The Origin of Value Through Information Networks: a Preliminary Framework from an Evolutionary Holonic Perspective (March 19, 2010)

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Abstract

The worldwide extraordinary level of interest in digital information networks deployment among nations is due to the strong perception that they bring economic, social and environmental value. Our literature review on studies aiming at clarifying the value of information networks, led us to conclude that these studies take speculative, elusive or limited conclusions. We identify the requirements to capture the value of information networks and indicate a possible theoretical ground to account for it. Based upon this, we propose a preliminary framework supported with data from Eurostat. Furthermore, we identify the added-value of our framework with a precise and comprehensive comparison with two state of the art reference frameworks. We demonstrate that our framework, even in a preliminary stage, provides significant conceptual added-value and, more fundamentally, allows for traditional measures of economic value (e.g. productivity and growth), as well as for social and environmental value. Hence, our framework is an essential input to any policy maker interested in information network-related private and public policies. Finally, we demonstrate with examples the wider application range of our framework in comparison with existing work.

1. Introduction

Since the 1980s, the telecommunication sector has been expanding rapidly (Shiu and Lam (2008)). The exponential growth of telecommunication-supported information network services can be explained by many factors, including technological advancements, market liberalization and privatizations. The worldwide extraordinary level of interest in information networks deployment among nations is due to the strong perception that information networks bring economic, social and environmental benefits (Firth and Mellor (2005)). OECD

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(2001) speculates that information networks may have a similar impact as transport networks had during the 20^{th} century. The benefits have both a quantitative nature (e.g. deployment of the infrastructure) and a qualitative nature (e.g. better quality of health care services, improved education and organizational efficiency). Policy makers have for long expressed this perception upon the value of information networks (World Bank (1998)). OECD (2001) considered broadband as key to enhancing competitiveness and sustaining economic growth. Many governments are increasingly committed to extending information networks to their citizens (Katz et al. (2009)), particularly in the developing nations (Kagami et al. (2004)). Consequently, the levels of interdependency between users and information network providers increased dramatically (van Dijk and Mulder (2005)) and the information network infrastructure became an essential facility for other sectors.

The contribution of this paper is as follows. In section 2, we describe the state of the art with: a) two paradigmatic views on the value of information: orthodox and evolutionary economics; b) the major conclusions of a thorough literature review of 23 studies spanning the years 1980-2009 aiming at clarifying the value of information networks; c) the major conclusions of a thorough literature review of 36 studies on the value of Information Technology (IT) in general (with hard- and software); and d) a set of requirements for any framework aiming at capturing the value of information networks. In section 3, we provide a theoretical background to account for these requirements. In section 4, we propose a novel preliminary framework to address the value of information networks. In section 5, we compare our framework with two reference frameworks and we discuss the empirical validation and application of our framework. In section 6, we resume the most relevant conclusions.

In order to support further investments in digital information network infrastructures (e.g. in Fibre To The Home (FTTH)), it is necessary to justify expenditures that have already been made and demonstrate their value. The framework described in this paper adds up significant conceptual and applied value in comparison with previous work in the field. Therefore, it is an essential input for policy makers in the development of private and public information network-related policies.

2. State of the art

2.1. Orthodox and evolutionary economics

Two views can be distinguished to account the value of information networks (Bulkley and Alstyne (2004)): the *orthodox economic* approach and the *evolutionary economic* approach.

The orthodox economic approach views information as an observable production input changing the uncertainty regarding the performance of an economic system. In this context, the value of information is the difference between an informed economic system and a uninformed economic system (Hirshleifer (1973) and Arrow (1962)). For example, in Koutroumpis (2009), information was observed by measuring the broadband penetration rate and the economic system performance was observed by measuring economic growth. The value of information was measured by the correlation between the broadband penetration rate and the economic growth.

The evolutionary economic approach views information as procedures to change the nature of an economic system. In this context, the value of information is the difference between the results obtainable by invoking procedures from one economic system to that of another (Alstyne (1999)). For example, recruiting agencies have multiple procedures to locate, evaluate and place job candidates. An information procedure has value if it changes the obtainable results for the better.

The orthodox view of an economic system is coarse grain as a black box transforming inputs into outputs. The evolutionary view is finer grain: modular input procedures can be rearranged to rearrange outputs. The orthodox view helps understanding the value of information networks as facts from observations. The evolutionary view helps understanding the value of information networks as procedures leading to changes in observations. The orthodox view applies statistical inference to the observations. The evolutionary view applies rule based logic to construct paths with modularity, robustness, search and connectivity through a collection of problems. From this perspective, the evolutionary approach extends logically to flows and information networks. Descriptions of economic systems are typically orders of magnitude larger in evolutionary economics than in orthodox economics. Thus, it is not uncertainty, but complexity or computational costs to generate and search an enormous space state of information procedure possibilities that concerns evolutionary researchers.

Kallinikos (2006), in an attempt to understand the complex character of technologically sustained information processes, takes some conclusions about the nature of information: information is self-referential and non-foundational. Self-referential in the sense that for information to have value it must be able to add a difference to what is already known. Using words of Borgman (1999): "to be told that the sun will rise tomorrow is to receive no information. To learn that one has won the jackpot in the lottery is to have great news". Non-foundational in the sense that informational differences emerge through comparison of two or more objects or items, thus, are not singular, but relational entities. The central criticism to the orthodox approach is that it fails to picture the fundamental nature of information and of the economic agent as an information processing entity (Dopfer (2004)). Doing so, it misstates the nature of reality, not in a marginal way, but in a fundamental way.

2.2. Literature on information networks

Information networks do not act in economy by itself, but in conjunction with other IT (primarily consisting of hard- and software). Therefore, the separability of the value of information networks is not an elementary task and most of the research done aims at understanding the general value of IT. We reviewed 23 studies, from 1980 to 2009, focusing on the value of information networks and they all have an orthodox economic character. We just present here the major conclusions.

