Value of digital information networks: a holonic framework

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Contents

Summary

The extraordinary level of interest worldwide in Digital Information Networks (DINs)' deployment is due to the strong perception that they bring economic, social and environmental value. However, scientific attempts to evidence this perception lead to speculative, elusive or limited conclusions. In this thesis, we propose a novel framework to account for the value of DINs. Most relevantly, our framework is capable to account for any form of value, whereas existing literature tends to focus solely on orthodox economic measures of performance such as productivity. To exemplify, we use our framework to explain evolutionary change in policy making, economy and biology. With this approach, we underpin how DINs generate value in these three domains. We also provide significant theoretical contributions regarding the Advocacy Coalition Framework, the initiative Generalized Darwinism and the Modern Synthesis, which are frameworks used in policy making, evolutionary economics and biological evolution respectively. Finally, this thesis addresses business interoperability, and as such also contributes to increasing the value generated through DINs. From an empirical perspective, our work is supported by a rich dataset of Eurostat on the use of ICT by enterprises and households, and a case study regarding an electronic identification management system in Austria.

Chapter 1

Introduction

1.1 Digital Information Networks (DINs)

Since the 1980s, the telecommunication sector has been expanding rapidly (Shiu and Lam, 2008). This is mainly caused by the conversion of analogue communication networks designed for telephony or TV services into multi-functional Digital Information Networks (DINs). The exponential growth of services offered over DINs can be explained by many factors, including technological advancements, market liberalization and privatizations. The worldwide extraordinary level of interest in deploying information networks is due to the strong perception that information networks bring economic, social and environmental benefits (Firth and Mellor, 2005). Some speculate that DINs may have a similar impact on society as transportation networks had during the 20th century (OECD, 2001). In long wave theory, this information driven economic era is known as the 5th Kondratieff economic cycle (Perez, 2003). A Kondratieff cycle manifests itself by a sinusoidal-like long-term cycle from approximately 40 to 60 years in length with a semi-period of high productivity growth followed by a semi-period of relatively slow growth (Freeman and Louca, 2001). Some benefits of DINs can be observed directly. For example, construction of network infrastructures leads to direct increase in job employment. The benefits might also be more intangible, such as better quality of health care services, improved education and organizational efficiency (European Commission, 2010). The Organization for Economic Co-operation and Development (OECD) considered broadband DINs as key to enhancing competitiveness and sustaining economic growth (OECD, 2001). Many governments are increasingly committed to extending DINs to their citizens (Katz *et al.*, 2009), particularly in the developing nations (Kagami *et al.*, 2004).

Consequently, the levels of interdependency between users and DINs' providers increased dramatically (Dijk and Mulder, 2005) and the DIN infrastructure became an essential facility for all economic sectors.

1.2 Problem statement

To justify policy support for further investments in DINs (e.g. in Fiber To The Home (FTTH)), it is necessary to learn from expenditures that have already been made and demonstrate their value. Our literature review on studies aiming to evidence the economic impact of DINs concluded that so far only speculative, elusive or limited conclusions have been taken. Generally speaking, these studies model an economic system as a black-box transforming inputs into outputs. DINs are considered an observable production input changing the uncertainty regarding the performance of the economic system. From this perspective, the difference in the performance between an economic system with and without access to the infrastructure corresponds to the value of DINs. For example, in (Koutroumpis, 2009), DINs were observed by measuring the broadband penetration rate and the economic system performance was observed by measuring economic growth. The value of broadband was measured with a regression between the penetration rate and economic growth. The obvious limitation of this approach is that such direct statistical relations provide few insights on the actual intermediate processes from DINs to economic value, i.e. the causality.

DINs 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. Our literature review on the general value of IT, led us to conclude that some of these studies take more insightful and refined conclusions by depicting the value of particular subcomponents of IT. For example, in the specific domain of Transaction Cost Economics (TCE), the value of IT is analyzed in terms of its impact on transaction costs and coordination risks. These studies provide first real evidence of specific benefits of IT. However, they loose track of the holistic perspective, and therefore fail to establish a bridge to the more traditional economic approach which aims at estimating macro economy-wide impacts.

1.3 Research objective

The main research objective of this thesis is to contribute to the understanding of the value of DINs. Specifically, we want to contribute from three perspectives:

1. The literature on the value of IT mentioned above tends to focus on particular subcomponents of IT. For example, TCE focus on transaction costs and coordination risks. Therefore, TCE neglects several other dimensions from which DINs generate value. For instance, online education is a crucial IT resource in the current knowledge-based economies, and it is not addressed in TCE. Our first objective is to design a framework capable to provide an overarching and holistic view of the processes enabled by DINs which generate value. With such framework, specific domains such as TCE and more general ones such as the Information Systems (IS) studies and organizational theory, can be interrelated and cross-fertilized.

2. The orthodox economic approach mentioned above, based upon input-output production functions, focuses on economy-wide impacts. The most recent literature on the value of IT came up with important evidences of the value of IT, but only of particular subcomponents of IT. Our second objective is to design a framework capable to link macro- (aligned with macro-economic theory) with micro-level type of studies (aligned with IS literature and organizational theory). To do so, the concepts in the framework need to be meaningful and observable for small and large units of analysis (e.g. individuals and whole economies).

3. Generally speaking, the existing studies on the value of DINs and IT tend to focus on orthodox economic type of value measures such as productivity. Nevertheless, DINs generate value that is hardly accounted for with such measures. For example, (Majumdar *et al.*, 2010) referred to social welfare. The third objective for our research is that our framework can be capable to account for other forms of value, in addition to the traditional economic ones.

In this thesis, we are not concerned with the direct economic consequences of deploying a new infrastructure, such as increased employment and increased production of construction companies. Those effects are already well captured in the literature. Instead, we focus on the effects on the demand side (i.e. users) that relate directly with information and its value. Besides, we are only concerned with the effects with *evolutionary* value (e.g. productive value), not with recreational value (e.g. online gaming). Later in this thesis, we will define *evolutionary value*.

Finally, an important aspect that limits the value that is extracted from DINs is interoperability between IT systems. A secondary objective of this thesis is therefore to contribute to the understanding of business IT interoperability with the ultimate goal of increasing the value generated through DINs.

1.4 Research approach and book outline

Our research approach is succinctly described in figure 1.1 (read bottom-up). Chapter 2 provides a thorough literature review of 24 studies aiming at clarifying the value of DINs and 38 studies on the general impact of IT (with hard- and software). From our literature review, a set of general requirements is derived for our framework. Based upon these requirements, the most relevant theoretical background for this thesis is described: evolutionary economics and holon theory. Building upon this theoretical background, a new framework is proposed to account for the value of DINs: the Holonic Framework (HF), which is the main proposition of this thesis.

In chapter 2, we demonstrate that the HF provides a more overarching and holistic view of the processes enabled by DINs compared to two reference frameworks (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004), and the processes that they account for. Thus, we fulfill our objective 1. In chapter 3, we demonstrate that the concepts in the HF are multi-level using Eurostat data at the individual and enterprise levels of analysis. Thus, we fulfill our objective 2. Additionally, chapter 3 allows us to demonstrate the empirical power of the HF, to take further theoretical insights and raise potential implications to be explored in future work.

To show that DINs generate various forms of value and that our framework can account for this value, we will follow a unique approach. The HF identifies a set of simple and fundamental concepts which describe how information flows are processed and from which value is generated. Irrespective of the technical aspects involved in the coding, transmission and decoding of information, digital networks allow humans to exchange information, just like any transport, organizational, physical or biological information network. Therefore, we hypothesize that the HF and its processes apply to information networks in general, digital or not. This includes biological networks, economical networks and networks of policy makers. Thus, the HF hypothetically allows us to understand how biological, economical and policy making units generate value using information networks. Rather than choosing one of these fields and study this assumed analogy in depth, we decided to make a first exploration in all of these fields. The advantage of this approach is that it shows the validity of this analogy in its breadth. The disadvantage is that most of our results are still relatively abstract and that we generate more research questions than we solved.

Chapter 4 integrates the HF with the state-of-the-art framework in policy making, the Advocacy Coalition Framework (ACF). The resulting framework, labeled Capability-aware Policy Framework (CaPF), is capable to address several criticisms previously made to the ACF. Chapter 4 also illustrates the practical value of the

CaPF with a use case on an electronic identification management system in Austria. By applying the HF to the domain of policy making, we underpin how DINs generate value for policy making. Additionally, our approach demonstrates that the study of the value of DINs provides useful information for theory building in policy making.

Chapters 5 and 6 investigate the application of the HF to the domains of biology and economy respectively. The Modern Synthesis (MS) is the current paradigm for biological evolution. However, the MS is under scrutiny by evolutionary biologists. Chapter 5 motivates the use of the HF as an alternative conceptual model for theory building in evolutionary biology.

The Generalized Darwinism (GD) initiative abstracts the MS from biology to the domain of *evolutionary economics*. If the MS is being scrutinized in biology, then it may very well limit GD's in economy. Chapter 6 motivates the use of the HF in evolutionary economics. Chapters 5 and 6 demonstrate how information networks generate biological and economical value and, more fundamentally, as with policy making, provide a new domain for theory building in evolutionary biology and evolutionary economics: the study of the value of DINs.

Chapter 7 studies how interoperability may increase the value that is extracted from DINs. Interoperability refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged. Studies unveiled the costs of inadequate interoperability to be in the order of millions of euros per year. Existing research on interoperability mostly covers technical aspects, without linking them to business aspects. Chapter 7 integrates the HF with a state-of-the-art reference framework in interoperability, the ATHENA framework, to derive a new framework to address business interoperability, the Capability-aware Business Interoperability Framework (CaBIF).

In figure 1.1, the dark blue building blocks have a descriptive nature, the light blue have an analytical nature and the green ones have an empirical nature.

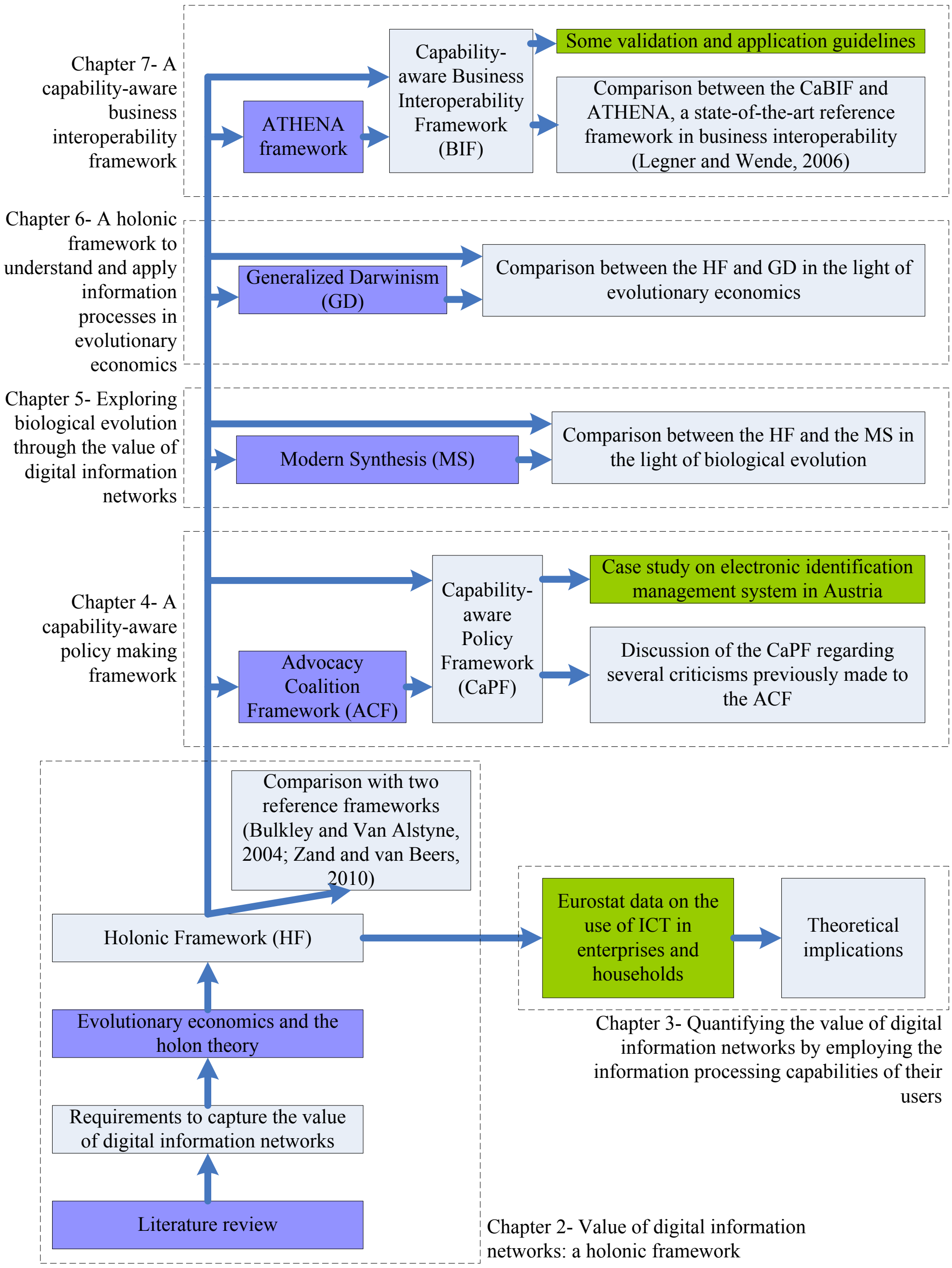


Figure 1.1: Research approach

1.5 Relevance of this thesis

Today, the telecommunication sector is undergoing a radical transformation, creating new opportunities and challenges for infrastructure and service providers. The established value chain is increasingly being deconstructed, with the entry of powerful new players and radical restructuring of the industry (Baken *et al.*, 2007a,b; Yang *et al.*, 2004). Telecommunication providers realize that in order to survive they need to expand their classical service portfolio (voice, Internet and TV). DINs connect all sectors and thereby are instrumental to explore and support a huge spectrum of digital trans-sector innovations. The framework proposed by this thesis describes the mechanisms which enable DINs to generate value. Therefore, based upon this framework, new digital trans-sector innovations can be identified based upon those mechanisms, increasing efficiency, generating new value network streams, and promote development (Madureira *et al.*, 2009b).

Governments have also come to view the important role of DINs to national development (Sein and Harindranath, 2004). In order to support further investments in DINs infrastructures (e.g. in FTTH), it is necessary to justify expenditures that have already been made and demonstrate their value. Therefore, this thesis is a relevant input for policy makers in the development of private and public information network-related policies. The importance of the research stream on the value of DINs and IT is reflected on the extensive number of studies in the subject which started to arise in mid 80s. Scientifically, the challenge was stated by the Nobel-awarded economist Robert Solow in 1987 with the famous quote: ”you can see the computer age everywhere but in the productivity statistics” (Solow, 1987).

In chapter 4, this thesis contributes to the domain of policy making. The public section of the American Political Science Association describes itself as ”committed to producing rigorous empirical and theoretical knowledge of the processes and products of governing and the application of that knowledge to policy issues” (Weimer, 2008). The first part of this commitment- the theoretical part- demands frameworks to explain the public process. This thesis improves the state-of-the-art reference framework in policy making, the ACF, and therefore provides a relevant contribution to the policy domain.

In chapter 5, this thesis contributes to the domain of evolutionary biology. Huxley (1942) stressed that evolution may claim to be considered the most central and the most important of the problems in biology. The study of biological evolution started with Darwin's ”very ingenious theory to account for the appearance and perpetuation of varieties and of specific forms on our planet” (foreword by C. Lyell and

J. Hooker referring to the theory of natural selection (Kutschera and Niklas, 2004)). Subsequent work led to the MS, to a large extent still the current paradigm in evolutionary biology (Mayr, 2001). However, the MS provides too limited explanatory power (Grant, 2010). Chapter 5 describes how the HF can be used as a different approach to conceptualize evolutionary biology, because it is not based upon the MS or the foundations of the MS (Darwinism and neo-Darwinism (Pigliucci, 2007)), and is able to capture, at an abstracted level, several features associated with biological evolution which are not explicitly accounted for by the MS. Therefore, this thesis provides a relevant contribution to biological theory.

In chapter 6, this thesis contributes to the domain of evolutionary economics. In its largest sense, this domain is an attempt to look at an economic system, whether of the whole world or of its parts, as a continuing process in space and time (Boulding, 1991). To do so, it stresses the importance of bounded rationality, path dependency, complex interdependencies, competition, growth, structural change, resource constraints, etc. In the absence of alternatives, evolutionary economics turned to evolutionary biology to conceptualize how economies evolve (Hodgson, 2010). However, the limitation of this approach has been recognized. For example, (Foster, 1997) stated: "the espousal of biological analogies by evolutionary economists cannot reveal the most important features of evolutionary change in economic processes". Chapter 6 describes how the HF can be used as a different approach to conceptualize evolutionary economics. Therefore, this thesis provides a relevant contribution to economic theory.

Finally, chapter 7 contributes to the domain of business interoperability. Existing research on interoperability mostly covers technical aspects, without linking them to business aspects. Consequently, (Legner and Lebreton, 2007) outlined a research agenda for business interoperability after verifying that "a broader discussion related to interoperability is about to start". Building upon a previous interoperability framework called ATHENA, chapter 7 provides a conceptual framework which identifies the fundamental artifacts and challenges related to business interoperability. Therefore, this thesis is also relevant for researchers investigating how companies can achieve value gains through increased business interoperability levels and bundling of core-competencies.

The relation between the author's publications and each chapter is described in table 1.1.

Publication	Chapter 1	2	3	4	5	6	7	8
BAKEN, N., E. VAN BOVEN, AND A. MADUREIRA (2007): "Renaissance of the Incumbents, Network Visions from a Human Perspective," eChallenges, The Hague, Netherlands.	√							
MADUREIRA, A., E. VAN BOVEN, AND N. BAKEN (2009): "Towards Systematic Development of Trans-sector Digital Innovations," IEEE International Conference on Infrastructure Systems and Services, Chennai, India.	√							
MADUREIRA, A., N. BAKEN, AND H. BOUWMAN (2009): "Towards a Framework to Analyze Causal Relations From Digital Information Networks To Micro Economic Productivity," World Congress on the Knowledge Society, Venice, Italy.		√						
MADUREIRA, A., N. BAKEN, AND H. BOUWMAN (2010): "The Origin of Value Through Information Networks: a Preliminary Framework from an Evolutionary Holonic Perspective," 18th Biennial Conference of the International Telecommunications Society, Tokyo, Japan. Distinguished as one of the best student papers.		√						
MADUREIRA, A., N. BAKEN, AND H. BOUWMAN (2011): "Value of digital information networks: a holonic framework," *Netnomics* (Springer), 12(1), 1-30 ("to my opinion it is a very good work, worth accepting it for the Netnomics Journal", anonymous reviewer).		√						
MADUREIRA, A., F. DEN HARTOG, H. BOUWMAN, AND N. BAKEN (2011): "Quantifying the value of digital information networks by employing the information processing capabilities of their users," submitted to *Information Economics and Policy* (Elsevier).			√					
MADUREIRA, A., N. HUIJBOOM, AND N. BAKEN (2011): "A Capability-aware Framework for Policy Making," submitted to *Administration & Society* (SAGE).				√				
MADUREIRA, A., F. DEN HARTOG, AND N. BAKEN (2011): "Exploring biological evolution through the value of digital information networks," in preparation.					√			
MADUREIRA, A., F. DEN HARTOG, AND N. BAKEN (2011): "A holonic framework to understand and apply information processes in evolutionary economics," submitted to the *Journal of Evolutionary Economics* (Springer).						√		
MADUREIRA, A., F. DEN HARTOG, E. SILVA, AND N. BAKEN (2010): "Model for Trans-sector Digital Interoperability", 6th International Conference on Interoperability for Enterprise Software and Applications, Coventry, UK.							√	
MADUREIRA, A., F. DEN HARTOG, AND N. BAKEN (2011): "A Business Interoperability Framework", submitted to *Information Systems Frontiers* (Springer).							√	

Table 1.1: Relation between the author's publications and the book's chapters and appendices

Chapter 2

Value of digital information networks: a holonic framework

Abstract: The worldwide extraordinary level of interest in Digital Information Networks (DINs)' 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 DINs, led us to conclude that these studies take speculative, elusive or limited conclusions. We identify the requirements to capture the value of DINs and indicate a possible theoretical ground to account for it. Based upon this, we propose a novel framework to account for the value of DINs. 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 provides significant conceptual added-value and, more fundamentally, allows for traditional measures of economic value (e.g. productivity and growth), as well as for other measures of value (e.g. social and environmental).

This chapter was matter of publication in (Madureira *et al.*, 2011a, 2010a, 2009a).

2.1 Literature on the value of DINs

Two views can be distinguished to account for the value of DINs (Bulkley and Van 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 less informed economic system. For example, in (Koutroumpis, 2009), the amount of information was observed in an economic system by measuring the broadband penetration rate, and the economic system performance was observed by measuring economic growth. The value of information was measured with a regression between the broadband penetration rate and 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 (Van 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 relatively coarse grained, being a black box transforming inputs into outputs. The evolutionary view is finer grained: modular input procedures can be rearranged to rearrange outputs. Unfortunately, models of economic systems are typically orders of magnitude larger in evolutionary economics than in orthodox economics, in terms of complexity and computational costs to generate and search an enormous state space of information procedure possibilities.

