early stage of the technology, there is no robust empirical evidence with regard to the practical implementation of this model. The main data sources have been primary information about the project and its vision from extensive discussions with one of the main instigators of the project, Dr. Primavera De Filippi. Simultaneously, the relevant information has been triangulated through various online sources and media that have been covering the case. Furthermore, the validity of the information is supported by the documentation of an early experimental trial of the Backfeed protocol by the OuiShare community, a network of researchers, activists and entrepreneurs working in the collaborative economy, conducted in the context of the organization of the OuiShare festival in Paris, in 2015.

Sensorica, on the contrary, is a large network that has been operating since 2011 with a growing number of participants and numerous mature projects. All relevant information on the governance, business model and technological infrastructure of Sensorica has been heavily documented since its beginning and is massively accessible online, in a variety of formats (inter alia shared documents, wiki articles, forum conversations), while project-related data are accessible in the network's online platform. Moreover, interviews have been conducted with four people involved on different levels in Sensorica, namely Tiberius Brastaviceanu, one of the main instigators of Sensorica, Bob Haugen and Lynn Foster, the architects of its technological infrastructure, and Jim Anastasiou, one of the most active contributors of Sensorica at the time of the writing of the current thesis.

## 3.2 Backfeed

Backfeed is a social operating system for decentralised organisations. It builds upon blockchain technology to develop a distributed governance model for decentralised value creation and distribution (Davidson et al, 2016). Before presenting the Backfeed model, its technological backbone is introduced, namely blockchain technology and the practices associated with it. As most existing implementations of the blockchain are to a large extent on an experimental phase, there is still no definite terminology to describe the relevant concepts.

### 3.2.1 Blockchain technology

A blockchain is a distributed ledger or database of transactions recorded in a distributed manner, by a decentralised network of computers (Wright & De Filippi, 2015:6). As the name implies, it is organised in a linear sequence of smaller encrypted datasets called 'blocks', which contain timestamped batches of transactions. Each block contains a reference to its precedent block and an answer to a complex mathematical puzzle, which serves to validate the transactions it contains. The innovation behind the blockchain emerges from a combination of existing technologies: peer-to-peer networks; cryptographic algorithms; distributed data storage and decentralised consensus mechanisms (Wright & De Filippi, 2015). As a general purpose technology (Davidson et al, 2016), the blockchain serves as a means to record, in a secure and verifiable manner, a particular state of affairs which has been agreed upon by the network (Wright & De Filippi, 2015). As such, the blockchain can be used in any system that comprises valuable information, including money, titles, deeds, intellectual property rights and even votes or identity register data (Davidson et al, 2016; Tapscott & Tapscott, 2016).

Blockchain was first introduced as the underlying technology of the crypto-currency Bitcoin (Swan, 2015). Trying to solve the problem of double-spending within a peer-to-peer electronic cash system (Nakamoto, 2008), Bitcoin introduced two innovative solutions: (a) the blockchain, a decentralised, immutable and incorruptible public ledger shared by all network nodes; and (b) the 'Proof-of-Work' consensus protocol, a method used to decide on the validity of the transactions recorded on the blockchain (Davidson et al, 2016). The Proof-of-Work mechanism comes as a complement to the blockchain. It improves its security by requiring network nodes to solve computationally-intensive mathematical problems before they can validate a particular block of transactions.

A new block is added to the blockchain only after the network has reached consensus about the validity of all the transactions contained into that block (Wright & De Filippi, 2015). New

Bitcoin tokens are simultaneously awarded by the network to the first user that solves the mathematical problem related to any given block. This process, called 'mining', is designed to reward people for contributing computational power to the Bitcoin network, to secure the network whilst supporting its growth.

Bitcoin is the first concrete example of a distributed network with an intrinsic incentive mechanism (Van Valkenburgh et al, 2014). Following Bitcoin's innovation, there has been an increasing interest to explore the potential of blockchain technology in other fields of human activity. New applications have been developed with the blockchain, including digital currencies, self-executing smart contracts platforms, along with many financial and non-financial services (Wright & De Filippi, 2015).