These studies can be grouped into three classes: 1) macro-economic type of studies using general equilibrium theories and/or input-output tables (Katz et al. (2009), Greenstein and McDevitt (2009), Correa (2006), ACIL Tasman (2004), CEBR (2003), Röller and Waverman (2001) and Hardy (1980)); 2) econometric type of studies not addressing the issue of causality (Thompson and Garbacz (2008), Thompson and Garbacz (2007), Shideler et al. (2007), Duggal et al. (2007), Crandall et al. (2007), Lehr et al. (2006), Datta and Agarwal (2004), Sridhar and Sridhar (2004), Madden and Savage (2000), Madden and Savage (1998), Greenstein and Spiller (1995) and Leff (1984)); and 3) econometric type of studies claiming to address causality (Koutroumpis (2009), Shiu and Lam (2008), Ford and Koutsky (2005), Cronin et al. (1991)).

The usefulness of the models from the first class comes from the fact that they provide policy analysts a tool to study the effect of information networks across the interdependences and feedbacks of an economy (Borges (1986)). But due to the nature of the underlying assumptions (e.g. perfectly rational behaviour and equilibrium solutions), empirical validation is not addressed (Farmer and Foley (2009)). Hence, claims like "the economic impact of broadband development over a ten year period in Germany amounts to 968000 additional jobs" (Katz et al. (2009)) tend to have a speculative character.

Madden and Savage (1998) found out that the causality between information networks and economic growth is generally in both directions. Similar observation was made by Shiu and Lam (2008) who observed a "bidirectional relationship between telecommunications development and economic growth for European countries and those belonging to the high-income group". Thus, causality is a methodological challenge inherent in disentangling the value of information networks. This is obvious, given the self-referential character of information referred above. Thus, all the results of these studies should be interpreted cautiously.

Recently, some econometric studies have claimed to address the issue of causality. However, in orthodox economics, causality is traditionally considered redundant or methodologically impeding. Thus, either it is simply left apart or it is given a deterministic interpretation which strips it of its original substance (Dopfer (1986)). On the other hand, evolutionary economics stands upon finer grain procedural descriptions of causal paths which led to a much more sophisticated and realistic concept of causality (*circular and cumulative causality* pioneered by Thorstein Veblen in 1898 (Samuels (1993))). It is symptomatic that, although Koutroumpis (2009) claims important direct benefits from broadband to economic growth, the actual intermediating processes are not clarified.

2.3. Literature on IT

We also reviewed 36 studies on the value of IT (including hard- and software). The first studies on the value of IT provided equivocal results. For example, Santos et al. (1993) evidence that, on average, IT investments are zero Net Present Value (NPV) investments, thus, they are worth as much as they cost. These earlier studies have led to the so called *IT productivity paradox*, best stated by Robert Solow's famous quote in 1987: "you can see the computer age everywhere but in the productivity statistics". In 1996, Hitt and Brynjolfsson (1996) resumed the *status quo* stating that "while some authors have attributed large productivity improvements and substantial consumer benefits to IT, others report that IT has not had any bottom line impact on business profitability". The same authors in the same year (Brynjolfsson and Hitt (1996)), proclaimed the end of the IT productivity paradox after verifying that IT spending has made a substantial and statistically significant contribution to firm output in their dataset including 367 large firms.

Despite this claim from Brynjolfsson and Hitt (1996), the subsequent studies were cautions about the end of the IT productivity paradox. Mitra and Chaya (1996) found out that IT investments are associated with lower average production costs, lower average total costs and higher average overhead costs. Byrd and Marshall (1997) mention that "direct linkage between technology investment and increase in organizational performance and productivity has been extremely elusive". In 2000, Brynjolfsson and Hitt (2000) raised the issue of causality reviving serious doubts about the positive results obtained until then. Brynjolfsson and Hitt (2000) suggest that the link between IT and increased productivity emerged well before the recent surge in the aggregate productivity statistics and that the current macro-economic productivity revival may in part reflect the contributions of intangible capital accumulated in the past. Sircar et al. (2000) express the view at the time stating "there have been several attempts in the past to assess the impact of information technology on firm performance that have yielded conflicting results" (see also Thatcher and Oliver (2001)). Some attempts were made to improve the econometric results by observing different variables related with IT and performance (Hitt and Brynjolfsson (1996), Sircar et al. (2000) and Stiroh (2002)).

All the previous research mentioned treats IT as one whole system much in line with the orthodox economic approach. A more advanced stream of literature, more in line with evolutionary economics, attempts to depict the value of particular subcomponents of IT (Lee and Treacy (1988), Sambamurthy et al. (2003), Bulkley and Alstyne (2004) and Aral et al. (2008)). With these more specific studies, recognized scientific fields emerged in the information economic domain. One of them was Transaction Cost Economics (TCE) which analysed the value of IT in terms of its impact on transaction costs and coordination risks (Bartel et al. (2007), Zaheer and Venkatraman (1994) and Garicano and Kaplan (2001)). Another emergent scientific field was Resource Based View (RBV) economics. The resource-based view of the firm attributes superior financial performance to organizational resources and capabilities (Wade and Hulland (2004), Hitt et al. (2002), Bharadwaj (2000), Corso and Paolucci (2001) and Melville et al. (1994)). Recently some scholars started investigating the value of individual IT Enterprise System (ES) (Zand and van Beers (2010) and Hendricks et al. (2007)).

2.4. Framework requirements

From the literature review, we can extract some requirements for our framework. A paradigmatic shift from orthodox economics to evolutionary economics seems to be imperative. The reasons are two-fold: 1) to provide a finer grain view of the intermediate processes between information networks and economic value (for example, in line with the work of Samuels (1993)), instead of the prevailing use of direct statistical deterministic relations which provide few insights on how the actual value of information networks spreads across the economy; and 2) to provide a more convincing explanation of the causality issue.