(Kallinikos, 2006) attempted to understand the complex character of technologically sustained information processes. He drew some important conclusions about the nature of information: it is self-referential and non-foundational. Self-referential means that information has value if it adds a difference to what is already known. (Borgman, 1999) stated: ”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 means that informational differences emerge through comparison of two or more objects or items. They are not singular, but are relational entities. The central criticism to the orthodox approach is that it fails to picture the fundamentally differential 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.

DINs 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 DINs is not an elementary task and most of the research done aims at understanding the general value of IT. We reviewed 24 studies on the value of DINs spanning a period from 1980 to 2010, and they all have an orthodox economic character. These studies can be grouped into three classes: 1) macro-economic 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; Hardy, 1980); 2) econometric studies not addressing the issue of causality (Thompson and Garbacz, 2008, 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, 1998; Greenstein and Spiller, 1995; Leff, 1984); and 3) econometric studies addressing causality deterministically (Majumdar *et al.*, 2010; Koutroumpis, 2009; Shiu and Lam, 2008; Ford and Koutsky, 2005; Cronin *et al.*, 1991). The first class of studies provide a tool to policy analysts to study the effect of DINs across the interdependences and feedbacks of an economy (Borges, 1986). Empirical validation is not addressed due to the nature of the underlying assumptions, e.g. perfectly rational behavior and equilibrium solutions (Farmer and Foley, 2009). Hence, claims such as ”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 that the causality between DINs and economic growth works in both directions. Similar observations were 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, the direction of causality is a methodological challenge inherent in disentangling the value of DINs. The results of the class 2 studies, not addressing causality, should therefore be interpreted cautiously. Recently, some econometric studies (class 3) have addressed the issue of causality deterministically. In such context, the value of DINs is typically measured with regression techniques between the penetration rate of DINs and economic growth. However, this approach provides few insights on the actual causal mechanisms that explain how DINs generate value.

2.2 Literature on the value of IT

We also reviewed 38 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 *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" (Solow, 1987). 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 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 (Brynjolfsson and Hitt, 1996).

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 that IT investments are associated with lower average production costs, lower average total costs and higher average overhead costs. (Byrd and Marshall, 1997) mentioned that the "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. They suggested 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) expressed 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)). (Carr, 2003), referring to IT management, stated that "the key to success, for the vast majority of companies, is no longer to seek advantage aggressively but to manage costs and risks meticulously". Some attempts were made to improve the econometric results by observing different variables related with IT and performance (Stiroh, 2002; Sircar *et al.*, 2000; Hitt and Brynjolfsson, 1996). For example, (Sircar *et al.*, 2000) investigated statistical relations between seven input measures of IT and corporate investments with seven measures of firm performance using a large database consisting of over 2000 observations of 624 firms.

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 (Aral *et al.*, 2008; Bulkley and Van Alstyne, 2004; Sambamurthy *et al.*, 2003; Lee and Treacy, 1988). For example, (Sambamurthy *et al.*, 2003) used a multi-theoretic lens to argue that IT investments and capabilities influenced firm performance through three significant organizational capabilities (agility, digital-options and entrepreneurial-alert) and strategic processes (capability-building, entrepreneurial action and co-evolutionary adaptation). With these more specific studies, recognized scientific fields emerged in the information economic domain.

A particular important one was Transaction Cost Economics (TCE) which analyzed the value of IT in terms of its impact on transaction costs and coordination risks. (Zaheer and Venkatraman, 1994), drawing on theoretical and empirical research on transaction costs, developed and tested a model of the determinants of the degree of electronic integration in the commercial segment of the property and casualty industry. Based on a sample of 120 independent agencies, they provided empirical support for three hypotheses on the determinants of electronic integration. (Garicano and Kaplan, 2001) investigated the changes in transaction costs from the introduction of the Internet in transaction between firms Business-to-Business (B2B) e-commerce. They differentiated between coordination and motivation costs. Their results suggest that process improvements and marketplace benefits were potentially large. (Bartel *et al.*, 2007) assembled a dataset on manufacturing plants in one narrowly defined industry (valve manufacturing) and analyzed several plant-level mechanisms through which IT could promote productivity growth. Their results showed that: 1) plants that adopt new IT-enhanced equipment shifted their business strategies by producing more customized valve products; 2) IT investments improved the efficiency of all stages of the production process by reducing set-up times, run times and inspection times; and 3) adoption of new IT equipment coincided with increases in the skill requirements of machine operators, notably technical and problem-solving skills, and with the adoption of new human resource practices to support these skills.

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; Melville *et al.*, 1994). For example, (Kelley, 1994) focused on a well-defined, easily recognizable process- precision metal-cutting- to conclude that there is a significant efficient advantage from using IT technologies. Recently, some scholars started investigating the value of individual IT Enterprise Systems (ESs) (Zand and van Beers, 2010; Hendricks *et al.*, 2007). An ES is a software application that provides services to a whole organization rather than a single department or group within it. For example, (Zand and van Beers, 2010) provided first large-scale evidence on the differential effects of ESs on corporate performance and provided new insights into the mediating role of innovation (see also section 2.4).

2.3 Holonic Framework (HF)

2.3.1 Framework requirements

From the literature review, we can extract some requirements for a framework willing to account for the value of DINs. A paradigmatic shift from orthodox economics to evolutionary economics seems to be imperative. The reasons are two-fold: 1) to provide a finer grained view of the intermediate processes between DINs 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 DINs 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)). 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 DINs 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.

2.3.2 Holon theory and the evolutionary view on the value of information

The term *holon* combines the Greek word for *whole* (*holos*) with the suffix *on*, which suggests particle or part (Koestler, 1967). Thus, the holon is a part-whole, a nodal point in a nested hierarchy (referred to by Koestler as a *holarchy*)[1]. A holon can be described in terms of its holistic and independent nature as well as its partness and dependent nature (Edwards, 2005). Depending on the viewpoint in a nested holarchical structure, the perception of what is the whole and what is the part will vary. Through its whole-part, dependent and independent dimensions, holon theory is capable of representing 1) nested systems as organizations or economic systems, which exist in mechanistic physical sciences, behavioral sciences, holistic system theories and sociological sciences; 2) evolutionary processes that take a holon to a differ-

[1] Prof. Nico Baken proposes the following definition: a holon is a logical entity (of matter, energy and or information) that distinguishes itself from its environment and is both a whole and a part.

ent holarchical position; and 3) the individual micro-level, as well as the collective macro-level. The HF uses the concept of *holon* to refer to an entity that is part of and makes use of multi-level networks for exchange of information.

As mentioned previously, the evolutionary view on the value of information is concerned with the study of procedures or intermediate processes that transform an economy. The notion that an economic system should be studied as a system of interactions and procedures is not new in disciplines such as the social sciences (Giddens, 1993). For example, (Sambamurthy *et al.*, 2003) argued that IT investments and capabilities influence firm performance through three significant organizational capabilities (agility, digital options and entrepreneurial alertness) and strategic processes (capability-building, entrepreneurial action and co-evolutionary adaptation). (Sambamurthy *et al.*, 2003) here define capability as an intermediate procedure. (Eisenhardt and Martin, 2000) referred to it as ”the organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die”. Particularly referring to IT capabilities, (Sambamurthy *et al.*, 2003) defined IT competence as ”the organizational base of IT resources and capabilities and describes a firm's capacity for IT-based innovation by virtue of the available IT resources and the ability to convert IT assets and services into strategic applications”. These IT capabilities are developed over time through a series of linked strategic decisions about investments in IT in parallel with development of organizational processes and knowledge (Barua and Mukhopadhyay, 2000). (Prahalad and Hamel, 1990) defined capability as ”communication, involvement, and a deep commitment to working across organizational boundaries” involving many levels of people and all functions. Other authors have referred to capabilities as *routines* (Nelson and Winter, 1985; Cyert and March, 1963; March and Simon, 1958).

Independent of the label and definition, capabilities or routines are fundamentally processes that operate upon information. The HF defines *capabilities* as procedures that a holon can use to navigate through streams of information flowing through networks that potentially bring value. The HF identifies a set of 13 capabilities[2]:

1. Coordinatibility
2. Cooperatibility
3. Selectibility
4. Biddability

[2]To identify the capabilities of the framework, the HF mixes the action/verb/process specific to a capability (being aware that this is not always in line with the English language).

5. Adoptability
6. Creatibility
7. Brokerability
8. Normatibility
9. Trustability
10. Culturability
11. Decisability
12. Modelability
13. Perceptability

These concepts are simple and fundamental, and are the underlying principles that capture how DINs generate value. They were derived by investigating the large amount of literature on the value of DINs for processes depending on DINs. These processes were then interrelated, abstracted from specific details, refined and finally conceptualized into the framework of capabilities. They are described in the next section, in no particular order.

2.3.3 The 13 capabilities of the HF

Coordination is a cross-disciplinary process (Ossowski and Menezes, 2006). Sociologists observe the behavior of groups of people, try to identify coordination mechanisms among them and explain how and why these mechanisms emerge. Biologists observe flocks of birds coordinating perfectly without central mechanisms and try to identify the simple rules used by these animals. Economists investigate the structure and dynamics of markets as a particular coordinating mechanism. Based upon (Malone and Crowston, 1994), the HF defines *coordinatibility* as the capability of a holon to manage dependencies between activities that are performed to achieve a goal.

Cooperation is achieved when a number of persons enter 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 on (Consoli *et al.*, 2006;

Blecker, 2003), is defined in the HF as the capability of a holon to enter in a relationship with other holons for a common purpose.

Selection is another cross-disciplinary process. The World Wide Web (WWW) is an important source of information, and therefore, search engines are an essential WWW selection facility. Yet, despite the pervasiveness of selection, (Price, 1995) mentioned that there has been no abstraction and generalization to obtain a general selection theory, and predicted the appearance of such a theory in the future. Based upon (Bulkley and Van Alstyne, 2004), the HF defines *selectibility* as the capability of a holon to scan for the unknown or generate courses of action that improve on known alternatives.

Through the ages, bidding has been used to determine the value of hard-to-price items (e.g. antiques). Around 500 BC, bidding was used in ancient Babylon to auction off wives, and the crown of a Roman emperor was sold by auctioning in 193 AD (Cassady, 1967). Objects, such as works of art, are typically awarded to the highest bidder. A contract to build a highway is usually given to the lowest bidder. (Gilbert, 1977) investigated bidding on cable television franchises. (Shubik, 1971) studied bidding in dollar auctions. (Smith, 1776) studied bidding within animals. The HF defines *biddability* as the capability of a holon to influence other holons through proposals.

The capability of integrating knowledge in existing knowledge structures is a crucial step for success. In current knowledge-based economies, growth is generated from innovation (Beesley and Cooper, 2008). The HF defines *adoptability* as the capability of a holon to acquire novel knowledge from other holons to be integrated in existing internal knowledge structures.

As firms struggle in competitive environments, innovation becomes increasingly important. Information networks render the firm's capabilities *amorphous* in nature, providing the ultimate potential for creation (Kandampully, 2002). For example, they allow for flexible maintenance of networks of customers and partners inside and outside a firm. Based on (Beesley and Cooper, 2008), the HF defines *creatibility* as the capability of a holon to deliberately and purposely collate knowledge to generate new or novel ways to understand a particular phenomenon.

The combination of experiences, knowledge access, prominence and power creates inducements across actors, giving origin to information network structures (Zaheer and Soda, 2009). Network opportunities enable an actor to create or restructure prior network structures (see Child's notion of strategic choice (Child, 1972)). Network opportunities and the inertial constraints imposed by prior network structures mutually reinforce and perpetuate information structures through a structuration process (Stevenson and Greenberg, 2000; Gulati and Gargiulo, 1999). Hence, markets and organizations are networks of interdependent groups, in which information flows at higher speed within than across group boundaries (Burt, 2000). Structural holes are network ties linking agents of separate network segments (Burt, 1992). A bridging actor assumes the broker role, making a connection between different non-redundant information structures (Fritsch and Kauffeld-Monz, 2008). Brokerage capability across structural holes is an advantage in detecting and developing new ideas synthesized across disconnected pools of information. Based on (Burt, 1992), the HF defines *brokerability* as the capability of a holon to act as a broker between unconnected holons.

A holon's preferences might conflict with other holons' preferences. In such a context, the importance of the concept of norms becomes apparent (Dignum *et al.*, 1996). The development, enforcement, observation, violation, control and upholding of norms has been a topic of interest to several disciplines: philosophy, anthropology, history, sociology, political sciences, psychology, economy, law, and even biology (Popper, 2007). Based upon (Horne, 2001), the HF defines *normatibility* as the capability of a holon to share with other holons norms as rules with at least a certain degree of consensus that are enforceable by social sanctions.

Culture contains the rich fabric of religion, art, morals, customs and beliefs that diversify societies. Culture also manifests itself with tangible artifacts, such as art and technology, with visible and audible behavior patterns as well as myths, images (Farr and Moscovici, 1984), heroes (Swidler, 1986), rituals and ceremonies (Pettigrew, 1979). In the past, most sociologists viewed culture as a ”seamless web” (Swidler, 1997), unitary and internally coherent across groups and situations (Bourdieu, 1984; Hofstede, 1980). In contrast, recent work depicts culture as fragmented across groups and inconsistent across its manifestations (Dimaggio, 1997; Martin, 1992). The HF defines *culturability* as the capability of a holon to share with other holons general assumptions, values and patterns of behavior emerging over time from their interaction.

Trust is an important lubricant of human relations (e.g. for friendship and economic transactions) (Fehr, 2009). Based on (Coleman, 1990), the HF defines *trustability* as the capability of a holon to engage in a common effort with another holon before knowing how that holon will behave.

Executives of organizations are constantly facing decision-making situations. The traditional approach to decision-making emphasizes the effects that executives can have on strategic decisions. This approach has been labeled the strategic-choice model (Montanari, 1978). Executives examine the firm's external environment and internal conditions and, using a set of objective criteria, decide upon the strategy (Newell and Broder, 2008). The decision is then benchmarked relative to a standard (Baron, 2004). An alternative perspective on decision-making argues that strategic decisions are mostly constrained by the external environment (Romanelli and Tushman, 1986). Decision-making involves a series of sequential, rational and analytical processes independent of the importance given to the decision-maker relative to the external environment (Huff and Reger, 1987). A set of objective criteria are used to evaluate strategic alternatives (Camillus, 1982; Ackoff, 1981). Based on (Camillus, 1982; Ackoff, 1981), the HF defines *decisability* as the capability of a holon to evaluate and decide among strategic alternatives.

Modeling is a widely used approach in problem solving. According to the basic ideas of Gestalt psychology (Kohler, 1947), human beings tend automatically to minimize inconsistencies in novel input information to make sense of the world and form consistent mental representations (Glockner and Betsch, 2008). Consistency-maximizing theories have traditions in social psychology (Simon and Holyoak, 2002), with ample empirical evidence (Wicklund and Brehm, 1976). Modeling allows organisms to learn contingencies among events and actions, and therefore, it is vital in adapting to dynamic environments (Newell and Broder, 2008). Based on (Newell and Broder, 2008), the HF defines *modelability* as the capability of a holon to understand the cause-effect structure of a system, thus facilitating causal reasoning, categorization and induction.

Both decisability and modelability are limited by the fact that biological organisms have limitations on how much information can be processed (Miller, 1956). A possible way to incorporate the limitations of the mind into models of cognition is to propose simplified heuristics that enable organisms to make good enough judgements (Payne *et al.*, 1993). Such approaches develop frameworks considering the *costs of thinking*. Limitations of the mind (e.g. memory and attention span) and limitations imposed by the environment (e.g. costs to achieve information) constrain the capability of perception (Simon, 1956). (Stewart, 1996) argued that the nature of cognition is strongly determined by its perceptual processes. (Anderson *et al.*, 2004) stated that ”the external world can provide much of the connective tissue that integrates cognition”. As an example, (Anderson *et al.*, 2004) mentioned the difficulty in making a proof in geometry without a diagram to inspect and mark. Traditional approaches to perception tend to deal with it in isolation from the processes of modeling and decision-making. However, due to their intricate and dependent nature, approaches have been proposed to integrate them, emphasizing their interface (Hommel *et al.*, 2001). Still, some authors value their conceptual separation based upon empirical evidence such as *direct parameter specification* (Neumann, 1989). (Neumann, 1990) conceptualizes perception not as an activity of picking up information for the control of action, but as a specific kind of information pickup, which serves to establish and update an internal representation of the environment. Based on (Neumann, 1990), the HF defines *perceptability* as the capability of a holon to pick information to establish and update internal representations of the environment.

The set of capabilities previously defined is presented in table 2.1.

Capability	**Definition**
Coordinatibility	Capability of a holon to manage dependencies between activities that are performed to achieve a goal
Cooperatibility	Capability of a holon to enter in a relationship with other holons for a common purpose
Selectibility	Capability of a holon to scan for the unknown or generate courses of action that improve on known alternatives
Biddability	Capability of a holon to influence other holons through proposals
Adoptability	Capability of a holon to acquire novel knowledge from other holons to be integrated in existing internal knowledge structures
Creatibility	Capability of a holon to deliberately and purposely collate knowledge to generate new or novel ways to understand a particular phenomenon
Brokerability	Capability of a holon to act as a broker between unconnected holons
Normatibility	Capability of a holon to share with other holons norms as rules with at least a certain degree of consensus that are enforceable by social sanctions
Culturability	Capability of a holon to share with other holons general assumptions, values and patterns of behavior emerging in time from their interaction
Trustability	Capability of a holon to engage in a common effort with another holon before knowing how that holon will behave
Decisability	Capability of a holon to evaluate and decide among strategic alternatives
Modelability	Capability of a holon to understand the cause-effect structure of a system, thus facilitating causal reasoning, categorization and induction
Perceptability	Capability of a holon to pick information to establish and update internal representations of the environment

Table 2.1: Labels and definitions of the capabilities

2.3.4 Summary of the HF

The HF is illustrated in figure 2.1. The three horizontal planes in figure 2.1 aim to capture different levels of complexity and predictability of holons. The lower plane corresponds to less complex and more predictable holons (e.g. an individual). The upper plane corresponds to more complex and less predictable holons (e.g. an enterprise). Hierarchies of holons are called *holarchies* and capture the idea that each plane is bounded to other planes in some way and is independent in other ways. A holon uses the set of capabilities previously defined, listed in table 2.1, to generate evolutionary value.

Evolutionary value corresponds to shifts in a system from states of higher entropy to lower entropy. The concept of entropy originated in the natural physical sciences as a measure of the number of possible microscopic configurations of individual atoms or molecules of a system that would give rise to the observed macroscopic state of the system (Boltzmann, 1870). Thus, entropy can be seen as a measure of randomness in a system (Sethna, 2006). The concept of entropy has been used to connect the physical sciences to various domains, namely biology (Brooks *et al.*, 1989), economy (Foster, 1997) and policy making (Simmons *et al.*, 1974).

On the one hand, the 13 capabilities of the HF are fundamentally different, i.e. one capability cannot be univocally identified by a subset of other capabilities. On the other hand, these capabilities are most likely not orthogonal, i.e. they have some overlap. For example, coordination and cooperation are often used interchangeably, but some theorists clarify that they are distinct concepts (Payan, 2007); and (Gual and Norgaard, 2010) described how culture affects selection at various levels.

2.4 Discussion

In this section, we compare analytically the HF with two reference frameworks (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004). Additionally, we generally discuss empirical validation of the HF and the HF's concept of *value*.

2.4.1 Comparison with the DUT framework

The Delft University of Technology (DUT) framework proposed by (Zand and van Beers, 2010) investigates the economic impact of ESs (see figure 2.2). 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

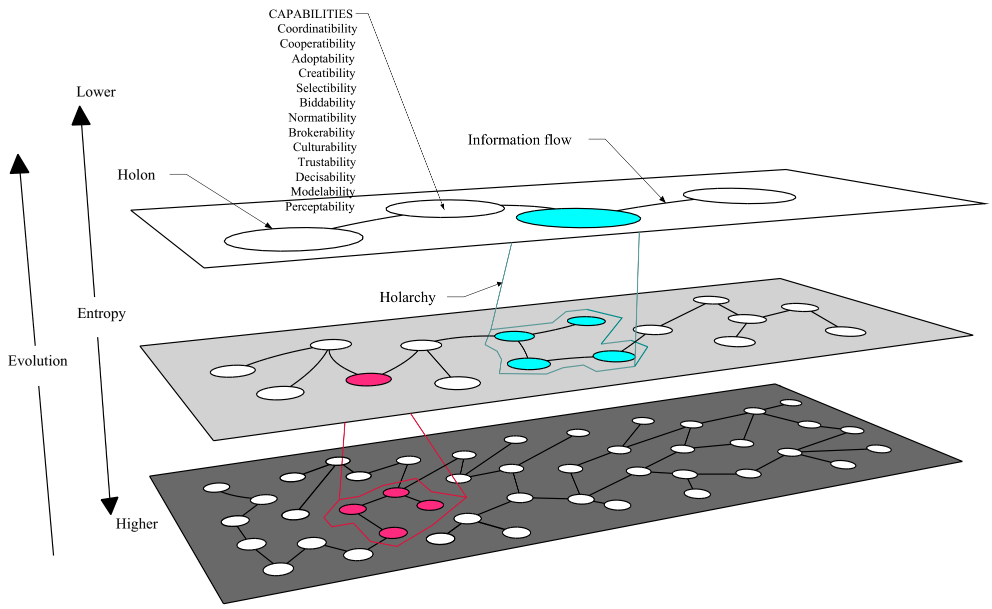


Figure 2.1: Holonic Framework (HF)

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 DINs and value: 1) ERP, 2) SCM, 3) CRM, 4) KMS, 5) DMS and 6) innovation. To compare the HF with the DUT framework we simply map the capabilities with the five groups of ES as well as innovation. The DUT framework also describes another component (*firm, market and country-specific conditions*) that, although not directly dependent on DINs, 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; 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 trustability. 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 chapter 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 the DUT concept of innovation both with adoptability and creatibility.