### 3.2.2 A social protocol for Decentralised Cooperation

Bitcoin has marked the beginning of a nascent industry of distributed applications with the issuance of tokens on a blockchain (Van Valkenburgh et al, 2014). These tokens represent a generic and measurable unit of value, imbued with the rules of the network that issued them. Most of these applications implement a specific protocol for the issuance of these tokens. Typically, they provide incentives for users to commit resources to the network and, thus, secure transactions without the need of a trusted intermediary. As long as people trust the underlying technological infrastructure, it is possible for them to engage in peer-to-peer transactions. But when it comes to more complex social relationships, involving meaningful collaboration and productive processess, blockchain technology alone does not suffice for people to engage in trusted interactions.

To address this issue, Backfeed has developed an additional trust layer, based on human relations, which enables people to engage in secure and decentralised trusted interactions on top of the 'trustless' blockchain technology. The inspiration for Backfeed has been 'stigmergy': a form of indirect coordination encountered in certain species of animals (such as ants, termites and birds), where individual agents leave trace in their environment, so as to inform the actions of other agents (Davidson et al, 2016; Marsh & Onof, 2007).

Backfeed builds on blockchain technology to replicate the same model peer-to-peer networks. This is achieved through an operating system, featuring a generic protocol layer that sits in-between the blockchain infrastructure and the actual applications that are deployed on the blockchain. This layer makes it possible for people to effectively manage, coordinate and reward contributions, while they collectively develop and deploy applications on the blockchain.

For the purposes of this presentation a new type of organisational structure may be introduced, called 'Decentralised Cooperation (DC)'. The DC encapsulates any type of structure that allows autonomous agents to collaborate and achieve a common goal, by making self-identified contributions with no central coordination or ruling authority.

In order to establish the value contributed to a DC, Backfeed developed a new consensus protocol named 'Proof-of-Value' (PoV), which consists of two components: (a) a peer-to-peer evaluation system that is used to determine the perceived value of the various contributions; and (b) a reputation system that allocates influence according to the value contributed and the alignment with the overall perception of value of the community (Davidson et al, 2016).

DCs encapsulate productive communities, whose members are represented in the Backfeed protocol by ‘agents’. An agent can be an individual or one facet of an individual (as an individual can be split into multiple agents), as well as a group of individuals, or any other entity that can act as an independent unit (e.g. a DC can be an agent in another DC). Agents are pseudonymous and they may choose what types of information they disclose about their identity. However, all agents in a DC have a unique account that tracks the record of actions (i.e. a historical log of contributions and evaluations) and record of equity (i.e. their balance of tokens and reputation score over time). This way, the information on the activity of any agent is shared with everyone in the network.

Agents make contributions to the productive processes in a DC. A contribution can consist of any type of action, tangible or intangible. For instance it may be a new piece of code, a design, an idea or a service. The value of each contribution is determined through a participatory evaluation process, where agents evaluate contributions (including their own) in accordance to a reputation score. Whenever a contribution is positively evaluated within the DC community, a reward is distributed to the contributor. The reward consists of a specified amount of economic tokens and reputation.

Token distribution serves to incentivise agents to make contributions to the DC, while the reputation score indicates their influence in the community and their alignment with its value system. The amount of tokens distributed to the contributor depends on the median value of all weighted evaluations, accounting for the total reputation in the DC, i.e. the sum of reputation scores of all agents. Tokens are issued after a minimum of 50% of the DC reputation took part in the evaluation of a certain contribution.

Tokens in a DC serve as transferable value-carrying units that can be used as items of reward, media of exchange, means of payment and measure for wealth. They simply indicate that

the value has been created, so they do not provide a link to the individual that they were initially issued. Hence, they may be transferred and exchanged like currency. Conversely, the reputation score indicates the level of alignment an individual has to the DC's value system. As such, reputation may not be transferred as it is linked to the agent who has earned it.

The reputation score can increase in two ways: (a) through a contribution that has been perceived as valuable by (all or a part of) the community; and (b) through a useful evaluation of others' contributions, meaning an evaluation that is retrospectively aligned with the evaluations of the rest of the community. Thus, the objects of evaluation are not only the contributions to the organisation, but also the alignment of the evaluations with respect to the overall value system of the organisation. Reputation is allocated to contributors whenever the median value of their respective contributions reaches a positive value, i.e. when more than 50% of the DC reputation considers that a contribution is valuable. The precise amount of reputation to be issued for each evaluation is specifically defined by the community, based on the chosen evaluation set (i.e. the set of possible values with which a person can evaluate a contribution, e.g. on a scale from 1 to 5).