Furthermore, the framework should be able to cope both with analyses at the micro-level (e.g. Aral et al. (2008)) as well at the macro-level (e.g. at the firm-level (Brynjolfsson and Hitt (2000)), at the industry-level (Thatcher and Oliver (2001)) and at the country-level (Katz et al. (2009))). Multi-level theorists have drawn attention to the assumptions made for each level of analysis and how those assumptions can influence the entire range of theoretical and methodological issues associated to organizational studies (Garicano and Kaplan (2001)).

Finally, the framework should be able to relate mechanistic views of the value of information networks in line with orthodox economics with more sociological views (Giddens (1993)). If this connection is indeed established, subsequent work should lay down theoretical and methodological propositions to connect different levels of analysis, from micro to macro-levels.

To identify the added-value of our framework, we compare it with two state of the art reference frameworks (Zand and van Beers (2010) and Bulkley and Alstyne (2004)). These frameworks were chosen due to their newness, conceptual richness and because they already led to relevant empirical results. The first one (Zand and van Beers (2010)), although with a strong empirical character, describes a rich conceptual framework which we will refer in this paper as the *Delft University of Technology (DUT) framework* as a reference to the origin of the authors. The framework in the second paper will be referred in this paper as the *Massachusetts Institute of Technology (MIT) framework* (Bulkley and Alstyne (2004)). In the discussion section, we make thorough and detailed comparisons between our framework and the DUT and MIT frameworks.

3. Theoretical background

3.1. Holon theory

The term *holon* was introduced by Koestler in his book *The Ghost in the Machine* (Koestler (1967)). The word *holon* combines the Greek word for *whole* (*holos*) with the suffix *on* which suggests particle or part. Thus, the holon is a part-whole, a nodal point in a nested hierarchy (called by Koestler as *holarchy*). A holon can be described in terms of its holistic and independent nature, as well as partness and dependent nature (Edwards (2005)). Depending on the view point in a nested holarchical structure, the perception of what is the whole and part will change. Koestler refined the properties of a holon with a very detailed set of propositions which he called *General Properties of Open*

Hierarchical Systems (OHS). The holon theory represents nested systems as organizations or economic systems by accounting for: 1) contrasting views of mechanistic physical and behavioural sciences, holistic system theories and sociological sciences; 2) evolutionary processes in social sciences; and 3) individual micro-level, as well as for the collective macro-level.

Several authors have illuminated the rise of a holonic society (Ulieru and Este (2004), Kurzweil (2003), Kurzweil (2001), Gleick (1999), Davis and Meyer (1998), Negroponte (1995) and Kurzweil (1990)), enabled by the Internet, multiple entities are connected through invisible links. These entities form virtual communities generating behaviours which current complexity can not be copped by traditional simplistic mechanistic and holistic views (Kauffman (1995) and Kauffman (1995)). Each of these entities has a variety of purpose-built capabilities (e.g. sensing and reporting) networked in Peer To Peer (P2P) and server/client modes for self-direction and interaction (Ulieru and Este (2004)). These entities interact in complex multi-level nested structures. For example, work teams include, but are more than the sum of individuals. Organizational departments include, but are more than the sum of work teams. Organizations include, but are more than the sum of departments, and so on.

In our framework we use the concept of **holon** to refer to an entity that is part of and makes use of multi-level networks for exchange of information. The use of the holon concept in the context of information systems is not new, even at a technological level. Peters and Többen (2005) describe how the holon theory is applied in the Supply Chain Management (SCM) domain and how insights achieve higher efficiency and effectiveness. Cheng et al. (2004) adopt the holon theory to develop a holonic information coordination system to support agile manufacturing activities. Adelsberger (2000) propose coordination mechanisms developed within economic frameworks to design manufacturing holonic multi agent systems. Fischer (1999) describes a design of the architecture of a Computer Integrated Manufacturing (CIM) system based upon holonic models. Brussel et al. (1998) discuss how a holonic reference architecture for manufacturing systems is crucial to achieve a high degree of self-similarity, which reduces the complexity to integrate new components and enables easy reconfiguration of the system. Although the use of the holon theory is still limited, we believe that further insights could be gained by interpreting the General Properties of OHS in the context of the value of information networks.

3.2. Evolutionary economics

In the case of the value of information networks, evolutionary economics procedures or intermediate processes lead to interactions across holons with information as an input and value as an output. The notion that an economic system should be studied as a system of interactions and procedures is common in structuralist and sociological views (Giddens (1993)). In our literature review on the value of IT in general, some authors mentioned this notion of intermediate process. For example, Sambamurthy et al. (2003) argue that IT investments and capabilities influence firm performance through three significant organizational capabilities (agility, digital-options and entrepreneurial-alert) and strategic processes (capability-building, entrepreneurial action and co-evolutionary adaptation). The intermediate procedure in the work of Sambamurthy et al. (2003) is a *capability*. Both theoretical (van der Hoek et al. (1994)) and implementation (Busetta et al. (2000)) work exists concerning the notion of capabilities. Others mention *routines* (Nelson and Winter (1985), Cyert and March (1963) and March and Simon (1958)) or *competencies* (Prahalad and Hamel (1990)).

Hence, **capabilities** refer to procedures that an holon can utilize to navigate through information network flows that potentially bring value. The preliminary framework that we lay down in this paper identifies six capabilities of a holon. These are *coordinatibility*, *cooperatibility*, *selectibility*, *biddability*, *adoptability* and *creatibility*. These concepts are simple and fundamental but are the underlying principles to really capture the value of information networks. With this framework, we expect to provide a set of simple, fundamental but powerful concepts that can be used to combine research from more general and detailed, macro and micro studies. In the next section, we will first discuss the core concepts, followed by examples of available data to illustrate the power of our concepts.