ERP, SCM and CRM are all mapped with coordinatibility. KMS and innovation with adoptability. DMS and innovation with creatibility. Hence, the DUT framework fails to identify ESs associated with eight capabilities: biddability, selectibility, brokerability, normatibility, culturability, decisability, modelability and perceptability. 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 DINs 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 (e.g. culturability), perhaps less significant (biddability) or underlying nature (selectibility).

2.4.2 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 grained 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

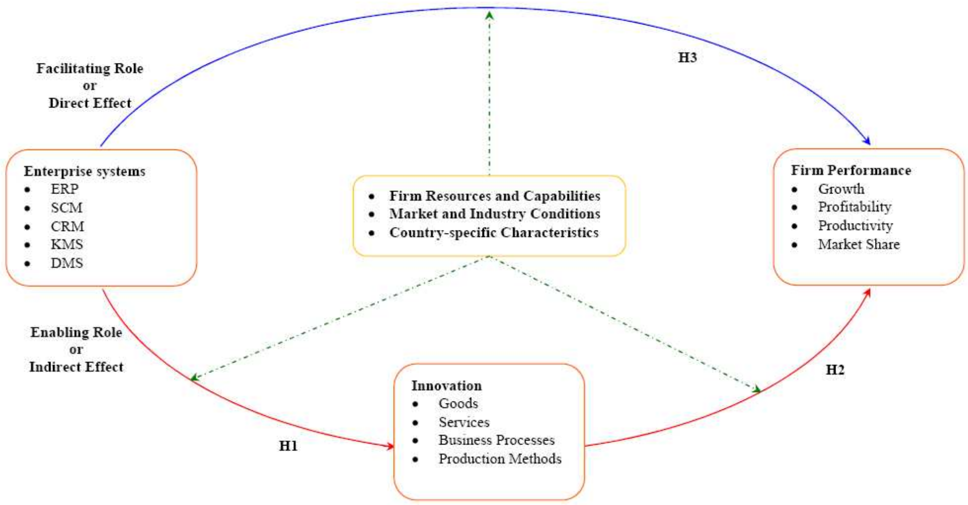


Figure 2.2: DUT reference framework (Zand and van Beers, 2010)

factors. For example, market concentration, competitive technology or regulatory regime. Naturally, these external factors also influence the value that a firm obtains from DINs. Thus, the value of DINs 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 DINs 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 which 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 DINs 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 for the external factors). 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? And many other aspects.

2.4.3 Comparison with the MIT framework

The Massachusetts Institute of Technology (MIT) framework proposed by (Bulkley and Van Alstyne, 2004) presents a set of seventeen hypotheses in an effort to connect information (in general) with productivity (see table **2.2**). To compare our framework with the MIT framework, we map the hypotheses with the capabilities described in our framework. Six MIT framework hypotheses are directly and uniquely mapped with six capabilities: 1) H1 ↔ coordinatibility; 2) H2 ↔ selectibility; 3) H3 ↔ adoptability; 4) H4 ↔ creatibility; 5) H5 ↔ brokerability; and 6) H6 ↔ modelability. Three MIT hypotheses are mapped with normatibility. These are: 1) H7; 2) H8 (norms/standards); and 3) H9 (modular design as a organizational norm for production). Three MIT hypotheses are mapped with decisability. These are: 1) H10; 2) H11; and 3) H12 (the intermediate process is information push, thus, a decision process made by the holon in face of an external factor: undervalued assets). Two MIT hypotheses are mapped with perceptability. These are: 1) H13; and 2) H14.

	MIT 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.	Brokerability
H6	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.	Modelability
H7	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.	Normatibility
H8	Information routines and standards reduce complexity. They foster interoperability and sharing, but limit adaptation and flexibility. Optimal information standardization increases with decision stability.	Normatibility
H9	Modular designs can increase productivity by spreading the risk of process failure or enabling new combinations of process that extend the efficient frontier.	Normatibility
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.	Decisability
H11	More precise information improves decisions by reducing waste.	Decisability
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.	Decisability
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.	Perceptability
H14	Optimal information gathering balances the costs of overload against the costs of ignorance.	Perceptability
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 2.2: Mapping with the MIT framework (Bulkley and Van Alstyne, 2004)

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 intermediate process, and therefore, we do not map it to any capability. 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).

Four capabilities (biddability, cooperatibility, trustability and culturability) 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 addressed (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 (see chapters 4, 5, 6 and 7). Additionally, the evolutionary holonic approach brings a significant difference to the concept of *value* than the one understood by the MIT and the DUT frameworks.

2.4.4 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 (Marx and Engels, 1998) saw labor as the ultimate supply of value. Then, mainly with the work of (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).

(Foster, 1997) stated: "economics, like all the sciences, builds on propositions concerning thermodynamics and, therefore, such propositions appear to be the correct starting point in developing analytical frameworks within which economic processes can be understood". 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, from an evolutionary perspective, information is the origin of value. This view does not contradict orthodox economics. For example, (Solow, 1956) saw knowledge as the origin of value, 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 allowing for more sophisticated measures for value. 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. penetration rate) in value creation, our framework specifies explicitly the intermediate processes by which information network flows can be processed and (evolutionary) value generated (economic or other).

2.5 Conclusions

The main contribution of this chapter is a framework, labeled Holonic Framework (HF), that accounts for the value of Digital Information Networks (DINs). We demonstrated that our framework provides significant conceptual added-value by comparing it with two state-of-the-art reference frameworks (the Delft University of Technology (DUT) framework fails to identify eight capabilities and the Massachusetts Institute of Technology (MIT) framework fails to identify four capabilities). Due to the theoretical ground upon which it was developed, we argued that our framework is able to capture the value of DINs, 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 perspective of value (e.g. social or environmental). We argued that our framework has a much wider application range than the DUT and MIT frameworks (see chapters 4, 5, 6 and 7).

The most important limitation of the HF lies in the level of formalization of the capabilities. The definitions of the capabilities were mostly based upon previous multiple and independently developed work. However, capabilities are essentially information processes, and therefore their definitions should be derived from a unique and fundamental theory of information. The quest for such theory is in progress. (Umpleby, 2007) stated: "matter and energy have been subject of scientific investigation for several hundred years, a scientific conception of information is relatively new". (Bateson, 1972) defined information as that which changes us or the difference that makes a difference. (Kallinikos, 2006) stated that information is self-referential and non-foundational. (Shannon, 1949) defined information as a reduction of uncertainty. (Adriaans, 2009) addressed the idea of meaningful information. (Buckland, 1991) defined information-as-thing, information-as-knowledge and information-as-process. While mathematical formulations are recurrent in traditional physics, it is questionable if mathematical formulations are possible in information related problems. Most of the research in social sciences still uses purely verbal representation of social phenomena (Ostrom, 1988) which has the downside of making it harder to investigate causal relations going from assumptions to implications and scientific knowledge to build up. With the advent of powerful and accessible simulation computational tools, more formal representation is emerging for social phenomena making it easier the assessment of consistency, generalization and other desirable properties.

Chapter 3

Quantifying the value of digital information networks by employing the information processing capabilities of their users

Abstract: Few doubt that Digital Information Networks (DINs) such as the Internet constitute the basis of a new technology-driven economic era. A large body of literature tries to understand and quantify the value of DINs to help policy makers justify investments in new or improved infrastructures. The prevailing methodological approach is to depict DINs as an observable production input changing the uncertainty regarding the performance of an economic system. In such context, the value of DINs is typically measured with regression techniques between the penetration rate of DINs and economic growth. This approach provides too little insight on the actual causality between DINs and economic value. Chapter 2 presented a Holonic Framework (HF) that identified and defined capabilities of users in a DIN. Capabilities are mechanisms that users apply to convert information into economic value. In this chapter, we show how a simple quadratic relation (Metcalfe's law) can be used to quantify how adequate users convert the ability to access information into economic value by applying a given capability.

This chapter was matter of publication in (Madureira *et al.*, 2011e).

3.1 Introduction

In chapter 2, we presented a first framework built entirely upon the evolutionary view on the value of Digital Information Networks (DINs). This framework, labeled Holonic Framework (HF), provides an overarching account for the intermediate processes between DINs and economic value. The HF provides deeper insights on the causality between DINs and economic value than the orthodox economic studies mentioned in chapter 2. It provides an answer to the question: *what are the intermediate processes between DINs and economic value?* The goal of this chapter is to quantify the effectiveness of these so-called capabilities, i.e. how adequate users convert the ability to access information into economic value by applying a given capability.

3.2 Model for value generation by holons in DINs

We can derive a number (value) for how effective a capability is in creating economic value from how it is used to generate income. For example, if a worker uses DINs for online education, then he uses adoptability to obtain a certain part of his income. The value (y_c) generated by a capability c is dependent on the size x of the DIN. With a larger network more value is extracted by a capability. k_c is the coupling strength between the size of the network and the value generated by capability c, and is a measure for c's effectiveness in creating value by accessing information. We assume that the size of the DIN and the coupling strength of each capability are independent.

Metcalfe's law states that the value of a network is proportional to the square of its size, relying on the observation that for a network with n members, each can make $n - 1$ connections with the other members (Metcalfe, 1995). If all those connections are equally valuable, the total value of the network is proportional to $n(n - 1)$, thus roughly to n^2. For example, if a network has 5 members, there are 20 different possible connections that members can make to each other. If the network doubles its size to 10 members, then the number of connections does not simply double, but roughly quadruples to 90.

If we assume that the capabilities contribute independently to the total value of a DIN, then we may expect that the value created by each individual capability is proportional to the square of the size of the DIN. This is a simplification, because the capabilities are in fact interrelated. Thus, we get the following model:

$$y_c = k_{c,M} x^2 \tag{3.1}$$

The size of the network x, is usually given by n, the amount of members or users of the network. However, x may also be expressed in terms of the relative size of the network. We use the latter, because our data set from Eurostat provides direct numbers for the fraction of potential members being connected to DINs, and to keep our measurement conditions constant (see section 3.5).

The limitations of Metcalfe's law have been described by (Briscoe *et al.*, 2006). Metcalfe's law assumes that each user adds equal value to the network, and this is not the case in general. For example, a connection between people communicating with different languages has in principle smaller value than within a single language domain. For large n, (Briscoe *et al.*, 2006) provided an alternative to Metcalfe's law which states that the value of a network of size n is proportional to $n \ln(n)$. The term n comes from the fact that there are n members, each drawing $\ln(n)$ value for the capability. The term $\ln(n)$ comes from an empirical rule known as Zipf's law that is used to characterize a vast range of real-world phenomena (Zipf, 1949). Zipf's law states that if some large collection of items is ordered by value, then the mth ranked item contributes to the total value with about $1/m$ of the value of the first item. So, if an information network has n members, the value for each member is in total proportional to $1 + 1/2 + 1/3 + ... + 1/(n-1)$ which approaches $\ln(n)$:

$$\lim_{n \to \inf} \sum_{m=2}^{n} \frac{1}{m-1} = \ln(n-1) + \gamma, \tag{3.2}$$

with γ equal to the Euler-Mascheroni constant (0.6). To use Briscoe's law, we need to know the absolute size n of the DIN, rather than its relative size x:

$$n = xI, \tag{3.3}$$

with I being the potential maximum size of the DIN. We thus get an alternative model for large n:

$$y_c = k_{c,B} xI \ln(xI) \tag{3.4}$$

3.3 Methodology

3.3.1 Data collection

To answer the research question stated in section 3.1, we measured the value created by the capabilities of the HF individually and their dependence on the size of the DIN using data from Eurostat. Eurostat, the European Union's official organization to collect statistical data, provides one of the richest data sources about the usage of IT in enterprises and households. We were allowed to use a significant part of their data set for our research. The data comes in two separate files with a total size of approximately 350 megabytes, which can be obtained at (Eurostat, 2010). By applying data mining techniques, we were able to relate many Eurostat variables more or less directly to our capabilities, and extract numbers representing the size of the relevant DIN.

Data was collected for every single year between 2002 and 2009, and for the following individual countries or federation of countries: European Union - 27 countries (Eurostat reference *EU27*), European Union - 25 countries (*EU25*), European Union - 15 countries (*EU15*), EuroZone - 15 countries (*EA*), EuroZone+SK - 16 countries (*EA16*), Belgium (*BE*), Bulgaria (*BG*), Czech Republic (*CZ*), Denmark (*DK*), Germany (*DE*), Estonia (*EE*), Ireland (*IE*), Greece (*EL*), Spain (*ES*), France (*FR*), Italy (*IT*), Cyprus (*CY*), Latvia (*LV*), Lithuania (*LT*), Luxembourg (*LU*), Hungary (*HU*), Malta (*MT*), Netherland (*NL*), Austria (*AT*), Poland (*PL*), Portugal (*PT*), Romania (*RO*), Slovenia (*SI*), Slovak Republic (*SK*), Finland (*FI*), Sweden (*SE*), United Kingdom (*UK*), Turkey (*TR*), Iceland (*IS*), Norway (*NO*), MK (*MK*), Croatia (*HR*) and Serbian Republic (*RS*). Furthermore, the data points are collected individually for various economic sectors and geographic regions.

3.3.2 Operationalization

Obviously, Eurostat did not obtain its data with the HF in mind. Therefore, the data does not provide enough empirical variables to cover fully and perfectly each capability of the framework. The empirical variables chosen in this chapter are limited by what is being measured in the Eurostat surveys, and some can better be considered to be proxies to the HF capabilities than others. Consequently, we have some capabilities that are relatively well operationalized (particularly coordinatibility, selectibility, adoptability, creatibility, normatibility and trustability), and others that are far from optimal (particularly cooperatibility, biddability, decisability, modelability and perceptability). Table 3.1 provides a summary of the operationalization. Below we explain how we related capabilities to the Eurostat parameters.

Within organizational management, coordination mechanisms are used in various applications, namely in systems of production, logistics and service operations. Therefore, we operationalize coordinatibility with the fraction of enterprises using systems for managing production, logistics or service operations (Eurostat reference *e_lnkpls*). Selectibility is operationalized with the fraction of enterprises using Internet information search engines (*e_iif*). Adoptability is operationalized with the fraction of individuals that have used the Internet for training and education (*i_iedut*). Creatibility is operationalized with the fraction of enterprises that consider the Internet significant for the development of new products and services (*e_beictnps*). Normatibility is operationalized with the fraction of enterprises that use agreed proprietary standards for automated data exchange (*e_adefpro*). Trustability is operationalized with the fraction of enterprises that regard the improving of the company image as an important reason why they are selling via the Internet (Eurostat references *e_benimv* and *e_benims*).

The capabilities in the previous paragraph are the ones that could be relatively easily related to the Eurostat variables. For the ones below, we feel that the relationship is not so straightforward. The deployment of DINs fueled the rise of electronic commerce, matching the goals of buyers and sellers to cooperate in a supply and demand relationship (Weiss, 2009). Therefore, we operationalize cooperatibility with the fraction of enterprises that have ordered products or services via the Internet (Eurostat reference *e_ibuy*). DINs have lowered costs of organizing bidding auctions, leading to an increasing number of transactions (Lucking-Reiley, 2000). (Milgrom, 1989) stated 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". We operationalize biddability with the fraction of individuals that have used the Internet for selling goods (e.g. via auctions) (Eurostat reference *e_iusell*).

Modelability, decisability, and perceptability have an intricate and dependent nature. Modeling endows organisms to learn contingencies among events and actions, and therefore it is a vital capability for making decisions in dynamic environments (Newell and Broder, 2008). Moreover, both decisability and modelability are limited by the fact that biological organisms have limitations on how much information can be perceived (Miller, 1956). Thus, approaches have been proposed in the literature to integrate decisability, modelability and perceptability (Hommel *et al.*, 2001). Nevertheless, the HF values their conceptual separation, based upon empirical evidence such as direct parameter specification (Neumann, 1989). Unfortunately, capturing each of these capabilities individually is not possible with the data provided by the Eurostat surveys. Therefore, we operationalize these three capabilities together with the fraction of enterprises that regard Internet sales as very important or of some importance in improving the quality of their services (Eurostat references *e_benquv* and *e_benqus*). Unfortunately, culturability and brokerability do not map at all with any variable from the Eurostat surveys.

Capability	Operationalization	Eurostat reference
Coordinatibility	Fraction of enterprises using systems for managing production, logistics or service operations	*e_lnkpls*
Cooperatibility	Fraction of enterprises that have ordered products or services via the Internet	*e_ibuy*
Selectibility	Fraction of enterprises using Internet information search engines	*e_iif*
Biddability	Fraction of individuals that have used Internet for selling goods (e.g. via auctions)	*i_iusell*
Adoptability	Fraction of individuals that have used Internet for training and education	*i_iedut*
Creatibility	Fraction of enterprises that consider the Internet significant for the development of new products and services	*e_beictnps*
Normatibility	Fraction of enterprises that use agreed proprietary standards for automated data exchange	*e_adefpro*
Trustability	Fraction of enterprises that regard the improving of the company image as an important reason why they are selling via the Internet	*e_benimv e_benims*
Decisability, Modelability and Perceptability	Fraction of enterprises that regard Internet sales as very important or of some importance in improving the quality of their services	*e_benquv e_benqus*

Table 3.1: Operationalization of the capabilities

To represent DINs and especially their size in terms of interconnected users, the Eurostat data provides two empirical variables: the fraction of enterprises that have access to the Internet (Eurostat reference *e_iacc*) and the fraction of households with access to the Internet (Eurostat reference *h_iacc*). The empirical variables use three different types of units of analysis: individuals, enterprises and households. To compare all the empirical variables mentioned previously in a fair way, we therefore assume that the units are proxies for holons. For example, if 10% of the individuals have access to the Internet, we assume that 10% of the holons have access to the Internet, irrespective of it being individuals, enterprises or households. Furthermore, the empirical variables use different sample sizes: samples per year, per country and per economic sector or geographical region. We assume that the resulting fractions are representative for all the domains observed. For example, if 10% of the enterprises in the construction sector, in Portugal, in 2004 used cooperatibility, then we assume that 10% of all the holons used cooperatibility.

Regarding model (3.4), we assume that n is given by x multiplied by the number of Internet Protocol (IP) addresses advertised in 2010 ($I \approx 2.2 * 10^9$ (Potaroo, 2010)). Furthermore, we assume that the size of the population (i.e. the theoretical maximum size of the network) is the same for every year in the Eurostat data source (2004-2009) and that each IP address acts as a node in the network and adds the same value as all the other addresses.

3.3.3 Analysis method

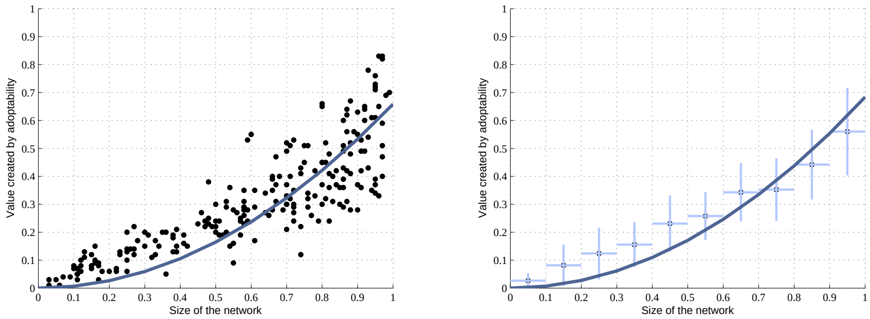
For model (3.1), the coupling strength $k_{c,M}$ of each capability is estimated by minimizing the sum of squared residuals:

$$\tilde{k}_{c,M} = \frac{\sum_i y_{c,i} x_i^2}{\sum_i x_i^4}, \tag{3.5}$$

in which $y_{c,i}$ is the operationalization for the value created by a certain capability and x_i is the operationalization for the relative size of the DIN. For model (3.4), the coupling strength $k_{c,B}$ of each capability follows from:

$$\tilde{k}_{c,B} = \frac{\sum_i y_{c,i} x_i I \ln(x_i I)}{\sum_i x_i^2 I^2 \ln^2(x_i I)}. \tag{3.6}$$

Our results are presented in a set of graphs such as shown in figure 3.1(b) in which the horizontal axis represents x or n, for model (3.1) and (3.4) respectively, and the vertical axis represents y_c, the normalized value created by a capability. The regression line is shown by the thick curve. For optimal representation of the results, a binning process was used due to the large number of available samples and their relatively large spread. For example, we have more than 3000 samples available for coordinatibility and their relative standard deviation is 16% of the expectation value. The bin size Δx that we used is 0.05 for the regressions with Metcalfe's law, which corresponds to the horizontal error bar in figure 3.1(b). For the fits with Briscoe's law, the horizontal error bar is $\Delta n = 10^8$. The vertical error bar corresponds to the standard deviation of the samples in each bin. Figure 3.1 provides an illustration of the binning process taking adoptability as an example. The individual samples are represented with black dots.