To make an evaluation, agents need to put some of their reputation at stake, meaning that a certain fraction of the evaluator’s reputation is deducted from its overall reputation score upon making an evaluation. The protocol encourages people to evaluate contributions at an early stage, as the reputation stake of each evaluation is allocated to all the evaluators that have been aligned earlier. Eventually, as others evaluate the same contribution with a similar evaluation, those who are the most in line with the overall community's evaluation will be able to retrieve the reputation they lost, and often gain more reputation than they initially had.

Backfeed suggests that every DC can set up its own tokens that function as transferable and exchangeable units of value. Each DC may feature a unique value system that organically emerges through its evolution, emphasising the elements that its purpose or vision values the most. In this sense, every set of DC tokens is an expression of the specific conceptions of value that characterise the DC, which will determine the issuance and distribution of tokens within the DC. Simultaneously, tokens represent equity share in the DC and new tokens are issued whenever new value is created or added. In turn, people can collect tokens by making valuable contributions to the DC operations.

At the same time, DC tokens represent the value provided by the DC within a broader ecosystem, as tokens can be exchanged for the products or services that a DC provides. In this case tokens acquire market value, which is then determined by the perceived value of the DC’s products

or services. In case the DC reaches a specific level of maturity with a stable user-base, the token value can be crystallised into a more steady value against other tokens or even fiat currency. People who do not contribute to the DC can then purchase tokens from the DC or other token holders.

Hence, an ecosystem can be envisioned, consisting of several DCs, where a multiplicity of value systems emerge out of their interaction. Mutually interacting DCs are the constitutive elements of this ecosystem and support each other to the extent at which they need each other's products or services. For instance, let's imagine two DCs, a community engaged in organic farming (DC1) and a FabLab (DC2). DC1 may need the services of DC2 to build certain farming tools. For this, DC1 would have to acquire a number of DC2 tokens to get access to their services. Therefore, DC1 would either have to contribute to DC2 operations to acquire tokens as a reward, or invest in the purchase of DC2 tokens, thus indirectly increasing the market value of these tokens.

Similarly, the same options would be available if a conventional business (not of DC-type) or a local municipality needed the services of the FabLab. Likewise, local citizens could enjoy organic products from the organic farming community by either contributing to their production or by purchasing tokens. The DC ecosystem is thus not isolated and DCs can also liaise with the market and the public sector. They can use their impact to engage more agents into their productive processes, but also share their vision and social mission.

## 3.3 Sensorica

Sensorica is an open collaborative network dedicated to the design and deployment of sensors systems in open source software and hardware solutions. It was officially launched in February 2011 in Montreal, Canada with the vision to empower new forms of open collaboration, by designing the proper business model and infrastructure to sustain decentralised operations. This effort has been inspired and informed by the Resources-Events-Agents (REA) model to better serve the agile and dynamic structure of Sensorica. Therefore, before the presentation of Sensorica, a brief review of the REA model is offered.

### 3.3.1 The Resources-Events-Agents model

Resources-Events-Agents (REA) is a model for an accounting system re-engineered for the information age. It was originally presented by McCarthy (1982) as a generalised framework designed to cover certain needs for information management that traditional accounting could not adequately address. The main motivation behind the development of REA have been the limitations

of double-entry bookkeeping, in providing the necessary information to facilitate decision making in business entities.

Double-entry is generally limited to monetary representations and dates and is overall alienated from the other functional areas of an enterprise, other than accounting. In most cases, the type of information and the classification systems used in traditional accounting are of little use to non-accountants and offer limited ability for decision makers to utilise the raw data from the actual economic activities. These limitations result to low integration of the information across the various functional areas of an enterprise, which often leads to inconsistencies and overlaps (McCarthy, 1980; Dunn et al, 2016).