4. Framework

Coordination is a cross-disciplinary process. From the organizational perspective, the emphasis is on the investigation of coordination mechanisms increasing organizational performance. Based upon Malone and Crowston (1994), we define **coordinatibility** as the *capability of a holon to manage dependencies between organizational activities performed to achieve a goal*. Within organizational management, coordination mechanisms are used in various applications, namely in systems of production, logistics and service operations. Figure 1 describes the relation between the % of enterprises using systems for managing production, logistics or service operations and the % of enterprises which have access to the Internet. The % of enterprises is given by sector, country and year (e.g. the reference *10_D RO 2007* refers to Romanian enterprises in 2007 from the Statistical Classification of Economic Activities in the European Community (NACE) sector of manufacturing). The regression line plotted reveals a strong coefficient of determination R^2 (0.43226) between information networks-usage (proxied by Internet-usage) and coordinatibility (proxied by systems of production, logistics or service operations-usage). This R^2 value certifies the relevance of coordinatibility to be considered in the framework.

Cooperation is achieved when a number of persons enters a relationship with others for a common benefit or collective action in pursuit of the common well-being (Consoli et al. (2006)). Most often, cooperation is associated with coordination, but a few theorists clarify that they are distinct concepts (Payan (2007)). Electronic commerce is just one example of **cooperatibility** which, based upon Consoli et al. (2006) and Blecker (2003), is defined as the *capability of a holon to enter in a relationship with other holons for a common purpose*. The deployment of information networks fuelled the rise of electronic

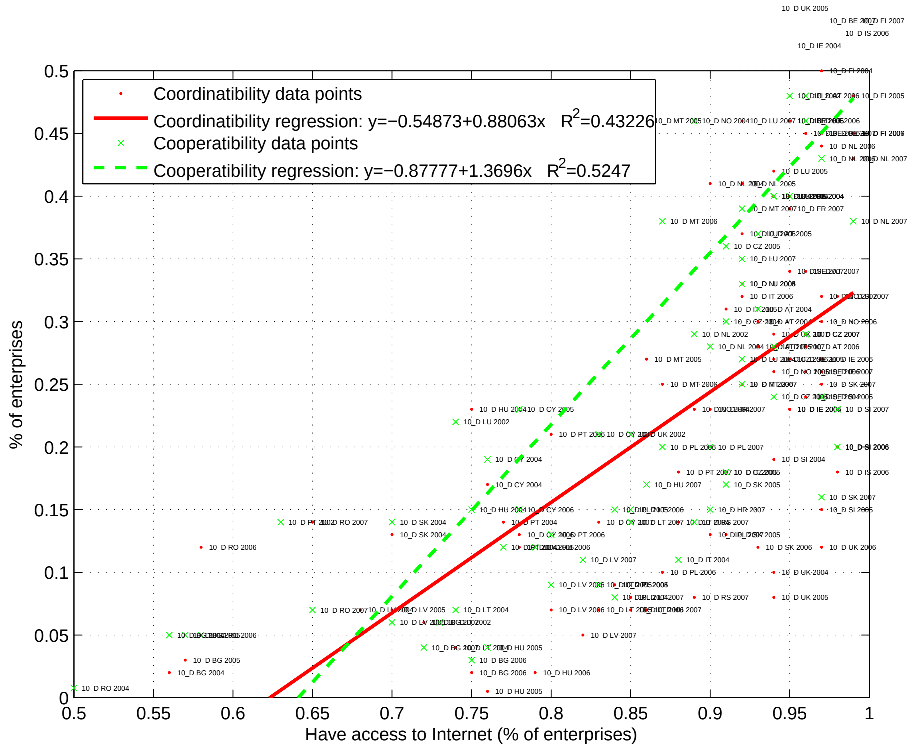

Figure 1: Coordinatibility and cooperatibility

commerce, matching the goals of buyers and sellers to cooperate in a supply and demand relation (Weiss (2009)). Figure 1 describes the relation between the % of enterprises that have ordered or received orders for products or services with the Internet and the % of enterprises which have access to the Internet. The enterprises in figure 1 belong to the NACE sector of manufacturing from various countries in different years. The regression line plotted reveals strong coefficients of determination R^2 (0.5247) between information networks-usage (proxied by Internet-usage) and cooperatibility (proxied by orders received and done with the Internet).

Selection is another cross-disciplinary process. Yet, despite the pervasiveness of selection, Price (1995) points out that there has been no abstraction and generalization to obtain a general selection theory. He predicts the appearance of such theory in the future, much as Shannon's communication theory appeared in the past. The World Wide Web (WWW) is an important source of information, and therefore, search engines are an essential WWW facility. Based upon Bulkley and Alstyne (2004), we define **selectibility** as the *capability of a holon to scan for the unknown or generate courses of action that improve on known alternatives.* Over 80% of WWW searches use search engines to locate information (Nielsen Media (1997)). Figure 2 describes the relation between the % of enterprises using Internet information search and the % of enterprises which have access to the Internet. The regression line plotted reveals a strong coefficient of determination R^2 (0.68502) between information networks-usage (proxied by Internet-usage) and selectibility (proxied by the use of Internet information search engines). This result is unquestionable about the importance of selectibility.