(a) Samples (b) Bins

Figure 3.1: Binning process for adoptability

3.4 Results

3.4.1 Metcalfe's law

Figure 3.2 shows the results obtained with model (3.1). All curves fit well within the limits provided by the error bars. The exception is selectibility, which behaves linearly with a slope of approximately 1, meaning that roughly every additional node will use selectibility. This can be theoretically expected. When a quadratic curve following model (3.1) gets close to the line $y = x$, it means that the fraction of holons using a capability is equal to the relative size of the network. This strongly indicates that every holon that is connected to the network uses the capability. From there on the curve follows $y = x$. This is in line with our model (3.4) and the literature (Briscoe *et al.*, 2006) where for large networks, the increase in the value is expected to tend more towards a linear behavior. Unfortunately, Eurostat does not provide data for the behavior of selectibility for small network sizes. However, we can safely assume that the use of selectibility also behaves quadratically with x for small network sizes. Thus, we know from model (3.1) that the selectibility curve behaves quadratically until the first available bin point or earlier, and from thereon linearly. With this assumption, we arrive at an estimation for the minimum of the coupling strength of selectibility ($k_{c,M} \geq 2.6$), which is accurate enough to conclude that selectibility is the most relevant capability (see the statistics in table 3.2).

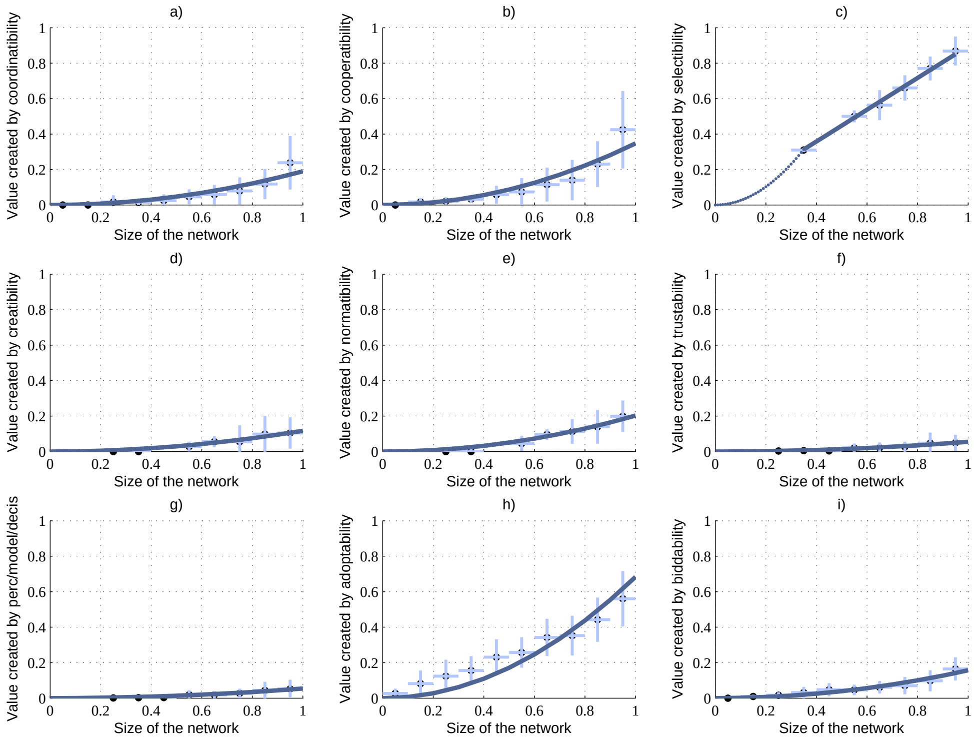


Figure 3.2: Applying Metcalfe's law to the Eurostat data (— regression, — precision, • bin points)

3.4.2 Briscoe's law

Figure 3.3 shows the results obtained with model (3.4). For each sub-graph, the horizontal axis represents n in billions (10^9), and the vertical axis represents y_c, the value created by a capability. The regression curve fits all the data quite well, including selectibility (see the statistics in table 3.3). If we compare the relative standard de-

Order	Capability c	Samples	Coupling strength $k_{c,M}$	Relative standard deviation of $k_{c,M}$
1	Selectibility	248	≥ 2.6	-
2	Adoptability	220	0.68 ± 0.05	7%
3	Cooperatibility	3635	0.35 ± 0.05	14%
4	Normatibility	887	0.20 ± 0.01	5%
5	Coordinatibility	3347	0.19 ± 0.03	16%
6	Biddability	191	0.17 ± 0.01	6%
7	Creatibility	805	0.117 ± 0.008	7%
8	Trustability	839	0.055 ± 0.004	7%
9	Perc/model/decis	836	0.054 ± 0.004	7%

Table 3.2: Coupling strength ranking of the capabilities with Metcalfe's law

viations in $k_{c,B}$ with those of $k_{c,M}$ (table 3.2), we observe that Briscoe's law fits the strongly coupled capabilities selectibility and adoptability better than Metcalfe's law. For less strongly coupled capabilities, Metcalfe's law fits better. This is in concordance with observations about the validity interval of Metcalfe's law (Briscoe *et al.*, 2006).

Order	Capability c	Samples	Coupling strenth $k_{c,B}$ (E-12)	Relative standard deviation of $k_{c,B}$
1	Selectibility	248	19.7 ± 0.2	1%
2	Adoptability	220	12.4 ± 0.5	4%
3	Cooperatibility	3634	6 ± 1	17%
4	Normatibility	887	3.5 ± 0.5	14%
5	Coordinatibility	3346	3.0 ± 0.7	23%
6	Biddability	191	2.6 ± 0.3	12%
7	Creatibility	805	2.1 ± 0.4	19%
8	Trustability	839	0.9 ± 0.1	9%
9	Perc/model/decis	836	0.9 ± 0.1	9%

Table 3.3: Coupling strength ranking of the capabilities with Briscoe's law

3.5 Discussion

3.5.1 Analysis of the models and the results

Both our regression models result in the same ranking of coupling strengths with selectibility on top and perceptability/modelability/decisability at the bottom. Se-

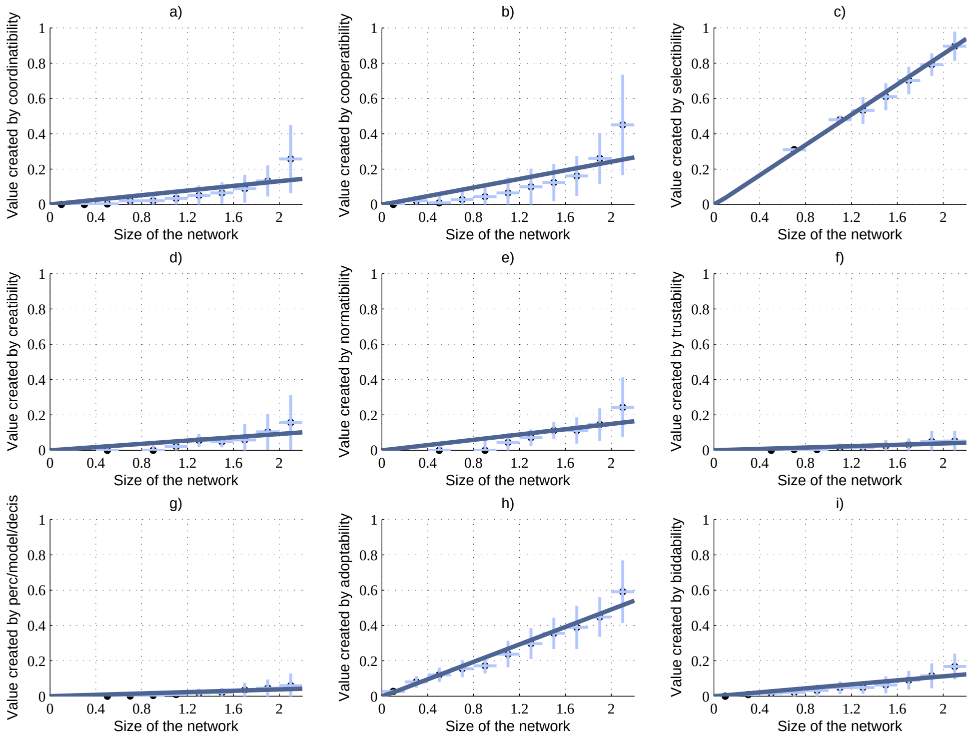


Figure 3.3: Applying Briscoe's law to the Eurostat data (— regression, — precision, • bin points)

lectibility is followed by adoptability and cooperatibility. Within the error bars, normatibility, coordinatibility, and biddability have the same coupling strength and so does trustability and perceptability/modelability/decisability.

Selectibility and, to a lesser extent, adoptability support the use of Briscoe's law rather than Metcalfe's law. The selectibility curve basically states that everyone who has a DIN connection uses it to select information. This is not surprising given the popularity of Internet search engines. Also the adoptability curve is best fitted with model (3.4) rather than (3.1). This is somewhat remarkable since the curve of figure 3.3h has not yet approached $y = n$, but seems to follow $y \approx 0.5n$. Apparently, there is a group of users which do not require adoptability at all, independently of the size of the network. The remaining capabilities seem to be better fitted with Metcalfe's law. Overall, we can safely state that the capabilities have either a quadratic or a linear dependency with the size of the DIN infrastructure.

An important aspect in our methodology is the use of normalized values in model

(3.1) instead of absolute values. This has the advantage of keeping the measurement conditions constant. If instead the model would have been of the form:

$$y_c * P = q_{c,M}(x * P)^2, \tag{3.7}$$

with P being the sample size, then expression (3.5) for $q_{c,M}$ would be dependent on the sample size and thus be meaningless. In model (3.4), we must use absolute values due to the $\ln$ function present. Instead of sample size we chose for I, the size of the global Internet, a number which is equal for every sample and which varies negligibly over the years.

3.5.2 Implications for theory and practice

In the mainstream literature, Metcalfe's law has been used more as a heuristic or metaphor than an iron-clad empirical rule. To our knowledge, empirical work validating and employing Metcalfe's law was nonexistent up to now. Therefore, this work is most likely the first empirical study which supports the implications of Metcalfe's law and its extension mentioned in (Briscoe *et al.*, 2006) concerning large networks.

Our work opens the possibility of using mediation analysis techniques for the study of large scale economic impacts of DINs. A mediation model is one that seeks to identify and explicate the mechanism that underlies an observed relationship between an independent variable and a dependent variable via the inclusion of a third explanatory variable, known as a mediator variable (Baron and Kenny, 1986). Extensions of our work could rely on the capabilities as mediator variables and their behavior as investigated in this chapter. The current literature on mediation analysis only applies to specific and small-scale impacts of general IT (e.g. (Grover *et al.*, 1998)).

Our study also helps relating small-scale studies on specific impacts of DINs with the macro-level studies reviewed in section 2.1. The capabilities of the HF, the coupling strengths k, and the functional forms provided by Metcalfe's and Briscoe's law can be used to extrapolate results from the micro- to the macro-level. For example, one may apply a k obtained from this chapter to a specific country for a nation-wide study. Additionally, they can be used to validate impact changes at the macro-level, because these changes necessarily need to be preceded by changes in the use of capabilities.

The orthodox economic studies reviewed in section 2.1 rely on Cobb-Douglas production functions to model an economic system as a black box and investigate the relationship between DINs as a production input and economic value as an output (e.g. see (Majumdar *et al.*, 2010; Koutroumpis, 2009)). Generally speaking, Cobb-Douglas functions take the form:

$$Y = AL^{\alpha}K^{\beta}, \tag{3.8}$$

in which Y is the total production, A is the total factor productivity, L is the labor input, K is the capital input, and α and β are the output elasticities of labor and capital respectively. α and β are assumed to be constants determined by the available production technology, such as DINs. However, our results show that the value created by capabilities are linearly or quadratically dependent on the size of the DIN infrastructure, including a transition region between linear and quadratic behaviors. Such complex behaviors might not be well captured with constant output elasticities. Thus, studies on the economic impact of DINs need to introduce more complex production functions, such as functions with variable returns to scale (Kim, 1992).

3.5.3 Limitations and future study

Although we based ourselves on one of the world's best sources of empirical data on the value of Information and Communication Technology (ICT), the match between the conceptual and operational definitions of the capabilities needs to be improved. Some of the capabilities were impossible to operationalize (brokerability and culturability) and others were operationalized in a limited way. Looking into other data sources is an obvious way to improve our empirical results (e.g. the United Nations (UN) Statistical Commission). Even better would be the understanding and construction of a targeted measuring and data-gathering campaign to further validate and quantify the importance and completeness of the capabilities identified by the HF.

The HF is a very recent development, and thus should be subject to more scrutiny and maturation. As mentioned above, mapping the Eurostat data with the capabilities of the HF was challenging. We assumed that this was due to the measurement limitations of the Eurostat data. Nevertheless, we should not exclude the possibility that the definitions of the capabilities need better formalizing. Using the Eurostat data to redefine the capabilities may be investigated. Additionally, future study could focus on the completeness and the level of orthogonality (and interrelatedness) of the capabilities.

3.6 Conclusions

To justify further investments in Digital Information Networks (DINs)' infrastructures (e.g. in FTTH), it is necessary to analyze expenditures that have already been made and demonstrate their value. Previous literature accounted for the causal relation between DINs and economic value through statistical relations which provide few insights on the real causal mechanisms involved. Chapter 2 presented a Holonic Framework (HF) which identifies these mechanisms as *capabilities* and specified 13 of these capabilities. Building upon the HF and Eurostat data, this chapter shows that the value that these capabilities create by using information show either a quadratic or a linear dependency with the size of the digital information network infrastructure. This quadratic dependency is explained by Metcalfe's law. The linear dependency is explained by an extension of Metcalfe's law as described in (Briscoe *et al.*, 2006). We were able to quantify the economic coupling strength of the capabilities and showed that the results are qualitatively the same irrespectively of using Metcalfe's law or Briscoe's adaptation of it. Not only can our observations be explained by Metcalfe's law, but it is also the first time that Metcalfe's law is empirically validated in a scientific way. This is a concrete result of taking an evolutionary economic approach, and our work thus provides various opportunities to improve traditional orthodox economic studies.

Chapter 4

A capability-aware policy making framework

Abstract: The Advocacy Coalition Framework (ACF) has gained a good reputation as a policy analysis instrument. However, several limitations of the ACF have been identified. In this chapter, we introduce a new framework for policy making labeled the Capability-aware Policy Framework (CaPF). The CaPF was derived by integrating the ACF with the Holonic Framework (HF), a framework originally developed to account for the value of Digital Information Networks (DINs). We demonstrate the conceptual added value of the CaPF in light of six criticisms previously directed at the ACF. We illustrate the practical value of the CaPF with a case study on the development and implementation of an electronic identification management system in Austria. This chapter also underpins the value of DINs to policy making.

This chapter was matter of publication in (Madureira *et al.*, 2011f).

4.1 Introduction

The public section of the American Political Science Association describes itself as "committed to producing rigorous empirical and theoretical knowledge of the processes and products of governing and the application of that knowledge to policy issues" (Weimer, 2008, p. 490). The first part of this commitment-the theoretical part-demands frameworks to explain the policy process. Recurrent questions in policy involve issues of learning, beliefs and the role of information. The various issues relevant to policy making operate in complex, interdependent political environments, where a large number of participants interact in the context of nested institutional arrangements, uneven power relations and uncertain information about problems and alternatives (Cohen *et al.*, 1972). Thus, (Milward and Provan, 2000) described modern governments as "hollow states" in which few policy entities have the power and authority to achieve their goals single-handedly. Therefore, policy networks among diverse policy participants are crucial for understanding the policy process. Among policy process approaches, one of the most relevant is an integrative policy making framework called the Advocacy Coalition Framework (ACF) (Sabatier and Weible, 2007; Sabatier, 1999; Sabatier and Jenkins-smith, 1993). The ACF has gained a good reputation, particularly because it directly incorporates the idea of policy networks (Kim and Roh, 2008). Additionally, the ACF captures a wide variety of factors, including economical, cultural, sociological, political, technological, legal and institutional, that affect policy change. (Schlager, 2007, p. 317) stated that existent policy process theories and comparative policy models "probably belong under a single roof and that roof is currently entitled advocacy coalition framework".

Nevertheless, various authors have pointed out several limitations of the ACF in explaining the diverse dimensions of the policy process (Nowlin, 2011; Weible *et al.*, 2009; Kim and Roh, 2008; Schlager, 1995; Hann, 1995; Zahariadis, 1995; DeLeon, 1994). In this chapter, we introduce and discuss a new framework, labeled the Capability-aware Policy Framework (CaPF), to explain policy change. In section 4.2, we provide a description of the ACF as well as criticisms of this framework. In section 4.3, we motivate the use of the body of literature on the value of Digital Information Networks (DINs) in searching for alternatives to conceptualize policy making and improve the ACF. In section 4.4, we discuss the motivation to integrate the Holonic Framework (HF) and ACF. In section 4.5, we describe the main proposition of this chapter, the CaPF. In section 4.6, we demonstrate an application of the CaPF. In section 4.7, we demonstrate the conceptual added value of the CaPF in light of six criticisms previously directed toward the ACF. Finally, section 4.8 presents the main conclusions of our chapter and suggests directions for future research.

4.2 ACF and its limitations

The ACF was created by Sabatier and Jenkins-Smith in the late 1980s in response to what they saw as essentially three limitations in the policy process literature: *stages heuristic* theory as an inadequate causal theory of the policy process; the strengths and weaknesses of top-down and bottom-up approaches to implementation research and the need for system-based theories of policy making; and the apparent lack of theory and research on the role of scientific and technical information in the policy process (Weible *et al.*, 2009; Sabatier and Jenkins-smith, 1993; Jenkins-Smith, 1990; Sabatier, 1988, 1986). The ACF is a system-based model that integrates most of the stages of the policy cycle, incorporates aspects of both the top-down and bottom-up approaches to implementation studies, and places scientific and technical information in a central position in many of its hypotheses.

(Sabatier, 1988) initially introduced the ACF as a symposium issue for the journal *Policy Sciences*. In (Sabatier and Jenkins-smith, 1993), the authors co-edited a book that outlined the ACF along with a set of hypotheses about science in policy, learning, beliefs and policy change. This book included six ACF case studies, four of which were written by other researchers, ending with a critical assessment and subsequent revisions of the framework. Later theoretical revisions occurred (Sabatier and Weible, 2007; Sabatier, 1999). The ACF's logic builds on a set of five main assumptions: 1) a central role of scientific and technical information in policy processes; 2) a time perspective of 10 years or more to understand policy change; 3) policy subsystems as the primary unit of analysis; 4) a broad set of subsystem actors from all levels of government, consultants, scientists and members of the media; and 5) policy changes best thought of as translations of beliefs. Additionally, the ACF specifies a model of the individual policy actor as rationally bounded with limited abilities to process stimuli, relying on beliefs as the principal heuristic to simplify, filter and sometimes distort stimuli (Scholz and Pinney, 1995; Quattrone and Tversky, 1988; Simon, 1985).

Various studies have demonstrated the empirical power of the ACF for explaining complex, multi-actor changes and thus for investigating processes of cross-agency policy change (Weible *et al.*, 2009; Fenger and Klok, 2001; Grin and Hoppe, 1997; Eberg, 1997; Schlager and Blomquist, 1996; Parsons, 1995). Case study research areas include policies regarding, for example, climate change, Internet censorship, workers' compensation and rehabilitation, metallurgical development, tobacco taxes, forests, waste management and incineration, steel, unemployment and paid leave, pharmacies, coastal flooding, planning, estuary development, land use, nuclear energy, drugs, domestic violence, roads, coastal water, transport and minerals, industrial pollution, antitrust issues, communications, airline deregulation, public lands, water, energy and oil, nuclear waste, nuclear security, estuary management, air and transportation, and reclamation (Colorado, 2011).

The ACF is illustrated in figure 4.1 (Weible and Sabatier, 2009; Sabatier and

Weible, 2007; Sabatier, 1999; Schlager and Blomquist, 1996; Sabatier and Jenkins-smith, 1993). The most useful way to see policy change is by focusing on *policy subsystems*, i.e. a group of actors from different institutions who follow and seek to influence governmental policy decisions in a policy area. Policy subsystems include substantive issues and specialized policy participants, usually within a geographic boundary. *Policy participant* is used to identify a wide array of actors who directly or indirectly attempt to influence subsystem affairs, including officials from all levels of government, interest group leaders, scientists, consultants, citizens-at-large, and members of the media.