These limitations are addressed by the REA framework through a semantic approach that aims to reflect real-world business activities rather than double-entry accounting objects (Dunn et al, 2016). As the name implies, the model creates computer objects that represent: (a) Resources (e.g. goods, services, cash, assets); (b) Events (e.g. processes, transactions, agreements, contracts); and (c) Agents (e.g. individuals, groups of individuals, entities, machines). REA preserved the duality of economic events that is typical of double-entry, retaining the causal relationship between inflows and outflows. For instance, in a productive process, several resources (e.g. components, labour time, machine time, etc.) are employed as input and produce in turn other resources (e.g. products, parts, etc.). Simultaneously, REA identifies the agents involved in these events and connects the activities with stock flows, which represent resources moving from one activity to another (Haugen & McCarthy, 2000). This way it integrates all the planning, monitoring and communication functions, providing greater granularity of data to effectively track the economic activities and inform decision making (Dunn et al, 2016).

Research on REA has progressed in recent years and the model has gradually evolved from a generalised framework to a design theory for enterprise systems that is based on semantics. It is the basis for the International Organization for Standardization/ International Electrotechnical Commission standard on economic exchanges (ISO/IEC 15944-4:2007), while it has been argued that the implementation of the model in enterprise systems, like Enterprise Resource Planning (ERP) systems, can have significant advantages in terms of cost reduction and user experience (Dunn et al, 2016). Recently developed enterprise systems, such as Workday and REA Technology, have applied the core of the model in their architecture, while many ERP systems that do not fully embrace the REA accounting model, are still largely consistent with the design theory (O'Leary, 2004; Fallon & Polovina, 2013; Dunn et al, 2016).

Nevertheless, REA has not yet been widely adopted in business due to path dependencies with the traditional accounting practices. Most ERP systems are consistent with double-entry bookkeeping artefacts in the way they provide information for their applications and thus include general ledger modules for the relevant accounting tasks (Vandenbossche & Wortmann, 2006). As this type of information is mainly handled by accountants and financial managers, they in turn prefer ERP systems to be designed in a way with which they are more familiar.

However, the rapid changes in the structures and business logic of enterprises in the information economy necessitate greater agility from information systems The demanding business climate rationalises collaboration and integration across the value chain, in the form of clusters (Porter, 1990; 2000) or strategic alliances (Teece, 1992), challenging the definition of corporate boundaries. The semantic representation of the enterprise reality offer such agility in a greater degree than on artificial constructs (McCarthy et al, 2003).

New enabling technologies and business models transcend the limits of the value chain towards an approach comprising 'value systems' (Allee, 2008), including all the interconnected economic agents and resource inputs involved in productive processes. The REA as a design theory can provide a common vocabulary to enable the coordination of all involved parties in integrated enterprise and inter-enterprise systems (Haugen & McCarthy, 2000; Dunn et al, 2016). It poses as a discontinuity in the design paradigm of electronic accounting systems, where instead of focusing on the automation of traditional accounting artefacts, it conceptualises a new way of representing the complex enterprise reality.

### 3.3.2 An Open Value Network[1]

Sensorica is arguably more complex than a traditional enterprise. It is a productive network that is simultaneously a commons-based community, as well as a market-oriented entity. On one hand, individuals and organizations pool resources to initiate projects, driven primarily by intrinsic motivations, rather than financial rewards. On the other hand, the innovative solutions developed in Sensorica are introduced to the market to generate income.

Its structure is to a large extent informal, legally represented as a non-registered association, with which all the affiliated individuals and organizations are linked (OVN Space, 2016a; Siddiqui & Brastaviceanu, 2013). A non-profit organization acts as a custodian, holding all assets and

1 Adapted from a piece written by the author of this thesis, originally included in Bauwens, M. & Niaros, V. (2017) "Value in the Commons Economy: Developments in Open and Contributory Value Accounting", co-published by Heinrich-Böll-Foundation & P2P Foundation, available at: https://www.boell.de/en/2017/02/01/value-commons-economy-developments-open-and-contributory-value-accounting.

liabilities of the network, based on a ‘non-dominium’ agreement (Brastaviceanu et al., 2013). ‘Non-dominium’ mandates that no party or combination of them can have dominant control over the common resources, which reflects Sensorica’s interpretation of the commons.