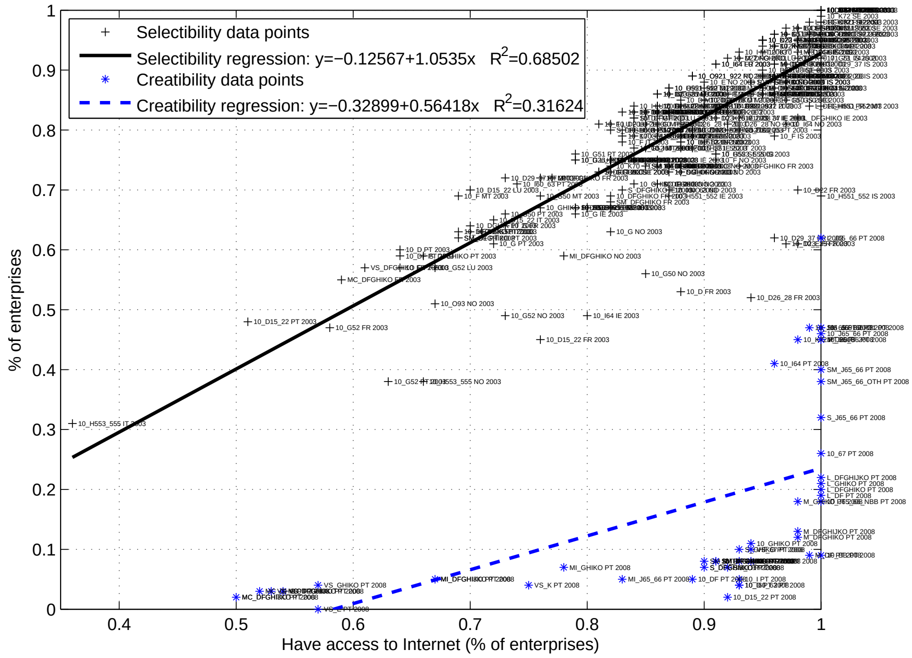

Figure 2: Selectibility and creatibility

Through ages, bidding has been used to determine the value of hard-to-price items (e.g. antiques). Around 500 BC, bidding was used to auction off wives in ancient Babylon and the crown of a Roman emperor was sold by auctioning in 193 AD (Cassady (1967)). Objects, such as an art work, are typically awarded to the highest bid. A contract to build a highway constructions is usually given to the lowest bid. Gilbert (1977) investigates bidding on cable television franchises. Shubik (1971) studies bidding in the *dollar auction*. Smith and Parker (1976) study bidding within animals. We define **biddability** as the *capability of a holon to influence other holons through proposals*. Information networks have lowered the costs of organizing bidding auctions, which is leading to an increasing number of transactions (Lucking-Reiley (2000)). Milgrom (1989) states that Internet transactions reduce the state space of the negotiation to the bid alone and has the "additional advantage of being an institution [Internet] where the conduct can be delegated to an unsupervised agent". Some developments enabled the development of online-bidding: security mechanisms, improved web browsers, increasing Internet usage, etc. (Beam and Segev (1998)). Figure 3 describes the relation between the % of individuals using Internet for buying and selling goods (within the last 3 months) and the % of households which have access to the Internet. The regression line plotted reveals a strong coefficient of determination R^2 (0.51356) between information networks-usage (proxied by Internet-usage) and biddability (proxied by the use of Internet for selling goods and services).

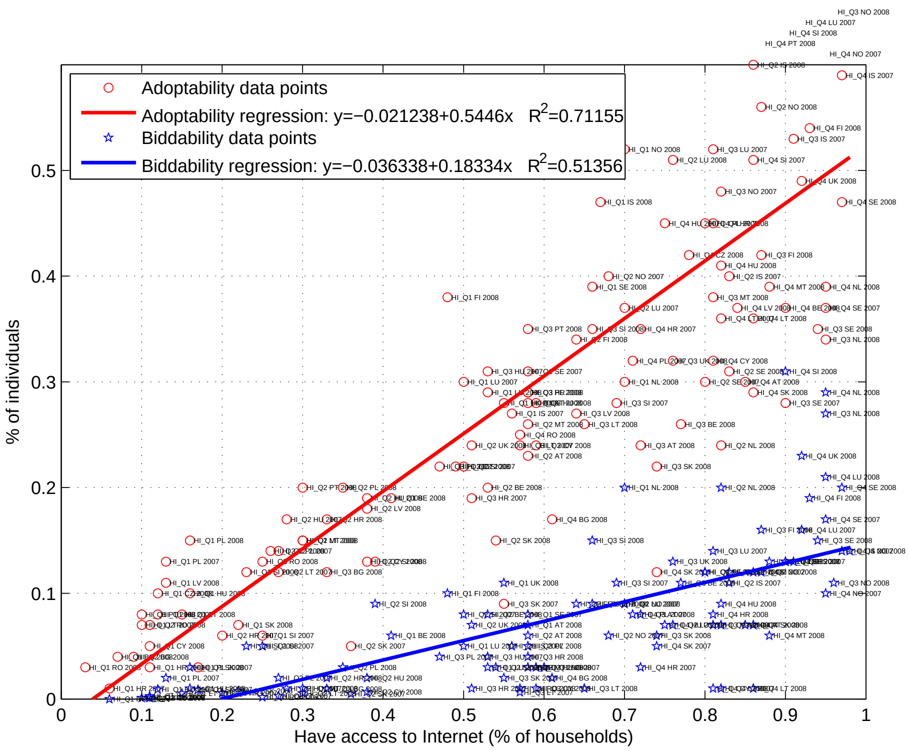

Figure 3: Adoptability and biddability

The capability of integrating knowledge in existing knowledge structures is a crucial step for success. In the current knowledge-based economies, growth is generated from innovation (Beesley and Cooper (2008)). We define **adoptability** as the *capability of a holon to acquire novel knowledge from other holons to be integrated in existing internal knowledge structures*. Knowledge Management (KM) is the discipline concerned with the conceptualization of knowledge and the design of best-practices for the management of knowledge. Due to the nature of knowledge, it owes much to other disciplines, namely philosophy (Piaget and Duckworth (1970)), psychology (Glaser (1984)), social sciences (Wilson (1996)), management sciences (Senge (1984)), computing, etc. Figure 3 describes the relation between the % of individuals using Internet for training and education (within the last 3 months) and the % of households which have access to the Internet. The regression line plotted reveals a strong coefficient of determination R^2 (0.71155) between information networks-usage (proxied by Internet-usage) and adoptability (proxied by the use of Internet for training and education).