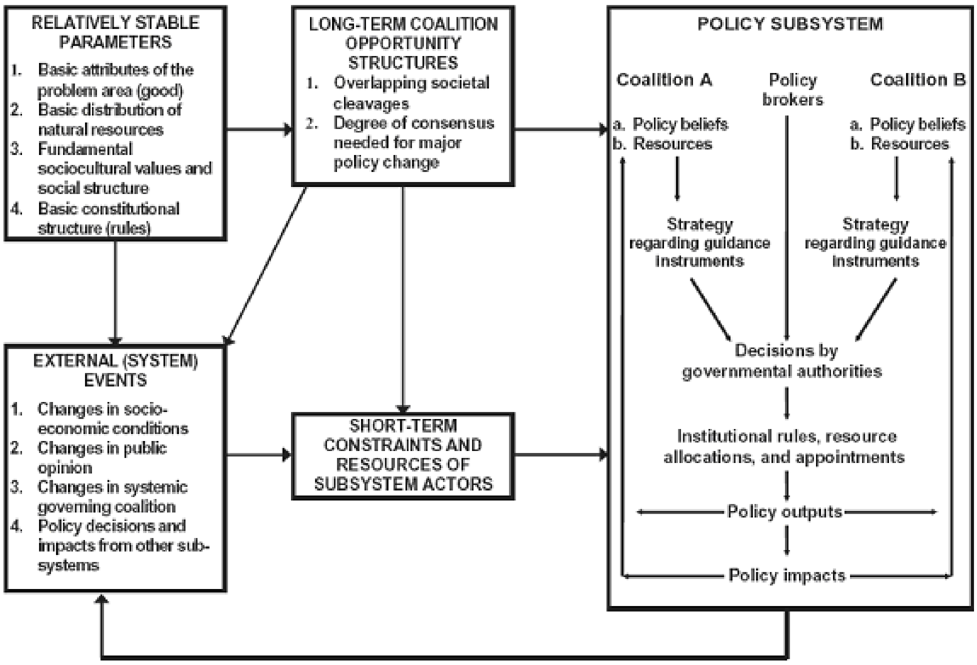


Figure 4.1: Advocacy Coalition Framework (ACF)

Coalitions are the network structures that bring multiple actors together for the policy process. Advocacy coalitions consist of individual actors "who share a particular belief system-i.e., a set of basic values, causal assumptions, and problem perceptions-and who show a non-trivial degree of coordinated activity over time" (Sabatier, 1988, p. 139). Shared *policy beliefs* are the core drivers behind coalition formation between actors within policy subsystems. *Policy brokers* assume a key role in the policy process by mediating conflicting coalitions. Of special relevance are research brokers who work at the intersection of research and policy on a daily basis. This special positioning allows them to provide first-hand accounts of research utilization to assist policy design (Rigby, 2005).

Policy subsystems are constrained by *long term coalition opportunity structures* that seek to describe structural constrains for coalition formation. For example, the higher the degree of consensus required in a society, the higher is the incentive for coalitions to be inclusive (involving more actors). Long term coalition opportunity structures are shaped by *relatively stable parameters* such as fundamental socio-cultural values and the basic distribution of natural resources. The relatively stable parameters also affect *external (system) events*, because socio-economic structures, values and legislation may contribute to the cause of an external event.

Both external (system) events and long term coalition opportunity structures impose a set of *short term constraints and resources* on the policy subsystem. Finally, the outcomes of the policy process directly affect external (system) events such as changes in public opinion. For instance, a certain policy impact (e.g. limited reduction of carbon emission) may affect public opinion on the effectiveness of environmental policy instruments. This, in turn, may affect the constraints and resources of policy actors (e.g. investments in new environmental programs) and subsequently the priorities of policy subsystems.

Despite its merits, a large body of published work reveals various limitations of the ACF (Nowlin, 2011; Weible *et al.*, 2009; Kim and Roh, 2008; Schlager, 1995; Hann, 1995; Zahariadis, 1995; DeLeon, 1994). First, the ACF fails to distinguish the importance of different policy actors, because it does not detail types of interactions among coalition members (Kim and Roh, 2008; Scharpf, 1993). For example, (Maloney *et al.*, 1994) distinguished consultation, bargaining and negotiation roles within British policy making and highlighted the important divide between the relatively few groups with more relevant roles and privileged status, and the greater number of groups who find themselves consigned to less influential positions because of their less relevant roles.

Second, (Schlager, 1995) argued that the ACF neglects collective action problems by assuming highly coordinated behavior among the coalition members. Coordination includes a range of activities from developing and executing joint plans to modifying behavior to achieve similar or non-interfering objectives (Sabatier, 1999). On the one hand, assuming that all coalition members interact is unrealistic (Nahrath, 1999). On the other hand, members of a coalition might not share the same benefits or costs, and therefore may experience conflicting decisions in the collective process (Kim and Roh, 2008). The ACF neglects that there might be a need for pre-conditions of coordination such as shared trust and norms (Paxton, 1999; Putnam, 1995).

Third, given that the ACF presumes that belief systems of individual members of a coalition are homogeneous, their individual interests are also considered homogeneous. However, in some instances, despite shared core beliefs, the interests of coalition members might conflict (Schlager, 1995). In other instances, despite shared interests, core beliefs might be different among coalition members (Hann, 1995). For example, (Cairney, 1997) showed that both feminists and political conservatives could be part of a coalition to regulate the availability of pornography, even without sharing core beliefs.

Fourth, the ACF does not account for the possibility that a policy domain may be structured by harmonious and stable relationships among participants who do not necessarily share the same core beliefs (see, for example, the notion of *iron triangle* (Kim and Roh, 2008; Maloney *et al.*, 1994; Freeman, 1955)). (Marsh and Rhodes, 1992) argued that networks can vary along a continuum according to the closeness of relationships within the network. Thus, policy coalitions at one pole involve tightly bound relationships. At the opposing pole, the interaction is much looser. Policy communities therefore exist within coalitions (Rhodes, 1986) that act as gatekeepers between insiders and outsiders (Maloney *et al.*, 1994).

Fifth, by assuming that individuals act based on their beliefs, the ACF lacks a basis for predicting or explaining strategic behavior (Schlager, 1995). The ACF presumes that individual coalition members act naively based on their beliefs, without attempts to misrepresent their preferences in favor of their own interests. Due to the variety of institutional structures, the absence of strategic behavior becomes an obvious limitation in the context of politics.

Sixth, the ACF focuses on the interaction of competing coalitions within policy subsystems as one of the critical factors for policy change (Sabatier, 1999). Despite the usefulness of the concepts of coalitions and policy subsystems as units of analysis, the significance of other levels of analysis cannot be excluded. For example, (Kim and Roh, 2008) depicts the policy arena with additional layers: policy actors, relationships between policy actors, policy coalitions, policy networks and policy domains (issues). With a more refined layering, a policy process theory could account for conflicts between coalitions from different policy subsystems, and not only between coalitions within policy subsystems as presumed in the ACF (Weible, 2008).

We have focused and described these six specific criticisms, because they have been recurrently leveled at the ACF in early and recent literature as well (Nowlin, 2011; Weible *et al.*, 2009; Kim and Roh, 2008; Schlager, 1995; Hann, 1995; Zahariadis, 1995; DeLeon, 1994). We will use them to demonstrate the conceptual contribution of our work. Some of these criticisms have been addressed individually.

For example, (Weible, 2008) introduced a distinction between principal and auxiliary actors to augment ACF with an accounting of the different importance of policy actors. However, no attempt has been made to change the fundamentals of ACF, and thus compensate for a significant number of its limitations. Such an attempt necessarily requires a fundamentally different approach from looking into policy making. In the next section, we use the body of literature on the value of DINs to search for alternatives to conceptualize policy making and improve the ACF.

4.3 An alternative approach: the value of DINs

The policy process is often modeled as a complex system of inputs and outputs (Easton, 1965). Among all the inputs and outputs, information is considered one of the most important. A vast body of literature exists on the role of information regarding policy making (Weible, 2008; van Kerkhoff and Lebel, 2006; Adams, 2004; Ingram *et al.*, 2004; Fischer, 2000; Jenkins-Smith, 1990; Kingdon, 1995; Knorr, 1977; DeWitt, 1994; Lee, 1993; Ozawa, 1991; Pelz, 1978; Rich, 1991; Sabatier, 1986). This literature shows how the use of information flowing through networks of policy actors directly impacts policy. For example, in *multiple streams* theory, entrepreneurs use expert-based information to shape agendas and policies for political gain (Zahariadis, 2007). In *punctuated equilibrium* theory, policy change is not only mostly incremental, but is also marked by sporadic punctuations triggered by the pace with which actors process information (Baumgartner *et al.*, 2009).

The ACF also emphasizes the role of information and learning as motivating factors in the process of policy change. Expert-based information affects policy indirectly by slowly shifting beliefs of policy actors in a process labeled *policy-oriented learning* (Sabatier, 1987; Weiss, 1977). During conflicts, the ACF predicts that expert-based information becomes a valuable asset to mobilize alliances and argue with competitors, typically within coalitions rather than between them (Weible, 2008; Sabatier, 1987). Additionally, improving understanding and keeping up to date with changes and innovations can lead to new mechanisms through which the policy objective might be more effectively achieved (see also the notion of *policy entrepreneur* (Kingdon, 1995)).

(Kallinikos, 2006) attempted to understand the complex character of technologically sustained information processes. He drew some important conclusions about the nature of information: it is self-referential and non-foundational. Self-referential means that information has value if it adds a difference to what is already known. (Borgman, 1999) stated: "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 means that informational differences emerge through comparison of two or more objects or items. They are not singular, but are relational entities. Due to its differential nature, information is hard to measure and conceptualize further. Nevertheless, the body of literature on the value of DINs and other IT has shown great progress regarding this issue. A significant amount of theoretical and empirical work has been produced to address the well-known paradox "you can see the computer age everywhere but in the productivity statistics" (Solow, 1987). In this chapter, we use the body of literature on the value of DINs as a new alternative approach to obtain insights on how to conceptualize policy making.

Specifically, we refer to a framework, labeled Holonic Framework (HF), which was suggested in chapter 2 for understanding, modeling and predicting the value of DINs. The HF describes a set of simple and fundamental concepts which describe how information flows are processed and from which evolutionary value is generated (e.g. economic evolutionary value). Our hypothesis is that the HF is not only applicable to DINs, but to other information networks as well. Irrespective of the technical aspects involved in the coding, transmission and decoding of information, digital networks allow humans to exchange information, just like any other transport, organizational, physical or biological network. An obvious evidence of this claim, is the meaningfulness of the HF concepts to policy making, as this chapter demonstrates.

Of all the frameworks proposed to account for the value of DINs and IT, the HF was chosen for two main reasons. First, it is a framework developed purely upon the premises of evolutionary economics regarding the nature and value of information, which were described in chapter 2. The evolutionary view on the value of information is coherent with the *procedural rationality* model (Simon, 1985) of the individual present in the ACF. From this perspective, the individual engages in limited search processes, makes choices based on subjective representations of the situation, and *satisfices* (Simon, 1956). Analysts become therefore mainly concerned with information resources, subjective representations and information processing capabilities. Coherence between the evolutionary view on the value of DINs present in the HF and the notion of procedural rationality present in the ACF is important to establish a conceptual link between the frameworks and allow for their integration. Second, the HF provides a more comprehensive view of the processes upon information. The latter is shown in chapter 2, where we compared the HF with two other reference frameworks on the value of IT (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004). This led us to the assumption, validated in this chapter, that the HF could be useful for policy making.

4.4 Motivation to integrate the HF with the ACF

The first evidence of the potential of the HF for policy making is that it has a few concepts identified in the ACF, although, at this point, without clear conceptual advantage. Most obviously, the role of policy brokers in the ACF is identified in the HF as the capability of brokerability. In the ACF, brokers generally refer to policy brokers that mediate conflicting coalitions. However, as described in section 4.2, it might also refer to *policy/research brokers* working at the intersection between science and policy. In the case of a predominant research activity, they should actually be addressed as *research brokers*. The HF definition of brokerability rests on a higher abstraction level, and therefore suitably refers to policy, research or even other types of brokers.

The HF accounts for coalitions with the capability of cooperatibility. Coalitions are a particular form of cooperation, in which a set of elements (e.g. determination, inspiration, beliefs) keep the individual members glued together. Abstracted from these elements, coalitions are identified in the HF with cooperatibility. The elements which make coalitions more specific than cooperations are captured in the HF with the notion that capabilities are interrelated and therefore influence each other. For example, the capability of trustability influences the capability of cooperatibility. Thus, in the HF, trust can be seen as a gluing element for cooperations. Contrary to the ACF which delimits coalitions to individuals with shared beliefs (one gluing element), the HF presumes the existence of twelve other gluing elements for cooperatibility (the remaining twelve capabilities).

Another example of commonalities between the ACF and HF are beliefs and the capability of modelability. (Denrell *et al.*, 2004) examined the emergence of beliefs through a recursive process of understanding the cause-effect structure of a system through intermediate path-dependent states that are viewed as being of value. These states are recursively rewarded, contributing to a belief which may not have any immediate or direct payoff consequence but sets the stage for subsequent states that bring an organization toward some actual payoff. In other words, beliefs are an outcome of modeling. Therefore, the HF concerns how beliefs develop with modelability, whereas the ACF takes beliefs as a given. As with brokerability/policy brokers and cooperability/coalitions, a shift from beliefs to modelability does not result in a significant conceptual advantage because HF researchers should still be concerned about how beliefs matter in regard to policy change. Nevertheless, this shift does not necessarily imply any limitation, because ACF researchers should also be concerned with how beliefs develop to subsequently understand how they influence policy change.

Apart from the commonalities between the ACF and HF, the other motivation to integrate these frameworks rests in the obvious conceptual differences between the two. The HF introduces several concepts not identified in the ACF that might be interesting for policy making. In fact, several of these concepts have already been introduced individually in previous policy research. For example, the notion of capability has had real impact in the development of human and social indicators (Sen, 1985). In addition, the concept of entropy (Simmons *et al.*, 1974) and the notion of selection (selectibility) are central to the analysis of policy making from an evolutionary perspective (Witt, 2003a). Other examples could be mentioned.

From the opposite perspective, the ACF has several concepts that are not covered by the HF. Specifically, we refer to contextual factors that affect the policy subsystem: relatively stable parameters, external (system) events and short term constraints and resources of subsystem actors. The lack of these factors in the HF results from its focus on information procedures endogenous to the actors (i.e. the capabilities) rather than on the environmental constraints that influence change. Consequently, the HF fails to account for adaptations and misalignments between policy actors and their social, economical and institutional environments. From this perspective, the ACF is complementary and capable of compensating for some of the limitations of the HF.

4.5 Capability-aware Policy Framework (CaPF)

The previous discussion of the ACF and HF, including their limitations and potential synergies, leads us to define two dimensions which are useful in guiding the integration of both frameworks. Generally speaking, one dimension refers to the information capabilities that empower political actors. The other is associated with the environmental constraints that influence or even determine the behavior and outcome of the capabilities. The distinction between capabilities and environment has a parallel in the Darwinian evolutionary view of policy making in which environmental natural selection acts upon behaviors or capabilities to favor the most suitable ones (Schubert, 2009; Mingst, 2008). Each of these theoretical dimensions includes blurred boundaries of inquiry that try to separate endogenous elements requiring explanation from exogenous elements assumed as given.

The dimension of capabilities in which the HF excels over the ACF involves how these capabilities develop and their outcomes, and relates to research streams such as the notion of procedural rationality (Simon, 1985); the evolutionary view on the value of information (Bulkley and Van Alstyne, 2004); network perspectives which suggest that social processes are not "the result of *central steering* or some king of *prestabilized harmony* but [emerge] through the purposeful interactions of individual actors" (Kenis, 1991); policy interests (Knoke *et al.*, 1996), such as the *minimum winning coalitions* used to argue that the primary goal of political coalitions is to maximize the benefit of the coalition members (Riker, 1962); resource-dependent approaches that emphasize that interactions among policy actors are facilitated by the necessity of accessing the resources of the other policy actors (Scharpf, 1978); and behavioral theories (Fenger and Klok, 2001).

The ACF, on the other hand, provides a better accounting of environmental factors than the HF. These factors constrain or influence how capabilities develop and their outcome. Much research has focused on the relationship between state and society in studying the policy process (Dye, 1966). (Marsh and Rhodes, 1992) has supported the necessity to pay attention to macro-level factors: "the concept of 'policy network' is a meso-level one which helps to classify the patterns of relationships between interests groups and governments. But it must be used in conjunction with one of the several theories of the state in order to provide a full explanation of the policy process and its outcomes". (Coleman and Skogstad, 1991) added that policy network approaches are best understood "when attention is paid to first, the broader political economic, and ideological environment within which they function; and second, the legacy of history". For example, the importance of cultural factors has been widely recognized among social scientists (Hofstede, 1980).

Of course, there is not a clear distinction between these two dimensions. As mentioned, environment influences capabilities. However, the inverse is also possible. (Schneider *et al.*, 2003) argued that repeated interactions can lead to the emergence of trust and norms which shape the institutional environment. (Bromley, 1989) saw policy changes as a result of actions by rational individuals to improve their circumstances by altering institutional arrangements. Integration of the HF with the ACF exposes the blurry border between capabilities and environment. While the ACF sees culture as an environmental factor mostly static and given, the HF sees culture as a capability which can be developed, shaped on a regular basis and used to gain benefits. In this regard, the HF is supported by evidence such as managers that use IT to deliberately manipulate corporate culture (Doherty and Perry, 2001).

The main proposition of this chapter, labeled CaPF, represents a general attempt to extract the best from each framework in a way that diminishes their individual limitations and increases their complementarity. Environmental factors are extracted from the ACF. Capabilities and the holonic individual and social constructs are taken from the HF. The Capability-aware Policy Framework (CaPF) is illustrated in figure 4.2 and its logic is as follows.

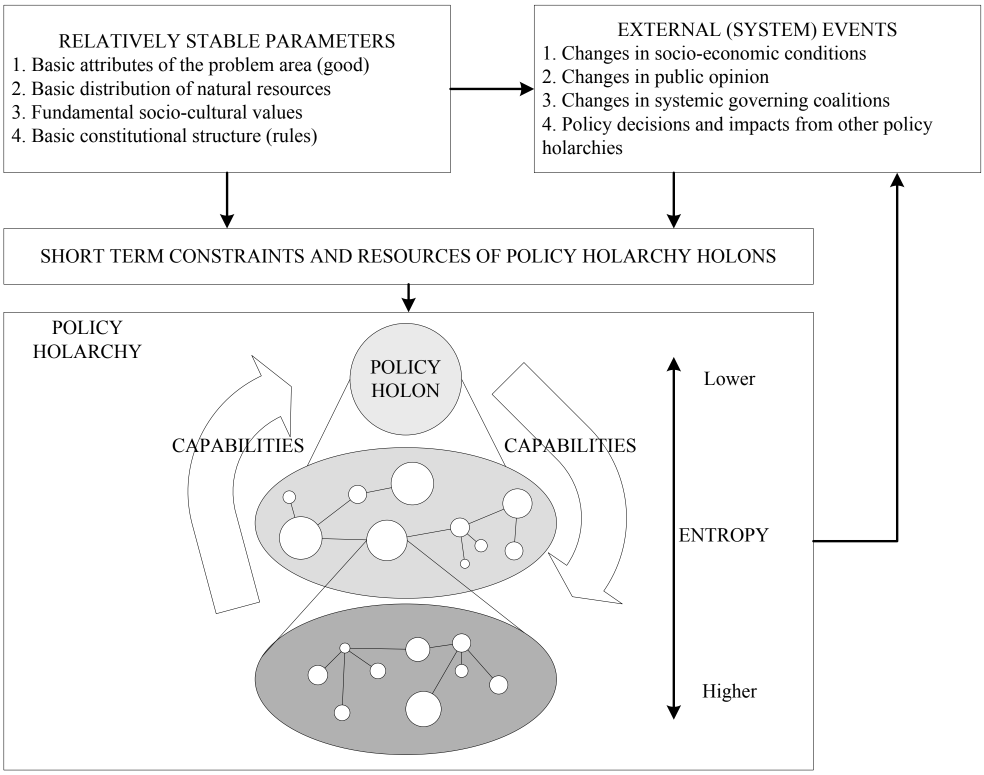


Figure 4.2: Capability-aware Policy Framework (CaPF)

A *policy holarchy* refers to a hierarchy of policy holons, with each holon bound to other holons in other planes in some way and independent in other ways. Rather than looking at a policy system as a black-box, a policy holarchy stresses the existence of hierarchies of diverse inter-dependent structures which influence policy change. From this perspective, the CaPF is similar to issue networks (McCool, 1995) and the multi-layered proposition of (Kim and Roh, 2008). In the ACF, policy holarchy refers to policy subsystem, defined as semi-autonomous decision-making networks of policy participants that focus on a particular policy issue usually within a geographical area (Sabatier, 1987). The definition of policy holarchy is broader, encompassing other variants such as coalitions, communities, policy monopolies (Baumgartner and

Jones, 1993) or iron triangles (Freeman, 1955). Depending on the observer’s perspective, a policy holarchy might include other policy holons and levels, their capabilities and the outcome of those capabilities. Equivalently to coalitions, policy holarchies can compete with each other.