Simultaneously, Sensorica uses independent exchange firms to interface with the market (OVN Space, 2016b; Sensorica, 2016a). Those firms are neutral entities, which serve to introduce the products co-developed in the network to the market. For this purpose they undertake all relevant operations, including marketing, sales and logistics, while they hold legal liability for the products. They can either be new firms launched by the network, or existing entities, internal or external. Their operation is fully transparent to the community and they are trusted to serve in the benefit of the network as a whole. The exchange firms are the exclusive carriers of the Sensorica brand in the market and are responsible for assuring the quality and ethical standards of the products (Brastaviceanu et al., 2016).

Sensorica identifies itself as a new type of organization which is referred as ‘Open Value Network (OVN)’ (Sensorica, 2016b). An OVN is a generic organizational and business model, apt to enhance and support commons-based peer production. As an organisation it is highly adaptive, fully decentralized and governed through distributed decision-making processes and resource allocation (Siddiqui & Brastaviceanu, 2013). As the name implies, it supports open participation, has very low barriers of entry and is designed to empower permissionless individual action through open knowledge and transparent processes.

The OVN is characterized by three fundamental principles: open membership; transparency and variety of contributions (Siddiqui & Brastaviceanu, 2013). Open membership means that members can freely join or leave the network and form, join or acquire enterprise entities. Also, members can either be individuals or organizations, including non-profits, government entities, enterprises or even other OVNs. Transparency enables the open source communities to gain access to information, knowledge and processes, with certain restrictions regarding specific types of resources that may need to be handled exclusively by special expertise (e.g. dangerous chemicals may be restricted to chemists, etc.). Finally, variety of contributions reflects the broad spectrum of what can be understood as a contribution, including material (e.g. resources, tools, consumables, etc.) and immaterial inputs (e.g. time, effort, information, etc.) or capital (e.g. financial investments, space, equipment, infrastructure, etc.).

The aspiration of the OVN model is to create a viable structure that harnesses the advantages of open collaboration and sharing, while it addresses the challenges of open source

projects related to governance and sustainability. Its economic dynamics are based on large scale collaboration and on customised production to create economies of scope. The OVN takes advantage of the diversity of inputs and shared resources to create innovative solutions and effectively reduce time-to-market for innovations. This way a unique potential is created through diversity and variety, which the linked business entities exploit to become competitive in the market. At the same time, the OVN model provides solutions for open source projects, so that they can effectively capture, manage and distribute financial rewards to the contributors; deal with issues related to trust; retain and protect a formal legal structure and brand; and formulate and execute a business strategy.

To achieve this, the Sensorica OVN rests on a techno-social infrastructure that reinforces decentralised organization and renders the network efficient and sustainable. It utilises the REA model to coordinate diverse agents, either individuals or business entities, with relevant flexibility with their legal and ownership arrangements, and perform all the traditional business functions, including R&D, coordination, production, distribution, marketing, sales, distribution of revenue, legal liability, etc. Simultaneously, it is keeping track of the different contributions in a transparent network-based system, which allows the created value to be fairly distributed within and beyond the network.

This infrastructure comprises three main interlocking systems (Sensorica, 2016c): (a) a Value Accounting System (VAS), which records and evaluates every member's input and calculates revenues in proportion to each contribution; (b) a reputation system, which determines the behaviour within the community and attributes merit in accordance to the collective interest; and (c) a role system, which allocates the arrangement and interrelation of the different activities among the agents, based on their skills and interests.

These systems enable the OVN to track and evaluate the contributions and redistribute revenue produced in the market. The Sensorica VAS is a contribution-based reward system, which fairly redistributes revenues in proportion to each contribution to the related projects. The logged contributions are evaluated, based on a metrics system, as well as participatory evaluations by the members (OVN Space, 2011). The aggregated data generated by the VAS are fed into the other two systems, which in turn support the VAS. This way the system generates a permanent quantitative and qualitative record of all contributions, in terms of who is doing what (role); how well (reputation) and how much (value) in a particular project.