As firms struggle in competitive environments, innovation becomes increasingly important. Information networks "renders the firm's capabilities *amorphous* in nature" (Kandampully (2002)) providing the ultimate potential for creation. Based upon Beesley and Cooper (2008), we define **creatibility** as the *capability of a holon to deliberately and purposely collate knowledge to generate new or novel ways to understand a particular phenomenon.* Figure 2 describes the relation between the % of enterprises that consider Internet significant for the development of new products and services and the % of enterprises which have access to the Internet. The regression lines plotted reveal a significant coefficient of determination R^2 (0.31624) between information networks-usage (proxied by Internet-usage) and creatibility (proxied by the significance given by enterprise to the Internet for the development of new products and services).

Any holonic process can be characterized according to two fundamental dimensions of existence: the interior-exterior and the individual-collective dimensions (Edwards (2005)). The interior-exterior dimension refers to the relationship between the interior subjective world (e.g. intentions) and the exterior objective world (e.g. actions). The individual-collective dimension refers to the relationship between the individual self-steered world (e.g. goals) and the collective communital world (e.g. values). Hence, holonic processes can be framed in four quadrants (interior/individual, interior/collective, exterior/individual, exterior/collective). The exterior/individual quadrant focuses in objective self-steered processes of the holon such as the capabilities identified in our preliminary framework so far: coordinatibility, cooperability, selectibility, biddability, adoptability and creatibility. In our future work, we intend to provide a complete set of capabilities covering all the four quandrants (see figure 4).

5. Discussion

5.1. Comparison with the DUT framework

The DUT framework (Zand and van Beers (2010)) investigates the economic impact of Enterprise Systems (ESs). An ES is a software application that provides services to a whole organization rather than a single department or group within it. The DUT framework considers five groups of ESs: Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), Knowledge Management System (KMS) and Document Management System (DMS). ESs enable innovation through new practices, routines, processes, methods, channels, services and/or products. The firm performance is evaluated using four metrics: growth, profitability, productivity and market share. Hence, the DUT framework identifies six intermediate processes between information networks and value: 1) ERP, 2) SCM, 3) CRM, 4) KMS, 5) DMS and 6) innovation. To compare our framework with the DUT

Upper-left **Interior-individual** **Intentional**	**Upper-right** **Exterior-individual** **Behavioral** Coordinatibility Cooperatibility Selectibility Biddability Adoptatibility Creatibility
Lower-left **Interior-collective** **Cultural**	**Lower-right** **Exterior-collective** **Social**

Figure 4: Framework

framework we simply map the capabilities and the holonic quadrants with these six concepts. The DUT framework also describes another component (*firm, market and country-specific conditions*) that, although not directly dependent on information networks, affects the performance of the firm.

ERP is an ES that is used to manage, coordinate and integrate all the resources, information, and functions of a business through shared data sources (Esteves and Pastor (2001)). Thus, the central capability of an ERP is to coordinate information. Therefore, we map ERP with coordinatibility. Similarly to ERP, SCM is an ES that plans, coordinates and manages all the activities related to movement and storage of raw material, work-in-process inventory, and finished goods throughout the whole supply-chain of a company (Mentzer et al. (2001) and Cooper et al. (1997)). Hence, we also map SCM with coordinatibility. CRM is an ES that centrally tracks, records, organizes and processes the contacts of a company with its current or prospective customers (Zand and van Beers (2010)). Clearly, CRM should also be mapped to coordinatibility. Moreover, by supporting customer relationship management and strategy, CRM facilitates cooperation processes between firms and prospective customers. Thus, we map CRM also with cooperatibility. Finally, CRM also enables the establishment of trust ties between firms and customers (Sin et al. (2005)). Thus, we map CRM with the interior/collective holonic quadrant, assuming trust as a subjective collective relation. KMS is an ES to collect, organize, process, share and manage the information and knowledge assets of an organization (Alavi and Leidner (2001)). Thus, the central feature of KMS is to facilitate the adoption of knowledge, and therefore, we map it to adoptability. DMS is an ES to collaboratively create, edit, review, index, track, search, retrieve, publish and archive electronic documents and digitalized images of paper documents (Zand and van Beers (2010)). The main feature of DMS is to support the creation of documents. Hence, we map it with creatibility. The final concept, innovation, is associated by the authors both to adoptability, in the sense of imitation of knowledge, and creatibility, in the sense of supporting the creation of new ideas. Thus, we map DUT concept of innovation both with adoptability and creatibility.

ERP, SCM and CRM are all mapped with coordinatibility. CRM is also mapped with cooperatibility and with the interior/collective quadrant. KMS and innovation with adoptability. DMS and innovation with creatibility. Hence, the DUT framework fails to identify ESs associated with two capabilities (biddability and selectibility) and two holonic quadrants (interior/individual and exterior/collective). Given the empirical character intended in the work of Zand and van Beers (2010), it is not strange that the DUT framework fails to identify some of the intermediate processes between information networks and economic value. The empirical objects chosen, ESs, are technologies for which is easy to verify the availability. Thus, the work of Zand and van Beers (2010) is still much in line with the orthodox economic approach. Doing so, it fails to identify the processes with a more intangible (the two holonic quadrants), perhaps less significant (biddability) or underlying nature (selectibility).

5.2. Empirical validation

In the state of the art, we discussed how differently the concept of causality is seen in the orthodox and in the evolutionary economic approaches. In orthodox economics, causality is simply left apart or it is given a deterministic interpretation. In evolutionary economics, causality stands upon finer grain procedural descriptions of causal paths in a much more realistic and sophisticated view of reality. The different view upon causality in orthodox and evolutionary economics raises a fundamental difference of what is referred to as empirical validation.

The performance of an economic entity is, in general, dependent on external factors. For example, market concentration, competitive technology or regulatory regime. Naturally, these external factors also influence the value that a firm obtains from information networks. Thus, the value of information networks can be said to depend on direct factors (e.g. the capabilities) and indirect (or external) factors.