In the CaPF, a policy actor is referred to as a *policy holon*. Generally speaking, policy holons are individual actors such as policy entrepreneurs, scientists, politicians, governmental officials, interest groups or journalists. However, a policy holon might also be a policy holarchy which, from the perspective of an observer, behaves at a high-level of autonomy and self-organization. An example would be a closed village community tightly knitted together by the strength of relationships, membership continuity, vertical interdependence and insulation from other holons (see the notion of *policy community* (Rhodes, 1985)). Holons at higher levels of a holarchy possess lower levels of *entropy*/randomness, and are therefore more complex and exert superordinate hierarchical influence over the holons below. For example, while coalitions are likely to be small to be effective, they can coalesce to increase their strength (Hann, 1995). If coalesced coalitions become indeed stronger into one single super-coalition, then this super-coalition occupies a higher position in the broader policy holarchy, acquiring predominance over weaker coalitions. The higher position of the super-coalition in the holarchy can be manifested, for example, by stronger capabilities and more complex internal information structures (e.g. more internal policy holons).

From within the holarchy, *capabilities* are the drivers, i.e. the information networks’ dependent processes, for policy change. The list of capabilities in table 2.1 is applicable to any level and holon of the holarchy. For example, whereas in the ACF cooperation occurs within a coalition, in the CaPF cooperation might occur inter-coalitionally, thus at a higher level of the holarchy as predicted, for example, by (Fenger and Klok, 2001). Additionally, capabilities on different levels influence each other vertically. From this perspective, the development of capabilities at the micro-level of the holarchy might shape the higher levels of the holarchy (see *social construction* theory (Ingram and Schneider, 2007)), perhaps with unexpected behaviors (see punctuated equilibrium theory (Baumgartner and Jones, 1993)). From the opposite view, the CaPF also accounts for policy changes in the holarchy guided by higher levels of the holarchy, for example, the influence of politicians on public opinion via campaign slogans and sound bites (see *policy images* (Baumgartner and Jones, 1993)). One the one hand, capabilities are fundamentally different, and therefore a capability cannot be identified by a subset of the other capabilities. For example, coordinatibility and cooperatibility are often used interchangeably, but some theorists clarify that they are fundamentally distinct concepts (Payan, 2007). On the other hand, capabilities might influence each other. For example, (Weible, 2008) described coalitions driven by analytical compatibility, i.e. experts with similar approaches or with similar scientific paradigms will elevate similar components of a system to study, use similar methods for measuring the chosen components and make similar arguments of cause and effect within a system. Using concepts from the CaPF, this causal relationship is expressed by cooperatibility driven by modelability. However, cooperatibility could also happen independently of modelability, but driven by any of the other 12 capabilities (e.g. trustability). At this stage of the development of the CaPF, we can only hypothesize that the relative causal weights of the capabilities, and the interrelationships between the capabilities most probably vary between case studies. Without these further insights, the CaPF at this stage might appear somehow artificial. Nevertheless, this is something that can be corrected with case study investigations.

The interplay between policy holarchy and environmental factors occurs as dictated in the ACF. Various characteristics of goods, such as excludability, affect institutional (policy) options. The distribution of natural resources strongly affects societal wealth overall and the viability of different economic sectors, many aspects of its culture and the feasibility of options in many areas (Sabatier and Jenkins-smith, 1993). The dominant cultural values and social structure affect policy options. For example, (Sabatier and Jenkins-smith, 1993, p. 150) stated: "large-scale nationalization of the means of production is a viable option in many European countries, but not in the United States". In most political systems, basic legal norms are quite resistant to change and affect the extent of policy change. Changes in socio-economic conditions can substantially affect a policy holarchy, either by undermining the causal assumptions of present policies or by significantly altering the political support for other policies. Swaying public opinion can affect the willingness of policy holons to make certain decisions. For instance, (Burstein and Freudenburg, 1978) investigated the influence of public opinion and anti-war demonstrations on senate voting for Vietnam war motions. Changes in systemic governing coalitions in critical elections (Burnham, 1970) normally impose formal constraints (e.g. the same coalition has to occupy certain positions). A policy holarchy is not fully autonomous. Consequently, it may be significantly impacted by other policy holarchies. Finally, the outcome of the policy holarchy directly affects external system events.

A bird's eye view comparison of the ACF (figure 4.1) and CaPF (figure 4.2) immediately reveals clear differences between the two. For example, while the ACF explicitly identifies beliefs as the causal drivers for political behavior, the CaPF presumes that change is driven equally by all the capabilities and their outcomes. The perspective of the CaPF is aligned with researchers who view policy change as the process of realizing the interests of policy actors. For example, (Riker, 1962) argued that the primary goal of political coalitions is to maximize the benefit of the coalition members (see minimum willing coalitions). (König and Bräuninger, 1998) defended the position that preference similarities among political actors are crucial for the choice of network contacts. Section 4.7 provides a more in depth comparison of the ACF and the CaPF in light of the six criticisms of the ACF described in section 4.2.

4.6 Case study

To illustrate the application of the CaPF, we make use of a case study previously presented on the development and implementation of an electronic identification management (eIDM) system in Austria (Huijboom, 2010). An eIDM system is a means of electronically and officially proving one's identity when interacting with businesses or governments. It enables end-users, for instance, to access secured databases (e.g. bank accounts), sign electronic documents (e.g. tax forms) and obtain digital products (e.g. building permits). The development and implementation of an eIDM system demonstrates how the contextual factors and capabilities involved play a crucial role in the policy design process.

The idea to develop an eIDM system for government services in Austria was proposed around 1999. The paper-based social security identification system had to be replaced by a smart-card, with the idea being to incorporate the Bürgerkarte into this new card, which would grant access to all government services. The Federal Ministry for Public Service and Sports together with A-SIT published a white paper in which the eIDM system, called Bürgerkarte, and its features were introduced (Gerstbach, 2004). The intention was to create an open concept in the sense that the Bürgerkarte could be integrated in multiple carriers (e.g. bank card, social security card). The first pilot project with the Bürgerkarte concept was launched in 2002 by the Austrian Computer Society (Osterreichische Computergesellschaft). In 2004, the MasterCard of several Austrian Banks and the student chip card of the Vienna University of Economics and Business were prepared for the Bürgerkarte. In 2005, a mobile application for citizen authentication was made available, as well as the e-Card of the Social Security Agency, which included the option of activating the Bürgerkarte function. Although the MasterCards of several banks, the e-Card, the Austrian Computer Society Member Card and the student chip card of the Vienna University of

Economics and Business were prepared for the Bürgerkarte, in 2007 citizen enthusiasm for the concept was still far behind expectations. In March 2007, a mere 20,000 Bürgerkarten had been activated, whereas the government had planned for 50,000 by 2006 (ARGEDATEN, 2007). Of the 8.2 million e-Cards that had been issued by October 2006, only 8,500 citizens used the opportunity to enhance their card with the Bürgerkarte signature, even though it was at no cost (FOKUS, 2006). Since January 2008, the e-Card of social security institutions has been fully replaced traditional signatures due to amendments in the Austrian eGovernment legislation (DIGITALES, 2008; ePractice, 2007). In November 2009, the take-up by service providers and citizens was still disappointing as a mere 120,000 Bürgerkarte certificates had been issued, and 15 government services were available through the Bürgerkarte concept (iDABC, 2009).

This case study relied on data collection and systematic interviewing. Data collection commenced with desk and Internet research with the goal of gathering general information on the innovation process, namely the successive steps, decisions made and actors involved. Several governmental websites were consulted and studied, such as electronic service portals. Additionally, information on contextual factors related to the innovation was collected such as government budgets and reports on socio-economic developments. Interviews were conducted with 13 individuals involved in the innovation, for example, the head of the E-Government Innovation Centre of Graz. Questions to assess the influence of the capabilities identified in the CaPF were presented to the respondents. For example, to test trustability, respondents were questioned regarding their perception of the strength of relationships. To test brokerability, respondents were asked if they had any involvement, and if so, with whom. Given that this case study only has illustrative purposes in this chapter, we do not present here the details of the case, which can be found in (Huijboom, 2010). Figure 4.3 shows our operationalization of the CaPF. Circles correspond to policy holons, with the black ones corresponding to individuals, and the gray ones to organizations. Lines mark the existence of information flows between policy holons. The sizes of organizational circles are meaningless. Coalitions, in the sense of the ACF, are not identified in the policy holarchy figure.

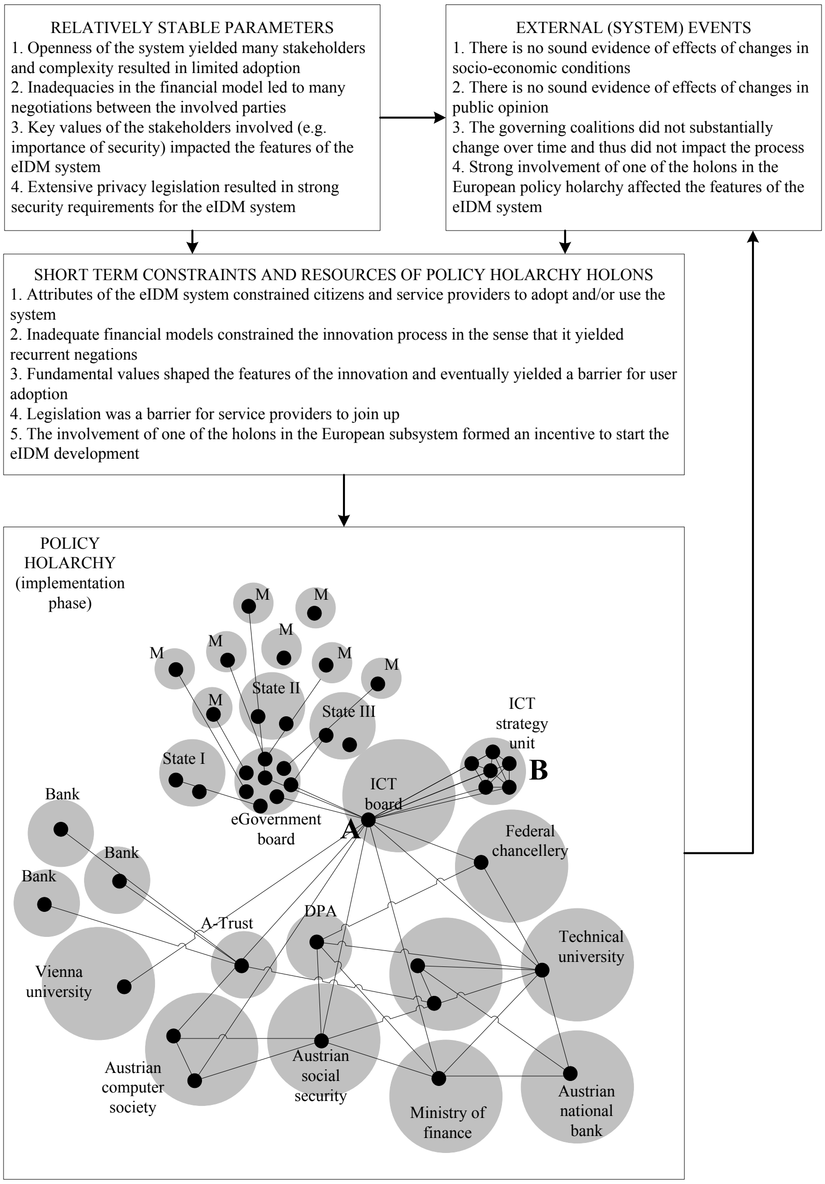


Figure 4.3: Capability-aware Policy Framework (CaPF) applied to the Bürgerkarte case

Regarding the basic attributes of the problem area (good), on one hand, the open technical concept of the Bürgerkarte solution increased the number of card providers involved. On the other hand, the complexity of implementation and re(activation) resulted in limited adoption by service providers. The basic distributions of resources affected the dynamics in the policy holarchy in the sense that there were many negotiations between involved parties on the funding of the Bürgerkarte concept. Additionally, the costs of the Bürgerkarte for service providers and citizens were perceived as being too high in relation to the benefits of the system, which made them reluctant to adopt the system. Fundamental socio-cultural values, particularly technological orientation and privacy concerns, have affected the features and subsequent adoption of the innovation. The strict requirements of the legal framework (in particular the e-Signature legislation) may have limited citizen take-up since the threshold for obtaining, activating and re-activing the Bürgerkarte was too cumbersome. However, there is not any sound evidence outlining the impact of the legal framework on interactions between policy holons of the policy holarchy or their strategies.

Regarding the external (system) events, there is no sound evidence that changes in socio-economic conditions and public opinion (e.g. articles about the Bürgerkarte concept and project in the newspapers (e.g. Die Presse)) affected the dynamics of the policy holarchy. Additionally, the governing coalitions did not substantially change over time. Strong involvement of the federal Chief Information Officer (CIO) in the European policy holarchy affected the outcome of the innovation in the sense that set requirements and developed ideas within that policy holarchy were used in the Bürgerkarte policy holarchy. Changes in the CIOs, the strategic team and the changed position of the strategic team did not have a substantial impact on the dynamics of the policy holarchy or innovation.

Regarding the short-term constraints and resources of policy holons, the attributes of the Bürgerkarte concept affected the number of card providers involved in the innovation. In addition, the complexity of the identification scheme and the cumbersome (re)activation process resulted in its limited adoption by service providers and citizens. Inadequacies in the financial model, caused by flaws in the dissemination model (limited take-up by service providers and end-users), impacted the dynamics of the holarchy in the sense that it led to much negotiation between involved parties and eventually to new funding and cost models. The importance attributed by developers of the Bürgerkarte solution to values such as security and the use of advanced technology impacted the features of the innovation and yielded a limited take-up and thus impact of the innovation. The basic legal structure did not substantially affect the dynamics of the holarchy, but did affect the innovation impact. Finally, the involvement of one of the holons in the European policy holarchy formed an incentive to start the eIDM development.

In addition, two capabilities, brokerability and trustability, particularly affected the innovation process. Notable is the central position of one of the holons of the network, who held several key positions in the network (see A in figure 4.3). He was federal CIO, scientific director of A-SIT, advisor at the Social Security Agency, head of the Institute for Applied Information Processing and Communications (IAIK) at the Graz University of Technology and participated in the negotiations for the directive on a common framework for electronic signatures of the European Union. He was one of the best-connected persons of the Bürgerkarte policy holarchy (in terms of number of connections and access to high-level positions) and mediated between the interests of several involved holons, for instance, between his institute IAIK at the Graz University of Technology, A-SIT, the Federal Chancellery, the European Commission and some service providers, such as the Austrian Computer Society (where he chaired a working group) and the Social Security Agency (where he was advisor). The majority of respondents contended that through his strategic position in the holarchy, he was able to significantly influence the innovation process.

According to the majority of respondents, the level of trust between holons has significantly affected the dynamics of the policy holarchy and the innovation process. The ICT Strategy Unit (see B in figure 4.3) can be characterized as a high-trust network. The majority of respondents involved in this unit have stated that the level of interpersonal trust was very high. In addition, several interviews reveal the connection between the level of trust needed and the presence of risks. In particular, the political environment was perceived as being risky. There are several examples where trust was counterbalanced by formal agreements (see normatibility). The interviews also demonstrate that the necessary level of trust depended on the degree to which the interests of involved holons (persons and/or organizations) were dependent on each other.

The case study also illustrates that the capabilities are interrelated. For instance, it shows a relation between brokerability and coordinatibility. The brokers involved in the Bürgerkarte project were able to coordinate resource flows. The CIO responsible for the development of the Bürgerkarte used his ties to coordinate information flows, funding and the involvement of stakeholders. The case also illustrates the relation between trustability and cooperatibility. In situations in which trust was high, cooperatibility was also high. For instance, in the ICT Strategy Unit, trust was very high as well as the willingness of the individual holons to cooperate with each other. Another interrelation revealed by the Bürgerkarte case is between trust and adoptability. In high trust relationships, the ability of holons to acquire novel knowledge from other holons is greater than in situations in which trust is low. In situations in which trust is low, holons deliberately withhold information from others.

4.7 Discussion

(Kim and Roh, 2008; Maloney *et al.*, 1994) argued that the ACF fails to distinguish the importance of different policy actors. To compensate for this limitation, some suggestions have been proposed. For example, (Weible, 2008) proposed introducing a distinction between principal and auxiliary coalition members. (Maloney *et al.*, 1994) suggested distinguishing insiders from outsiders in a coalition. The CaPF follows a different approach and proposes distinguishing the importance of policy actors according to their capabilities. For example, our case study demonstrates that individual A was an important actor in the innovation process by acting as a broker between several involved parties. Although perhaps not as much as in policy making, the notion of capabilities characterizing the importance of actors and firms has a long tradition in the managerial (Teece, 1994) and evolutionary sciences (Nelson and Winter, 1982).

A second criticism directed at the ACF is that it presumes there can be no coalition between actors that do not share deep core and policy core beliefs (Schlager, 1995). However, for example, fascists could coalesce momentarily with liberals for the issue of free speech (Hann, 1995). Also, in governmental agencies and material interest groups, it is doubtful that core beliefs are stable enough to guide policy change and more important than policy interests (Kim and Roh, 2008). Consequently, the ACF fails to explain intra-coalition rifts caused by underlying differences in interests (Schlager and Blomquist, 1996) and heterogeneity of beliefs within coalitions (Weible *et al.*, 2009). The CaPF, on the other hand, abstracts coalition to cooperatibility, isolating it from beliefs (modelability, see section 4.4) or any other mechanism. In doing so, the CaPF can account for cooperative initiatives motivated by any of the other twelve capabilities. See the example provided in section 4.5 of cooperatibility driven by modelability.

Additionally, the ACF does not account for the possibility that a policy domain may be structured by harmonious and stable relationships among participants who do not necessarily share the same core beliefs. For example, the notion of an iron triangle is characterized by regular interaction among a small number of long-term participants (e.g. governmental agency and certain privileged interest groups) operating within a large degree of consensus and closed off from other competing groups and areas of government (Marsh, 1998; Rhodes, 1990). For example, the European Union (EU) encourages long-term coalitions in Portugal among all the political parties independently of their core beliefs to legitimatize an external intervention for economic recovery. Contrary to the ACF, the CaPF predicts stability through other types of relationships rather than core beliefs. For example, an important element for coalition stability might be trust (Lubell, 2007; Coleman, 1988; Granovetter, 1973), which is covered in the CaPF by trustability. (Schneider *et al.*, 2003) argued that the emergence of trust and norms of cooperation (see normatibility in the CaPF) based on repeated interactions can foster collective action in policy communities even in the presence of conflicting values and beliefs.

Fourth, the ACF assumes highly coordinated behavior among the coalition members (Schlager, 1995). Therefore, it simplifies collective action aspects (do not confuse coordination with cooperation, see section 2.3). However, the members of a coalition may not share the same benefits and costs, thus may experience conflicts in deciding on their collective actions (Kim and Roh, 2008). Additionally, coordination may require other pre-conditions such as a set of agreed norms. (Schlager and Blomquist, 1996) stated that "understanding the types of coordination mechanisms that are adopted, how well matched those mechanisms are to the environment in which they are used, and how effectively they bind coalition members together should reveal much about the successes and failures of coalitions. This area has been little studied, but is critical for explaining policy outcomes". Contrary to the ACF which assumes highly coordinated behavior, and therefore does not identify explicitly coordination as a relevant policy issue (see figure 4.1), the CaPF brings coordination challenges explicitly into a policy framework with coordinatibility. Therefore, the relevance of coordination becomes immediately obvious for any practitioner. Additionally, through the remaining 12 capabilities, the CaPF provides a clear way to study effects upon coordinatibility (e.g. the effect of norms/normatibility).

Fifth, the German sociologist Georg Simmel and French anthropologist Claude Lévi-Strauss suggested that social processes are not the result of central steering or some kind of pre-stabilized harmony, but emerge through the purposeful interactions of individual actors (Kenis, 1991). The ACF, however, lacks a basis for purposeful or strategic behavior, presuming that individuals act naively on the basis of their beliefs (Schlager and Blomquist, 1996). Thus, it provides a limited account of the various behaviors that exist, such as those of legislators (Mayhew, 1974), bureaucrats (Niskanen, 1971), lobbyists (Salisbury, 1986) and entrepreneurs (Kingdon, 1995). Contrary, the 13 capabilities identified in the CaPF provide a much richer basis on which to distinguish the behavior of policy actors. For example, creatibility provides a very explicit definition of the creative side of policy entrepreneurs, defined as "highly motivated individuals or small teams [that] draw attention to policy problems, present innovative policy solutions, build coalitions of supporters, and secure legislative action" (Kingdon, 1995). Thus, the CaPF allows for an increased level of heterogeneity among policy actors (Szarka, 2010).