The different dimensions of value are made commensurable using a value equation system, which attributes a percentage of the total revenue to every participant, in the form of 'fluid equity' (OVN Space, 2016c). The fluid equity of every contributor in a certain project is visually represented in the form of a pie-chart, illustrating its share of the potential revenue related to the project. That is, if exchange value is created in the market, the VAS guides the redistribution of the revenue to the contributors.

Furthermore, as the OVN is a dynamic structure, certain types of contributions are simultaneously associated with the creation of new resources (Brastaviceanu, 2014). For example, a design or a prototype which had been contributed to one project, represents a resource that can be used in a different context. Therefore, in order to facilitate this interoperability of the resources in different projects, the VAS is complemented by a Network Resource Planning (NRP) system, which matches resources with certain value streams.

The NRP is an Enterprise Resource Planning (ERP) type of software, designed based on the REA model to support the complexity of operations in an OVN. It collects, stores and interprets data from all the different types of activities in the network and connects them to specific resources, events and agents to keep track of the contributed value on resource level. Everything in NRP is connected with everything else. Economic agents are associated with other agents and participate in events of various types, such as processes, exchanges or transfers. Events change the state of resources, by using, citing, consuming, creating or transferring them. A certain resource may be an output from one event and then an input to another one. Those events are then again connected with a resource flow.

The NRP integrates the function of the VAS in Sensorica, by allowing the re-use of resources in different contexts. This is especially relevant in the the case of CBPP that relies on the circulation of digital commons, which are abundant and can thus be utilised simultaneously in many different contexts. In turn, further utilization of the associated resources results to further increase in the aggregated use value for the network. The NRP-VAS thus enables the advantages of network effects, while effectively supporting the complex underlying relations.

At the same time, the NRP-VAS supports the expansion of the OVN, as it may attribute equity to resources generated by external sources and integrate them into the network (Brastaviceanu, 2014). For example, a piece of open source software code, which has been developed by someone who is not a member of Sensorica, can be used within a Sensorica project to compile a final product that is then exchanged in the market. The external developer will be given a

percentage of fluid equity in the project and a proportional distribution of any revenue. This way, the OVN can connect creative communities in mutually beneficial terms with the NRP-VAS providing the common language.

Income can be generated in Sensorica through market operations or government grants. The NRP-VAS allows revenue to flow back to all contributors, not just those directly connected to the sources of income, either market or government partners. The system allows the identification and evaluation of the different qualities of contributions, through a combination of self-logging and peer review. It thus effectively succeeds in avoiding rent seeking behaviour, not just by external forces, but also by privileged internal agents, which attempt to exploit the common value for their personal gain. The techno-social infrastructure of Sensorica, on one hand, supports the network's operations and its contributors and, on the other hand, reinforces a certain state of affairs that represents a common sense of fairness within and beyond the network.

Conversely, as the distribution of rewards is based on past economic activity, the accumulated data comprise a public socio-economic profile related to a particular person or organization. There is thus a significant amount of power that this type of information can potentially provide if it is appropriated or centrally controlled. For this reason, Sensorica is exploring the deployment of the NRP-VAS infrastructure on the blockchain, to maximize integrity and security (OVN Space, 2016d).

## 3.4 Discussion

Both cases have been analysed in relation to the developed solutions supporting CBPP in productive communities. Their focus has been to effectively record and capture value created in CBPP and fairly distribute rewards to the contributors. In relation to the theoretical framework, the two cases arguably make an interesting contribution towards a new theory of value, building on the three layers suggested: (a) production of value; (b) record of value; and (c) actualisation of value.

On the first layer, production of value, in both cases value is created from productive communities engaging in CBPP. Those coordinate their productive efforts in networks of autonomous agents that participate on equal footing to make self-identified contributions towards a common goal. They rely on pooled resources and share the produced use values.

On the second layer, record of value, each case deploys a different solution. Backfeed exemplifies a potential application of blockchain technology to assist communities in reaching consensus on the value of the various contributions. Sensorica utilises the REA model to effectively

capture and represent the value flows in network operations. The two technologies offer increased capacity to capture value from a multiplicity of inputs, support pluralism in economic events and agility in the efficient allocation and re-use of resources in a diverse ecosystem. Moreover, the architecture of the infrastructure offers great advantages in terms of interoperability, transparency, data integrity and security.