Following their view of causality, orthodox economists empirical validation is performed by investigating relations between variables using differential equations, regression or related techniques (Smith and Conrey (2007)). For example, orthodox economists would observe information networks measuring the penetration rate, the economic value by measuring productivity and their relation using a regression technique. These observations are necessarily very aggregated, and therefore, *rough.* One might get what in organizational theory is called a *garbage can model* and in software engineering a *garbage in garbage out* problem. Moreover, such an empirical validation approach provides few insights on the phenomenon under study. Finally, lack of readily available (only those concepts are included for with data is available) or frequently noisy data (for example, due to the influence of external factors) might hamper the progress of research.

Following their view of causality, evolutionary economists empirical validation is identified with a consistent covariation between two variables (see the *quasi-experimentation* design of Cook and Campbell (1979)). Thus, their concern is not to observe and correlate aggregated variables of information networks and economic value, but to identify stylized facts that reveal the intermediate multi-level processes (the capabilities). This form of empirical validation provides a much deeper understanding of the phenomenon, but fails to provide a statistical explanation of regularities across very aggregated variables (and, thus, also to account the external factors). However, if indeed evolutionary economists proceed to the orthodox view of empirical validation, then many challenges raise (Fagiolo et al. (2007)): how to relate and calibrate parameters, initial conditions and stochastic variability to existing empirical data? To what extent can we truly compare empirical data with stylized facts or, alternatively, with counter-factuals?

5.3. Comparison with the MIT framework

The MIT framework (Bulkley and Alstyne (2004)) presents a set of seventeen hypotheses in an effort to connect information (in general) with productivity (see table 1). To compare our framework with the MIT framework, we map the hypotheses with the capabilities and the holonic quadrants described in our framework. Four MIT framework hypotheses are directly and uniquely mapped with four capabilities: 1) H1 $\leftrightarrow$ coordinatibility; 2) H2 $\leftrightarrow$ selectibility; 3) H3 $\leftrightarrow$ adoptability; 4) H4 $\leftrightarrow$ creatibility. Four MIT hypotheses are mapped with the exterior/collective quadrant, because they relate to objective collective aspects of the holon, such as norms, policies and structure of information dissemination. These are: 1) H5 (information dissemination); 2) H6 (firm policy); H7 (norms/standards); and H8 (modular design as a organizational norm for production).

Six MIT hypotheses are mapped with the interior/individual quadrant, because they relate to subjective individual aspects of the holon such as cognition and decision. These are: 1) H9 (decision); 2) H10 (decision); 3) H11 (decision); 4) H12 (the intermediate process is information push, thus, a decision process made by the holon in face of an external factor: undervalued assets); 5) H13 (cognition); and 6) H14 (cognition).

One MIT framework hypothesis (H15) describes the value of information based upon network topological metrics (size, variety and centrality of the holon relatively to the network). Thus, it can be applied to any intermediate process that generates networks (e.g. social and cultural networks). This hypothesis is not helpful to identify any underlying microscopic intermediate process, and therefore, we do not map it to any capability or quadrant. Two other MIT hypotheses are also not mapped to our framework, because they relate to external indirect factors (environment change and risk) that, although indirectly affecting the productivity of an organization, are not necessarily intermediate processes between information and productivity. These are: 1) H16 (environment risk); and 2) H17 (environment change).

Two capabilities (biddability and cooperatibility) and one quadrant (interior/individual) are not addressed by the MIT framework. Contrary to our pure evolutionary approach, the MIT framework, partially, still follows the orthodox economic approach in the sense that there is a brief description of the intermediate process accompanied with explicit references to end-to-end observables. For example, in the hypothesis H4, the mediating process is briefly address (creatibility), the input observable is "know-how" and the output observable is "productivity". In our definition of creatibility, we elaborate rather upon the intermediate process: *creatibility is the capability of a holon to deliberately and purposely collate knowledge to generate new or novel ways to understand a particular phenomenon*. An important implication results from focusing in the intermediate processes without specifying the end-to-end observables: a variety of other applications becomes obvious. In parallel with value assessment, we are investigating two other applications for our framework: service design (Madureira et al. (2009)) and infrastructure interoperability (Madureira et al. (2010)). But even within value assessment, the evolutionary holonic approach brings a significant difference to the concept of *value* than the one understood by the MIT and the DUT frameworks.

5.4. Value from the evolutionary perspective

In earlier times, value in the economy lay on the supply side. For example, Richard Cantillon (1680-1734) in his *Land Theory of Value* (Hayek (1985)), believed that value depends on how much scarce land was used in making a product, and Karl Marx saw labour as the ultimate supply of value (Marx and Engels (1998)). Then, mainly with the work of Stanley Jevons (1835-1882) (Jevons (1988)) and the proposition that value is determined by consumers' utility, the origin of value moved to the demand side. Finally, in the neoclassical synthesis, the supply side meets the demand side: scarce factors of production meets individual consumer utilities through market mechanisms (Veblen (1900)). Orthodox economic views of value are still predominant today. For example, in the MIT and the DUT frameworks, value is the productivity of an organization (value in the supply side).

From the evolutionary economics perspective, value is fit-order to the environment which, in the most general sense, can be evaluated from the economic, social and environmental perspectives. Energy feeds the process of evolutionary value creation following the second law of thermodynamics (Atkins (1984)). Without processing information, "systems can not retain successful patterns of energy flow that enhance their ability to maintain order" (Burgin and Simon (2009)). Thus, evolutionary value creation is fuelled by flows of energy and steered by flows of information. Thus, from the evolutionary perspective, information is the origin of value. This view does not contradict orthodox economics. For example, Robert Solow saw knowledge as the origin of value (Solow (1956)), but intermediate information processes were treated as *mysterious* and accountable only by *rough* observables of value (e.g. productivity). By providing procedural descriptions of information processing intermediate processes, evolutionary economics puts information in the heart of value creation. Hence, more sophisticated measures for value become available, in comparison with the measures used in orthodox economics. Hence, our framework presents a fundamental difference in comparison with previous work (namely, the MIT and the DUT frameworks). Instead of accounting information with indirect inputs (e.g. productivity) in value creation, our framework specifies explicitly the intermediate processes by which how information network flows can be processed and value generated (economic, social and environmental).