Finally, the ACF focuses on coalitions and policy subsystems as the relevant units of analysis. A coalition consists of policy actors from private sectors, as well as governmental organizations that share a set of normative and causal beliefs, and engage in a nontrivial degree of coordinated activity over time. A policy subsystem is a group of actors from different institutions who follow and seek to influence governmental policy decisions in a policy area. Policy subsystems include a substantive issue and specialized policy participants usually within a geographic boundary. Despite the significance of the levels of coalitions and policy subsystems, other levels of analysis should not be excluded (Kim and Roh, 2008). For example, other authors have proposed other levels of analysis, such as policy networks among policy actors (Knoke, 1998; Jordan, 1990), sub-governments (Freeman, 1965), policy communities (Rhodes, 1985), issue networks (Heclo, 1978), individual actors (Blom-Hansen, 1997) and iron triangles (Marsh, 1998; Rhodes, 1990). The concepts of holon and holarchy used in the CaPF are more generic than the ones used in the ACF. Consequently, they cover any other possible units of policy analysis considered, such as the ones mentioned previously. The second advantage of replacing coalition by holarchy is the ability to cover relationships between policy holons that are not necessarily driven by shared cored beliefs, as it happens with the concept of coalition as defined by the ACF.

4.8 Conclusions

In this chapter, we introduced and discussed a new framework, labeled Capability-aware Policy Framework (CaPF), which has potential to analyze policy making and influence policy changes. The CaPF was derived by integrating the ACF with the Holonic Framework (HF), a framework introduced in chapter 2 to account for the value of Digital Information Networks (DINs). The applicability of the HF to the policy domain is a result of its *evolutionary economic* premises, which are coherent with the *procedural rationality* model of the individual present in, for example, the ACF. The evolutionary economic approach is concerned with the study of procedures or intermediate processes that transform an economy.

The importance of information processes is well recognized in the policy domain.

Nonetheless, our work shows that studying the value of DINs can lead to important insights for the policy domain. This counts in particular for the observation, capturing and measurement of information processes, which are well supported by IT nowadays. Using analogies and congruences as provided by holarchies then aids the translation of the results towards the policy domain. We have demonstrate the validity of this option in two ways. First, we showed that the CaPF can account for relevant policy premises already accounted for in the ACF. Second, we demonstrated the conceptual value of the CaPF in light of six criticisms previously directed at the ACF. Although policy-network approaches such as the ACF as well as the CaPF have been subject to criticisms in general (see (Kim and Roh, 2008) for a discussion), it is out of the scope of this chapter to compare the CaPF with non policy-network approaches. Such comparison is interesting matter for future work.

The CaPF relies upon the concept of a *policy holarchy* to refer to a hierarchy of policy actors, with each actor bound to other actors in other planes in certain ways and independent in other ways. Using terms from the ACF, a policy holarchy is comparable to a policy subsystem. Additionally, the CaPF relies upon the concept of a *policy holon* to refer to a policy holarchy that behaves at a high level of autonomy and self-organization. Examples are the ACF concept of coalition and policy actors, such as entrepreneurs and politicians. We identified the conceptual advantage of using a policy holarchy/holon instead of the ACF concepts of policy subsystem/coalition.

From within a policy holarchy, capabilities are the drivers for policy change in the CaPF. The CaPF includes a list of 13 capabilities, previously identified in the HF. Capabilities are applicable to multiple levels of a policy holarchy. Moreover, the capabilities are fundamentally different, but might influence each other, including at different levels. From outside a policy holarchy, policy changes in the way as dictated in the ACF.

We then illustrated the practical value of the CaPF with a case study on the development and implementation of an electronic identification management system in Austria (Huijboom, 2010). The application of the model illustrates empirical observation of the concepts described in the CaPF and how the framework can help to extract policy implications. Additionally, our case study illustrated interrelatedness between some of the capabilities. On the one hand, the CaPF seems more abstract than the ACF: it introduces new concepts such as policy holarchy and policy holon. On the other hand, the CaPF is more specific than the ACF, because it advances several concepts that are not identified in the ACF. Regarding operationalization of the framework, CaPF concepts such as coordinatibility and selectibility seem to have comparable implementation difficulties as the ACF concepts *policy beliefs* or *re-*

sources. Overall, we estimate both frameworks to have comparable empirical skills.

The CaPF advances several concepts that are probably unfamiliar to policy researchers. Naturally, this raises difficulties at the first contact with the framework, implying a period of adaptation, further conceptual strengthening, perhaps including the relabeling of some concepts or even breaking up concepts to make them more realistic. In this chapter, we have demonstrated that, from a theoretical perspective, future efforts in developing this framework are expected to pay off. (Nowlin, 2011; Schlager, 2007) mentioned the importance of merging various theories and frameworks into a unified framework of the policy process. We hope that the CaPF might provide some groundwork for this scientific endeavor. Building upon a very fundamental level, we have shown that the CaPF captures elements from various conceptual directions seen as relevant for policy making: institutionalism, policy entrepreneurship, multiple streams theory, procedural rationality, entropy, capability theories, evolutionary theories, resource-based approaches, behavioral theories, iron triangles, social construction, punctuated equilibrium and advocacy systems, among others.

Generally speaking, policy network approaches are expected to be capable to predict the influence of capabilities in certain segments of the policy process. Nevertheless, doubts remain as to whether those specific predictions can account for the final outcome of the total policy process. Additionally, the integration of the ACF with the HF enables the CaPF to account for the principles of processes involved in policy making, i.e. the capabilities. Principles regarding the status of a policy holarchy are not identified in the CaPF. This is left for future work. Future work could also advance operationalization of the CaPF and provide further investigation of the interrelatedness of the capabilities.

Chapter 5

Exploring biological evolution through the value of digital information networks

Abstract: The Modern Synthesis (MS) is the current paradigm for biological evolution. However, the MS is under scrutiny by evolutionary biologists. For example, the MS does not provide an explicit account for horizontal gene transfer. In this chapter, we first motivate the use of the Holonic Framework (HF) to conceptualize biological evolution. Secondly, we discuss HF's added value in the light of six criticisms pointed to the MS in the current literature. This chapter thus underpins the value of digital information networks for biological evolution.

This chapter was matter of publication in (Madureira *et al.*, 2011d).

5.1 Introduction

The Origin of Species introduced the new idea of natural selection (Darwin, 1859). Darwin observed that all organisms, even the most slowly reproducing ones, produce more offspring than can actually survive. Those individuals that are the fittest are most likely to survive and reproduce. Given that subsequent generations inherit this capability to be fitter, average fitness in the population tends to increase. However, there was a gap in the Darwinian theory: the source of variability among species.

The gap was filled by Gregor Mendel's work (Druery and Bateson, 1901). From the Mendelian perspective, the presumed loss of variability occurring with blending inheritance does not happen, but it is conserved by mutations.

In some ways, the Darwinian-Mendelian theory was still unsatisfactory. The issue was the need to reconcile a theory of gradual evolution (Darwinism) with the saltationism that emerged from the new discipline of genetics born with the work of Mendel (Pigliucci, 2007). (Fisher, 1918) provided an answer, showing correlations between relatives on the supposition of Mendelian inheritance. Subsequent work consolidated to what has become known as the Modern Synthesis (MS), a list of consensus statements that form the core of the synthetic theory of biological evolution (Reif *et al.*, 2000). The current MS is essentially provided in the content of six books (Stebbins, 1950; Rensche, 1947; Simpson, 1944; Huxley, 1942; Mayr, 1942; Dobzhansky, 1937). Others have made significant contributions as well (Junker, 2004; Junker and Hofeld, 2001; Reif *et al.*, 2000). The terms *evolutionary synthesis* and *synthetic theory* originate from the title of Julian Huxley's book in 1942: *Evolution: the Modern Synthesis*.

The MS is however under scrutiny by modern evolutionary biologists (Grant, 2010). Many authors have emphasized the need to expand (Carroll, 2000), extend (Pigliucci, 2007) or replace (Nazarov, 2007) the MS. In particular, the completeness of the MS is debated. (Delisle, 2009) stated that "evolutionary biology is still in a pre-paradigmatic state of development even today". One of the roots of this statement is the well-proven phenomenon of horizontal gene transfer between organisms, rather than vertically from their parents. Horizontal gene transfer is not explicitly accounted for in the MS, but its consequences are profound and may alter significantly the biological evolutionary process itself (Buchanan, 2010). The conclusion seems to be that biological evolution is not only guided by natural selection and mutation. In this chapter, we show that the HF provides a framework on which the MS can be extended as needed, based on the universal observation that evolution is partially a result of information transfer.

This chapter is organized as follows: in section 5.2, we describe the fundaments of the MS; in section 5.3, we describe six main criticisms that have been pointed to the MS; in section 5.4, we motivate the use of the theory on the value of Digital Information Networks (DINs) to study biological evolution; in section 5.5, we discuss the HF in the light of the six criticisms pointed to the MS in section 5.3 and we identify the main limitations of the HF. Finally, section 5.6 draws the conclusions of our chapter and future research directions.

5.2 Modern Synthesis (MS)

The basic principles of the MS are the following (Kutschera and Niklas, 2004):

1. The units of evolution are populations of organisms and not types of organisms (species). A population is defined as a group of organisms of a particular species that inhabits a particular area. (Mayr, 1942) developed the concept of biological species, which has been later defined as an interbreeding community of populations that is reproductively isolated from other such communities. Natural selection acts on traits within populations that are beneficial in the particular geographical area.

2. In biology, the phenotype is the combination of the organism's morphology and behavioral repertoire that determines the way in which the organism interacts with the environment. The genotype is the genetic information that codes for the way in which the phenotype develops. Thus, the genotype both enables and constrains the organism's interaction with the environment. Genetic and phenotypic variability in plant and animal populations is brought about by genetic recombination (reshuffling of chromosome segments) resulting from sexual reproduction and random mutations along the parent-offspring sequence. Mutations are not random in the absolute sense (e.g. they are constrained by physical and chemical rules) (Crow, 2003). However, from the perspective of their usefulness for evolution, they are the source for random genetic information (Stebbins and Ayala, 1981).

3. Natural selection is the most important force that shapes the course of phenotypic evolution. In changing environments, natural selection is especially important because it steers the population mean towards a novel phenotype better adapted to the changing environment. In small populations, natural selection might cause significant loss of genes from the gene pool.

4. Speciation can be defined as a step of the evolutionary process at which forms become segregated into two or more separate arrays that are physiologically incapable of interbreeding (Dobzhansky, 1937).

5. Evolutionary transitions in populations are usually gradual, i.e. new species evolve from pre-existing varieties by slow processes and maintain at each stage their specific adaptation. However, there are some exceptions. For example, in cichlid fishes (Meyer, 1993; Meyer *et al.*, 1990), polypoid angiosperms (Soltis

and Soltis, 2000) and southern African ice plants (Klak *et al.*, 2004), reproductive isolation and the resulting origin of novel species can occur relatively faster (within a few hundred or thousand generations).

6. Macro-evolution, defined as phylogenetic development above the level of species, is a gradual step-by-step process that is nothing but an extrapolation of micro-evolution (origin of races, varieties and species).

Resuming, in the MS, evolution is defined as the change in the frequencies of genes in a population of individuals from one generation to the next (Pagel, 2002) and (Mayr, 1998): 1) gradual evolution can be explained in terms of small genetic changes and recombination, and the ordering of this genetic variation by natural selection; and 2) the observed evolutionary phenomena, particularly macro-evolutionary processes and speciation, can be explained in a manner that is consistent with the known genetic mechanisms.

5.3 Criticisms to the MS

(Mayr, 1961) pointed out that Darwinism is about explaining behavior and distinguished two forms of causation: ultimate and proximate. Ultimate causation assesses *why* a certain behavior originated and is the form of causation addressed by the MS. Proximate causation explains the behavior in terms of *how* the behavior occurs. For example, how sex is determined in reptiles through environmental cues. By providing an ultimate and general explanation for evolution, the MS becomes too abstract failing to identify explicitly more proximate, and other specific and essential aspects which are relevant for biological evolution (Vromen, 2007).

The first example of one of these aspects is social behavior which, based upon the MS, was explained by (Hamilton, 1964) as follows: "for a gene to receive positive selection it is not necessarily enough that it should increase the fitness of its bearer above the average if this tends to be done at the heavy expense of related individuals, because relatives, on account of their common ancestry, tend to carry replicas of the same gene: and conversely that a gene may receive positive selection even though disadvantageous to its bearers if it causes them to confer sufficiently large advantages on relatives" (known as *inclusive fitness* theory). However, (Hamilton, 1972)'s theory implies that altruism is limited to kin or reciprocating partners (Kutschera and Niklas, 2004). Various experiments contradicted this theory: altruism towards unrelated group members in humans (Bowles, 2006; Fehr and Fischbacher, 2003), potentially altruistic behaviors from different population in chimpanzees (Boesch *et al.*, 2010), basic forms of helping from chimpanzees towards humans in the absence of rewarding (Warneken *et al.*, 2007), cases of amoebas that die on behalf of amoebas from other species (Jack *et al.*, 2008), etc. Therefore, on the one hand, altruism is often hard to explain in the light of the MS. On the other hand, altruism is an important evolutionary mechanism that due to its importance should come explicitly in a biological evolutionary framework to better assist practitioners.

The second example is cognition. A widespread accusation against Darwinism is that it accounts evolution as blind (Hodgson and Knudsen, 2006). In some sense evolution is blind: particular outcomes are not necessarily predictable in advance, thus, design emerges without a seeing designer (Vanberg, 2004). In another sense, evolution is only partially blind: any effective capacity for foresight or prescience must be based on tried and tested knowledge, otherwise there are no grounds to presume its effectiveness (Campbell, 1987). Cognition is at least of some importance, both in the human and non-human world. (Hinde, 1959) called attention to the variety of ways that the choices of animals could influence the subsequent course of evolution; and (Bateson, 2004) defended that evolutionary rate should be tied into to a measure of brain size. Although very relevant for biological evolution, cognition is not explicitly captured in the MS.

The MS also fails to account for self-organization in biological evolution. The self-organizational approach tries to capture structural change in a system as an irreversible and uncertain process that operates in different ways at all levels of structural complexity (Foster, 1997). An example of self-organization is the flocking behavior (e.g. flocks by birds and schools of fish). Several authors stressed that self-organizing complex systems' dynamics might provide the conceptual framework within which Darwinism continues to evolve (Weber and Depew, 1996; Kauffman, 1993). Self-organization provides a possible explanation for the theory of *punctuated equilibrium*, which proposes that macro-evolution (the evolution and branching of lineages at and above the species level) is not gradual, but is concentrated in evolutionary time around bursts of speciation (Gould and Eldredge, 1977). (Gould, 1989) explained this phenomenon by sudden reorganizations of largely self-organizing genetic networks, which then remain locked in place for considerable periods of time.

The fourth example of an aspect relevant for biological evolution that is not accounted explicitly by the MS is horizontal gene transfer, rather than vertically from their parents. The first hints on horizontal gene transfer came in the 1950s, when different species of bacteria around the world gained resistance to antibiotics surprisingly fast. Biologists hypothesized that such resistance spread too fast to have happened according to the MS principles, and it seemed to have happened directly from one specie to another. (Arnold *et al.*, 2008) described evidence of horizontal transfer in bacteria, fungi, plants and animals; (Pace *et al.*, 2008) identified horizontal transfer in rodents (rat/mouse), bushbaby (prosimian primate), little brown bat, tenrec, opossum and two non-mammalian tetrapods (anole lizard and African clawed frog); (Kunin *et al.*, 2005) expressed the idea that horizontal transfer means that the evolutionary structure is no longer tree-like, as sketched by Darwin, but more like a network; and (Goldenfeld and Woese, 2007) stated that the basic concept of an organism as an isolated biological entity with a unique genetic code makes little sense in the bacterial world, as the genetic material is readily available in an environment for an individual within it.

Due to its abstractness, the MS is hard to operationalize. Operationalization refers to the process of linking the conceptual definitions to a specific set of measurement techniques or procedures (Bridgman, 1927). In the MS, (natural selection by) the environment is seen as an observable input changing the uncertainty regarding the evolution of the population. However, the required delimitation and characterization of the biological environment is, in general, very difficult. Additionally, the logical value of natural selection is limited, and some even have considered it a tautology: "(natural selection) was described, in the last two editions of On the Origin of Species, as the principle of the survival of the fittest: 'Only the fittest survive' (to reproduce creatures like themselves). If the fittest are defined as those who survive to reproduce their kind, then Darwinism becomes an uninteresting tautology: Who survive? Those who are most fit. Who are most fit? Those who survive" (Campbell and Robert, 2005). Symptomatic of the limited empirical power of the MS is the fact that no sure marks of natural selection still exist (Dennett, 1995).

5.4 A different approach: the value of DINs

In light of increasing doubts raised about the MS, (Brooks and Wiley, 1984) put forward a research agenda to unify various efforts in biological evolution to "expand, extend or finish the job begun by Darwin". Their conceptual theme lies in the use of energy in maintaining and transforming ordered states of matter. Using the concepts of information and entropy as a common phenomenology for a number of organizing processes in biological systems, their core hypothesis is that biological evolution is an entropic process. By expressing evolution in terms of entropy, they provided a conceptual link between biological processes and physical laws showing that biological processes are not governed by laws specific to biology.

There are two classical definitions of entropy: the thermodynamic one (Clausius, 1850) and the statistical one (Boltzmann, 1870). The thermodynamic one is the fundamental definition of entropy, while the statistical one provides a deeper understanding of its nature. In the statistical definition, the entropy is a measure of the number of possible microscopic configurations of the individual atoms or molecules of the system which would give rise to the observed macroscopic state of the system (Boltzmann, 1870). Thus, entropy can be seen as a measure of randomness in a system (Sethna, 2006).

Organisms evolve by moving from states of high entropy to low entropy. The second law of thermodynamics states that over time the entropy of an isolated system which is not in equilibrium will tend to increase, approaching a maximum value at equilibrium (Atkins, 1984). Stated otherwise, concentrated energy disperses over time, and consequently less concentrated energy is available to do useful work (differences in temperature, pressure and density even out, and therefore randomness increases). Other formulations of the law exist (Dunning-Davies, 1969). Thus, only with a steady inflow of energy, the organism can keep a separation from the environment (e.g. skin), and ordered insides distinct from disordered outsides (Bunn, 2009; Beinhocker, 2006; Collier, 1986).

Although the contribution of energy to biological evolution is important, (Brooks and Wiley, 1984) argued that it has a secondary role because free energy is in abundant supply (e.g. solar energy). From their perspective, the way in which organisms are organized, allowing them to use the available energy, is more important than the availability of energy itself. This suggests that organisms are best understood in terms of their information content (see also (Collier, 1986)). Thus, biological entities maintain structural and functional integrity by the storage and transmission of information (Brooks *et al.*, 1989).

(Kallinikos, 2006) attempted to understand the complex character of technologically sustained information processes. He drew some important conclusions about the nature of information: it is self-referential and non-foundational. Self-referential means that information has value if it adds a difference to what is already known. (Borgman, 1999) stated ”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 means that informational differences emerge through comparison of two or more objects or items. They are not singular, but are relational entities. Due to its differential nature, information is hard to measure and conceptualize further. Nevertheless, the body of literature on the value of DINs and other IT has shown great progress regarding this issue. A significant amount of theoretical and empirical work has been produced to address the well-known paradox ”you can see the computer age everywhere but in the productivity statistics" (Solow, 1987).

The alternative (or rather a significant extension) to the MS proposed in this chapter is a framework, labeled HF, which was suggested in chapter 2 for understanding, modeling and predicting the value of DINs. The HF describes a set of simple and fundamental concepts which identify how information flows are processed and from which evolutionary value is generated (e.g. economic value). Irrespective of the technical aspects involved in the coding, transmission and decoding of information, digital networks allow humans to exchange information, just like any other transport, organizational, physical, biological, economical and political network. At this point, we therefore hypothesize that the HF is useful to explain biological evolution due to its conceptual value within the body of literature of DINs (see chapter 2 for a discussion between the HF and two other reference frameworks (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004)).

5.5 Discussion

In section 5.3, we pointed abstractness as the most obvious limitation of the MS. Recurring to (Mayr, 1961), two forms of causation have been described: *ultimate* explains why certain behaviors emerge and *proximate* explains behaviors in terms of how they occur. The MS provides an ultimate explanation for biological evolution: behaviors emerge to adapt populations to their environments. The HF, on the other hand, provides a more proximate explanation for biological evolution through its set of capabilities. Consequently, the HF becomes less abstract than the MS, and therefore more useful for practitioners. Due to its more proximate causation, the HF is capable to account for four aspects relevant for biological evolution described in section 5.3, which are not explicitly accounted for by the MS: altruism, cognition, self-organization and horizontal gene transfer.

The first aspect, altruism, is only explainable in the light of the MS to favor the genetic selection of kin or reciprocating partners. However, various experiments have shown cooperation among individuals apparently without genetic motives. Additionally, although cooperation is a relevant biological evolutionary mechanism, it is not identified explicitly by the MS, and therefore could not be recognized directly by a practitioner as a mechanism worthwhile to be considered. The HF, on the other hand, identifies explicitly and individually cooperatibility. Without questioning the emergence of cooperatibility, the HF presumes it to be a mechanism which leads to evolution in biology, and therefore a mechanism that should be considered by practitioners interested in empirically studying biological evolution.