Finally, on the third layer, actualisation of value, the two cases are arguably emblematic of the broader ecosystem of productive communities, which has been their inspiration. CBPP is a new modality of value creation that is moving beyond the existing cannons of value. Nevertheless, it is still bound by the limits of the dominant system, in which it has been born and developed. Therefore in both cases the actualisation of value is a hybrid process, that is simultaneously coordinating and colliding with the capitalist market. Backfeed envisions an ecosystem in which different value systems are interoperable through the exchange of digital tokens that embody these different value perceptions. Sensorica is interfacing with the market through independent entities that exchange its products to generate income. The produced value may entail a different interpretation of meaningful action in their respective productive systems, it however materialises through some form of market exchange that is either based on the existing (Sensorica) or an alternative (Backfeed) price system.

It is indeed difficult to reflect from those two cases alone on an economic system that will ultimately actualise the perception of value that is being formulated in the ‘greater whole’ of CBPP. However, there are arguably interesting aspects to be identified that point out to a different actualisation of use value, which is expressed through sharing and the practice of commoning. Future research could further explore this relation, reflecting on the capacity of a new theory of value to effectively allocate the vital resources of human subsistence based on the types of social relations underpinning CBPP.

Moreover, several limitations can be identified in both cases. On one one hand, Backfeed is on very early stage and the comprehension of its model is merely superficial. Also, the early OuiShare experiments have indicated several issues in its actual implementation, mainly regarding the quantification of contributions by a community that is built on solidarity (Pick, 2016). Moreover, there are many challenges related to the implementation of blockchain technology in large scale (Tapscott & Tapscott, 2016). On the other hand Sensorica has still not fully solidified its business model and is thus restrained in its capacity to provide sustainable livelihoods for the majority of its contributors. Furthermore, the REA model is still only sparsely taken up in enterprise systems and its overall efficiency is yet to be proven in practice. Nevertheless, both technologies

definitely present interest for future research from the perspectives of information systems, accounting theory and organisational theory.

# 4 Summary and conclusions

The topic of the current thesis was the concept of value and the way it is perceived and interpreted in distributed networks of autonomous agents. Specifically, the main inquiry was how value is conceived and captured in commons-based peer production (CBPP), the new modality of value creation that has been first exemplified in Free and Open Source Software and the internet.

For this, a certain theoretical position has been adopted in relation to value, recognising it as a coordination mechanism that determines meaningful action within a certain context. First, a historical analysis has been conducted exploring value in the history of economic thought, to identify the interplay of certain perceptions of value and the capitalist mode of production. Next, a review of the theory of techno-economic paradigms was used to inform the analysis of how the business and institutional reality evolves and changes. Subsequently, the information economy was investigated, as the emerging techno-economic context of CBPP, and several challenges have been discussed in relation to value. Finally, a theoretical framework for a new theory of value has been synthesised, comprising three layers: (a) production of value; (b) record of value and (c) actualisation of value.

The main research question was explored through two illustrative cases: Backfeed, a protocol for decentralised consensus implemented on blockchain technology; and Sensorica, a productive network that develops open hardware solutions utilising sensor technologies.

Backfeed offers a blockchain-based consensus protocol which allows communities to evaluate contributions that are made to a collaborative project. In return, it calculates the value of each contribution and generates a reputation score for the contributor, and a reward in the form of digital crypto-tokens. Respectively, Sensorica relies on a socio-technical infrastructure to support its network-based productive operations. A value accounting system logs all contributions that are made in a collaborative project and distributes revenue proportionally. Simultaneously, a Network Resource Planning system builds on the Resources-Events-Agents accounting model to track, connect and represent all activities that take place in the network.

The models presented by the two cases arguably illustrate elements that compose a new practical perception of value in collaborative productive activities. Furthermore, they also suggest a new theoretical conceptualisation of value in the types of social relations that underpin CBPP.

Given that CBPP still operates within the confines of the existing political economy, and regardless of the relevant limitations and concerns about the technological solutions presented, the two cases arguably synthesise an interesting interpretation of how value can be perceived and captured in CBPP. Simultaneously, they contribute to the general understanding of the relevant phenomena in the information economy and assist in the formulation of intriguing questions for future research in the various related fields.

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