6. Conclusions

Two different paradigmatic views exist about the value of information: orthodox and evolutionary economics. Our literature review overviews 23 studies on the value of information networks, spanning the years 1980-2009. We concluded that all these studies have an orthodox economic character, and they provide either speculative, elusive or limited conclusions. Hence, they fail to provide a clear explanation of how information networks generate value.

We also looked into a significant number of 36 studies on the general value of IT (including computers and software). A significant sub-group of these studies still has an orthodox economic character, but a more advanced stream of literature, in line with evolutionary economics, attempts to depict the value of particular subcomponents of IT. With these more specific studies, recognized fields emerged. Transaction Cost Economics (TCE) analysed the value of IT in terms of its impact on transaction costs and coordination risks. Resource Based View (RBV) economics view of the firm attributes superior financial performance to organizational resources and capabilities. Other researchers investigated the value of particular Enterprise System (ES) IT systems.

From our literature review, three requirements were extracted for any framework accounting for the value of information networks: 1) a paradigmatic shift from orthodox economics to evolutionary economics is imperative; 2) the framework should be able to cope with analyses both at the micro and macro-level; and 3) the framework should be able to relate mechanistic views of the value of information networks in line with orthodox economics with more sociological views. To address these requirements, we proposed to use evolutionary economics and the holon theory as the theoretical background for our framework.

From the evolutionary economics perspective, our framework identifies the concept of *capability* to provide a clear explanation of how information networks generate value. Capability is basically a procedure that an economic agent can utilize to navigate through information network flows that potentially brings value. Our preliminary framework identifies six capabilities. These are *coordinatibility*, *cooperatibility*, *selectibility*, *biddability*, *adoptability* and *creatibility*. We support our framework with data from Eurostat on IT use by enterprises and households (2002-2008). These capabilities are simple and fundamental but are the underlying principles to really capture the value of information networks. With this framework, our expectation is to provide a set of simple, fundamental but powerful concepts that can be used to merge the research from orthodox economic and evolutionary economic studies. From the holon theory, we use the concept of holon, defined as a nodal point in a nested hierarchy, to refer to an entity that is part of and makes use of multi-level networks for exchange of information.

We demonstrated that our framework provides significant conceptual added-value by comparing it with two state of the art reference frameworks (the DUT framework fails to identify two capabilities and two quadrants and the MIT framework fails to identify two capabilities and one quadrant). Due to the theoretical ground upon which it was developed, we argued that our framework is able to capture the value of information networks, not only from the orthodox economic perspectives accounted both in the DUT (growth, profitability, productivity and market share) and the MIT framework (productivity), but also from any other economic, social or environmental perspective. Hence, our framework is an essential input to any policy maker interested in information network-related private and public policies.

Finally, we demonstrated that our evolutionary holonic framework has a much wider application range than the DUT and MIT frameworks. For example: 1) to make the development of information network-supported services more systematic (Madureira et al. (2009)); 2) to investigate levels of economic cross-sectoral IT infrastructure interoperability (Madureira et al. (2010)); and 3) to be used by Eurostat to redesign their surveys in a more conceptually valid way.

Hypothesis	Capability
H1: Coordinating information improves the efficiency of existing processes by reducing the number of bad handoffs and improving resource utilization rates.	Coordinatibility
H2: Efficient information search relies on structuring a solution to provide a balanced index, sorting choices to provide best option first, and stopping when the net expected value of the best unsampled choice no longer exceeds the best sampled choice.	Selectibility
H3: Optimal sharing occurs between partners with partial information overlap.	Adoptability
H4: Know-how can increase productivity by creating new options for those who are unfamiliar with it. This includes options for recursively creating new process know-how. Sharing disseminates these options.	Creatibility
H5: Information sharing reduces balkanization, increasing productivity by promoting economies of scope and scale.	exterior/collective
H6: Absolute incentives encourage information sharing, which promotes group productivity; relative incentives discourage information sharing, but promote individual productivity. The optimal incentive policy in terms of productivity becomes increasingly absolute with increasing task interdependence.	exterior/collective
H7: Information routines and standards reduce complexity. They foster interoperability and sharing, but limit adaptation and flexibility. Optimal information standardization increases with decision stability.	exterior/collective
H8: Modular designs can increase productivity by spreading the risk of process failure or enabling new combinations of process that extend the efficient frontier.	exterior/collective
H9: Simulation and modeling help decision makers more accurately identify leverage points within dynamic systems and reduce the cost of exploring alternative courses of action. They boost productivity by reducing wasted resources and creating new options.	interior/individual
H10: Centralized decisions promote decision consistency, global perspective, and avoid wasteful duplications. Decentralized decisions promote data gathering, distributed incentives and adaptation. Productivity increases to the extent that distributing control optimally balances these factors in light of complementarity and indispensability.	interior/individual
H11: More precise information improves decisions by reducing waste.	interior/individual
H12: Information push benefits individuals and organizations that control undervalued assets (owners of overvalued assets incur loses). Efficiency increases when resource allocations rebalance to account for problems and opportunities.	interior/individual
H13: The need for redundant links to critical information sources increases with the likelihood of agent incapacitation. Latent links are needed for occasions when novel domain specific experience becomes essential. Redundant links conflict with the desire to use these links for new information.	interior/individual
H14: Optimal information gathering balances the costs of overload against the costs of ignorance.	interior/individual
H15: Network efficiency balances network size and diversity of contacts. Network effectiveness distinguishes primary from secondary contacts and focuses resources on preserving primary contacts. Individuals who are more central will be more effective.	
H16: Information that reduces risk aversion increases productivity when it leads to actions that are closer to true risk neutral levels.	
H17: The optimal rate of information gathering and flow increases with the rate of environmental change.	

Table 1: Map with the MIT framework.

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