Identical line of reasoning could be applied to cognition which is identified in the HF with three capabilities: perceptability, modelability and decisability. These three capabilities imply that the HF presumes the existence of agency in biological evolution, and therefore also self-organization. The holon theory used by the HF actually stems from the attempt of (Koestler, 1967) to create a model for self-organization in biological systems (Ulieru *et al.*, 2002). Holarchies are nested hierarchies of self-organizing structures, the holons. The term *holon* reflects the tendency of holons to act as autonomous entities and yet cooperating to form apparently self-organizing hierarchies of sub-systems, such as the cell, the tissues and the organs in living species (Christensen, 1994). By accounting explicitly for self-organization, the HF is capable to account for the possibility that the evolution and branching of lineages at (and above) the species level is not gradual, but is concentrated in evolutionary time around bursts of speciation (*punctuated equilibrium* theory (Gould, 1989)).

Finally, in the light of the HF, horizontal gene transfer can be seen as an instance of adoptability at the level of organisms. And, by providing a more proximate account for biological evolution, the HF has also empirical power (see chapter 3).

Despite the conceptual advantages relatively to the MS, the HF has two important limitations. The first is a reductionist view of evolution just to information, neglecting for example the role of energy. Approaches neglecting energy and focusing on information have been questioned previously. For example, (Weber and Depew, 1996) stated: "it seems to us a bit hasty, however, to move from the acknowledged fact that the notion of fitness cannot be reduced to the uniform currency of energetics to the conclusion that energy flow is irrelevant to natural selection, or that the requirements of energy flow do not themselves constitute components of fitness". Not only energy and information play a role in biological evolution, but form (or matter) should be accounted for as well. For example, the drifts of continents certainly impacted biological evolution, and it is not an evolutionary factor recognized by the HF. (Pigliucci, 2007) stated: "evolutionary theory has shifted from a theory of form to a theory of genes [or information], and that it is now in need again of a comprehensive and updated theory of form" (text in brackets was added). The second limitation of the HF is the level of formalization of the capabilities. The definitions of the capabilities are mostly based upon previous multiple and independently developed work. However, capabilities are essentially information processes, and therefore their definitions should be derived from a unique and fundamental theory of information.

5.6 Conclusions and future work

Paradigms work well for periods of theoretical stability, but from time to time enter into a crisis arising from new discoveries that are not easily explainable within the current paradigm (Kuhn, 1970). The MS never actually went through a paradigmatic shift, relying on augmentations without overthrowing any of the previous foundations (Gould, 2002). The HF may contribute to the development of a new paradigm for biological evolution. The reasons are two-fold: 1) the HF is not based upon the MS or its foundations: Darwinism and neo-Darwinism (Pigliucci, 2007); and 2) the HF accounts for various aspects in biological evolution not explicitly accounted for by the MS. We discussed the conceptual added-value of the HF regarding six criticisms pointed to the MS: abstractness, altruism, cognition, self-organization, horizontal gene transfer and empirical power. Moreover, we are confident that the HF is capable to address other relevant mechanisms related with biological evolution. For example, we invite theorists to discuss the HF and the MS regarding the following aspects:

1. *Lamarckism*. Lamarckism refers to the possibility of (genotypic) inheritance of acquired (phenotypic) characters at the level of organisms. Immediate objections to the theory arose. For example, if every characteristic was inherited, what would prevent the inheritance of injuries or impairments? The MS rejects lamarckism mainly due to the work of Weismann, who demonstrated that changes in the phenotype of an organism during its lifetime, do not affect the genetic material that is passed on to its offspring. However, interest in lamarckism has recently increased, as several studies in the field of epigenetics (study of inherited changes in phenotype or gene expression caused by mechanisms other than changes in the underlying Deoxyribonucleic acid (DNA) sequence) have highlighted the possible inheritance of behavioral traits acquired by the previous generation. For example, (Jablonka, 2009) provided an extensive list of examples of epigenetic inheritance ranging from worms (*caenorhabditis elegans*) to *homo sapiens*.

2. *Co-evolution*. Co-evolution refers to the idea that the different units and levels are not independently evolving, but rather influence each other. Co-evolution is present in the MS with the distinction between genotype and phenotype and their causal feedback loop. However, co-evolution happens through other feedback loops as well. (Gual and Norgaard, 2010) stated: "once homo sapiens appeared and spread on Earth as a result of natural selection, the development of cultural systems came to produce an interacting complex of social institu-

tions and technologies. From the industrial revolution, the fast development of market in western (and eastern) economies is literally affecting biological processes and reshaping at great speed the biophysical environment in which they exist" (co-evolution between selection and culture).

3. *Variability*. The research domain called *evo-devo-eco* tries to explain why wild-life populations that harbor vast amounts of hidden genetic variation, only phenotypically express them in particular environments or genetic backgrounds (Gibson and Dworkin, 2004; Gibson *et al.*, 1999). The notion of variability was proposed to account for this phenomenon and defined as the capacity to respond to genetic and environmental change (Flatt, 2005). Variability manifests itself through two phenomenons: phenotypic plasticity and environmental canalization. Canalization is the reduced sensitivity of a phenotype to changes or perturbations in the underlying genetic and non-genetic factors that determine its expression (Meiklejohn and Hartl, 2002; de Visser *et al.*, 2003). Canalization is usually manifested through its equivalent opposite: phenotypic plasticity. Phenotypic plasticity is the sensitivity of the phenotype produced by a single genotype to variation in the environment (Roff, 1997; Stearns, 1989).

4. *Modularity*. A common characteristic, in both natural and human products, is their modular structure (Hartwell *et al.*, 1999). Modular architectures that exhibit functional separation are more robust and flexible to design and adaptations. (Lipson *et al.*, 2002) stated: "modularity creates a separation that reduces the amount of coupling between internal and external changes, allowing evolution to rearrange inputs to modules without changing their intrinsic behaviors and so to reuse modules as high-level building blocks". (Bonner, 1988) elaborated on the evolutionary implications of modularity, which he calls *gene nets*. Examples of modularity in nature are the evolution of metazoan animals from protozoans colonies, where all the cells are from the same species (Buss, 1987).

Chapter 6

A holonic framework to understand and apply information processes in evolutionary economics

Abstract: Economists unsatisfied with the basic neoclassical assumptions of rational economic actors and economic evolution towards equilibrium states founded the *evolutionary economic* approach. Their goal was to provide more realistic assumptions regarding economic agents and their institutional environments. The Modern Synthesis (MS), the current conceptual paradigm for biological evolution, was used as a source of inspiration for conceptual development. Along the biologically inspired line of thought, the Generalized Darwinism (GD) initiative relies on the abstraction of the MS to provide a unifying conceptual framework for evolutionary economics. Despite its merits, GD has been subject to criticism, particularly regarding its level of abstractness and lack of an explicit account of the social and cognitive processes that drive economic evolution. The goal of this chapter is to introduce and explore an alternative conceptual framework for evolutionary economics: the Holonic Framework (HF). Contrary to GD, the HF is not biologically inspired, but builds upon the body of literature on the value of Digital Information Networks (DINs). We discuss the analytical strengths and limitations of the HF relative to GD in light of several aspects pertinent to evolutionary economics (e.g. self-organization, culture, cognition, cooperation). This chapter underpins the value of DINs for economic evolution.

This chapter was matter of publication in (Madureira *et al.*, 2011c).

6.1 Introduction

Neoclassical economic theory continues to dominate economic thinking based on Walrasian general equilibrium theory devised in the 19th century. The general equilibrium approach produces an aggregated representation of the economy with two main assumptions (Tesfatsion, 2005): 1) rational behavior of economic actors (e.g. firms as cost minimizers and households as utility maximizers) and their constraints (e.g. technological processes); and 2) a market equilibrium solution, in the sense that for each commodity and factor, their prices always adjust to a level such that demands added across all the actors do not exceed total supplies. Modern developments, such as the introduction of information asymmetries, did not involve alteration of the neoclassical theory's fundamental foundations, but, instead, resulted in more complex outcomes (e.g. multiple equilibria) (Foster, 1997).

Although with little initial impact in mainstream economics, the basic assumptions in the neoclassical theory of rationality and equilibrium have been questioned. For example, (Schumpeter, 1949) already questioned the economy being in a state of equilibrium: ”development (...) is a distinct phenomenon, entirely foreign to what may be observed in the circular flow or in the tendency towards equilibrium. It is spontaneous and discontinuous change in the channels of the flow, disturbance of equilibrium, which forever alters and displaces the equilibrium state previously existing". Economists interested in a conceptualization of economic evolution with more realistic assumptions regarding economic agents and their institutional environments founded the *evolutionary economic* approach (Sober, 1993; Boulding, 1991). Several recent survey articles emphasize that an agreement on basic aspects of evolutionary economics is still missing (Rahmeyer, 2010; Witt, 2008; Fagerberg, 2003). Nevertheless, there is an almost common consensus on structuring the economic process inductively rather than towards an equilibrium, with the behavior of the collective agents characterized by bounded rationality (Dosi and Marengo, 2007; Metcalfe, 1995; Silverberg and Verspagen, 1995). Institutionalist economists focused on the impact of cultural evolution and the exercise of power (Hodgson, 1998); neo-Austrians emphasized creativity in the presence of uncertainty (White, 2008); post-Keynesians questioned time-reversibility present in the equilibrium setting (Arestis, 1996); neo-Schumpeterians investigated innovation processes and their inherent non-linearity (Nooteboom, 2007; Heertje, 1994); (Boulding, 1991), concerned with the profound indeterminacy of evolutionary processes, questioned the applicability of the experimental method in evolutionary economics; and (Foster, 1997) advocated the use of the self-organization approach for evolutionary economics. Additionally, there is a growing body of literature on the evolution of business organizations (Gavetti and Levinthal, 2000; Romanelli, 1991; Nelson and Winter, 1982). All these strands of evolutionary thought provide realistic insights into the process of economic change. However, despite considerable overlaps between these strands, a widely accepted unifying analytical framework is still lacking within which each stream can be placed as a special case.

With an apparent absence of alternatives, evolutionary economists use the Modern Synthesis (MS), the current conceptual framework for biological evolution, as a useful metaphor and source of analogies for the development of theories in economics. As early as the 19th century, (Bagehot, 1872; Ritchie, 1896; Veblen, 1899) and others proposed that the principle of natural selection could help to explain the survival of groups, businesses, nations and even languages. For decades, the refinements in neoclassical economics obscured the biological analogy as a valid alternative for mainstream economics (Schumpeter, 1954; Penrose, 1952). However, there has been a surge of interest recently into how insights from biological evolution can strengthen the conceptual foundations of evolutionary economics (Vromen, 2007; Witt, 2006; Dopfer, 2004; Klaes, 2004; Witt, 2003b, 1999). Particularly, Generalized Darwinism (GD) has captured large attention. GD abstracts the core biological principles described in the MS of mutation, selection and genetic recombination to provide a unifying meta-analytical framework capable of inspiring, framing and organizing causal explanations for evolutionary economics (Hodgson, 2010; Aldrich *et al.*, 2008; Hodgson and Knudsen, 2006; Dawkins, 1983). However, the usefulness of GD has been widely questioned, particularly its level of abstractness (Vromen, 2007), and its lack of an explicit account of social and cognitive evolutionary processes (Nelson, 2005).

The goal of this chapter is to explore a conceptual framework for evolutionary economics alternative to GD: the Holonic Framework (HF). The HF provides a less abstract, more substantive departure point to study economic evolution. For example, it accounts explicitly for social and cognitive processes lacking in GD. The HF is also relatively easy to operationalize. Therefore, it allows relating of theoretical propositions with empirical data. Furthermore, we show that the HF is capable of accounting explicitly for other aspects considered relevant for evolutionary economics, such as self-organization. The HF does not build upon biological sciences, but on social sciences, particularly the body of literature on the value of Digital Information Networks (DINs). In this regard, the HF is aligned with the pleas of (Schumpeter,

1954) to forget biological reductionism, and instead examine economics in its own unique social, psychological and political context.

This chapter is organized as follows. In the next section, we summarize the initiative GD. Here we assume that GD is the most advanced unifying analytical framework for evolutionary economics to date, and thus represents the state-of-the-art reference framework. Section 6.2 ends with an overview of the criticisms directed at GD which serve as our motivation to search for an alternative framework. In section 6.3, we use the body of literature on the value of DINs as a departure point to find an alternative to GD. In section 6.4, we discuss the strengths and limitations of the HF relative to GD. After summarizing our conclusions in section 6.5, section 6.6 describes various implications and possible extensions of our work.

6.2 The initiative Generalized Darwinism (GD)

The appeal of evolution as a unifying theory for various sciences (Alexander, 1975) led researchers to apply the basic tenets of the MS (see chapter 5) as a conceptual ground to explain evolution in other scientific fields. A prominent and recent example is the GD initiative, which proposes a radical abstraction of the MS from its biological evolutionary details so that *selection*, *retention* and *variation*, regardless of the very different ways in which they operate in different areas of application, provide an overall meta-theoretical framework universally applicable to various areas, including evolutionary economics (Hodgson, 2010; Aldrich *et al.*, 2008; Hodgson and Knudsen, 2006; Dawkins, 1983).

The motivation of the proponents of GD was "to derive a powerful over-arching theoretical framework in which theorists can develop auxiliary, domain-specific explanations" (Aldrich *et al.*, 2008). Darwin himself recognized the potential broader application of his core ideas upon the elements of language, and that natural selection favored tribal groups with moral and other propensities that served the common good (Darwin, 1859). Writers such as (Keller, 1915; Veblen, 1899; Ritchie, 1896; Bagehot, 1872) have argued that natural selection could explain the survival not only of individuals, but also of business firms, nations and other social institutions.

(Stoelhorst, 2008; Stoelhorst and Huizing, 2005) described the explanatory logic of GD as follows (see figure 6.1). Open complex systems consist of different components and need resources from the environment to function. To secure the necessary resources, the system needs to interact with the environment. This interaction is done by what is usually called behavior: the act of doing something to have an effect upon the outside world. The system is subjected to selection pressure because the required resources are scarce. Information regarding the way of interacting with the environment (behavior) is fed back into the system and coded in the codex of the system (an abstraction of the biological genotype) (Wilkins, 2001). Thus, behaviors that were more successful in the past are more likely to be repeated in the future. Additionally, random changes in behaviors are more likely to negatively affect the functional integrity of the system than to improve its performance. However, in the long run, there is a need to vary behaviors to adapt to changing environmental conditions. Such variation can occur through changes in the system codex or by changing behaviors.

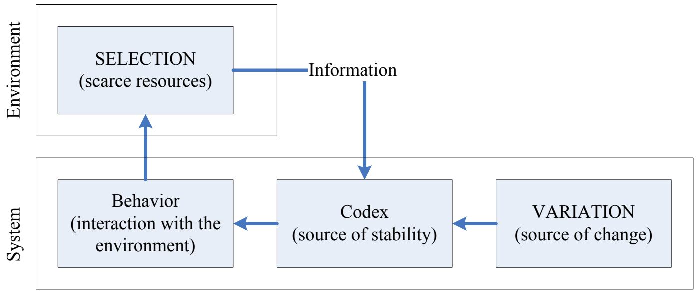


Figure 6.1: A framework for Generalized Darwinism (GD) (Stoelhorst, 2008; Stoelhorst and Huizing, 2005)

The mechanism of selection is an abstraction of Darwin's natural selection process, which is essentially a way of reducing the variety in a set of entities as a function of the characteristics of these entities (Knudsen, 2004, 2002). Selection operates upon multiple and different entities, and therefore a mechanism of variation is necessary that abstracts genetic changes and recombination as a mechanism that increases variety in the characteristics of the entities in the set (Stoelhorst, 2008). The mechanism of retention serves the purpose of reproduction in the biological realm, which is the maintenance of the characteristics that have been favored by selection in the set of entities.

Several streams of research concerned with change in populations of firms have drawn inspiration from Darwinistic ideas, although not necessarily explicitly or addressing all three mechanisms described by GD: selection, retention and variation. For instance, population ecology focuses on the selection mechanism (Hannan and Freeman, 1977); (Nelson and Winter, 1982) focused on variation and retention of firms' competences as an analogue to biological genes. (Porter, 2008, 2004, 1985) emphasized the forces that select the most competitive firms. Contingency theory investigates organizational dependence on contingencies set by the environment

(Mintzberg, 1979). (Burgelman, 1991; Campbell, 1994) investigated selection within firms rather than between firms.

The importance attributed to GD as an explanatory structure sufficiently general to apply across various domains has often been stressed (Stoelhorst, 2008; Vromen, 2007; Aldrich *et al.*, 2008; Hodgson and Knudsen, 2006). For example, (Stoelhorst and Huizing, 2005) stated ”so far, [GD] is quite simply the only fully fledged specified and logically consistent explanatory structure to account for adaptive fit that we know”. Nevertheless, criticisms to GD exist, and the two main ones are as follows:

1. Its abstractness, which limits its usefulness to elaborate domain-specific evolutionary hypotheses.

2. Its lack of completeness, because the three principles that GD identifies seem not enough to arrive at full-fledged causal theories about the evolution of economic phenomena.

(Stoelhorst, 2008) stated ”the supporters and opponents of generalized Darwinism disagree about two things: if a generalized Darwinism can adequately capture what is general about all evolution, and if a generalized Darwinism would also be able to explain what is essential about evolution in economics”. For example, culture is not explicitly captured by GD, although it is an essential economic mechanism to attenuate the inherent limitations of human cognition, serving as a simplified heuristic to make good enough judgments (Payne *et al.*, 1993). Economic evolution constrained by cultural differences differs sharply from biological evolution (Nelson, 2005). For example, culture itself has a collective property that cannot be simply characterized as the aggregation of the population of traits possessed by individuals.

Because of its abstractness and incompleteness, it is difficult to see how to advance new theory using GD as a departure point. Regarding this aspect, (Vromen, 2007) stated that the various proponents of GD simply assume that only domain-specific auxiliary hypotheses and empirical material have to be added to the three principles and do not question the need for additional principles. We thus can conclude that the potential of GD is still a matter of discussion, and the research program is still in its infancy.

As a matter of fact, the MS, which inspired GD, is under scrutiny by evolutionary biologists as well (Grant, 2010). Many authors have emphasized the need to expand (Carroll, 2000), extend (Pigliucci, 2007) or replace (Nazarov, 2007) the MS. In particular, the completeness of the MS is debated. (Delisle, 2009) stated ”evolutionary biology is still in a pre-paradigmatic state of development even today”. One of the roots of this statement is the well-proven phenomenon of horizontal gene transfer between organisms, rather than vertically from their parents. Horizontal gene transfer is not explicitly accounted for in the MS, but its consequences are profound and may alter significantly the biological evolutionary process itself (Buchanan, 2010). If the MS has limits to its explanatory power in evolutionary biology, then GD may inherently be of limited use in evolutionary economics as well.

6.3 An alternative approach: the value of digital information networks

In light of increasing doubts raised about the MS, (Brooks and Wiley, 1984) put forward a research agenda to unify various efforts in biological evolution to "expand, extend or finish the job begun by Darwin". Their conceptual theme lies in the use of energy in maintaining and transforming ordered states of matter. Using the concepts of information and entropy as a common phenomenology for a number of organizing processes in biological systems, their core hypothesis is that biological evolution is an entropic process. By expressing evolution in terms of entropy, they provided a conceptual link between biological processes and physical laws showing that biological processes are not governed by laws specific to biology.

Entropy can be seen as a measure of randomness in a system. Organisms evolve by moving from states of high entropy to low entropy. The second law of thermodynamics states that over time the entropy of an isolated system that is not in equilibrium will tend to increase, approaching a maximum value at equilibrium. Stated otherwise, concentrated energy disperses over time, and consequently less concentrated energy is available to do useful work. Thus, only with a steady inflow of energy can an organism keep a separation from the environment (e.g. skin) and ordered insides distinct from disordered outsides (Beinhocker, 2006).

The hypothesis that evolution is an entropic process may apply to economics as well. (Georgescu-Roegen, 1999) argued that economic systems must be understood in terms of the second law of thermodynamics (the entropy law). (Foster, 1997) stated that propositions concerning thermodynamics appear to be the correct starting point in developing analytical frameworks within which economic processes can be understood. The reason is twofold: 1) economy as well as biology must obey the same fundamental physical laws; and 2) as described before, evolutionary economics uses biological evolution as an inspiration for its own conceptualization.

Although the contribution of energy to biological evolution is important, (Brooks and Wiley, 1984) argued that it has a secondary role because free energy is in abundant supply (e.g. solar energy). From their perspective, the way in which organisms are organized, allowing them to use the available energy, is more important than the availability of energy. This suggests that organisms are best understood in terms of their information content (see also (Collier, 1986)). Thus, biological entities maintain structural and functional integrity by the storage and transmission of information (Brooks *et al.*, 1989).

Information concepts are widespread in the engineering sciences and started to penetrate the social sciences in the 1980s (Ruth, 1996). In the domain of economics, (Ayres, 1994) characterized the direction of evolution as an accumulation of information, and (Beinhocker, 2006) argued that evolution is caused by processes upon information. In 2001, G. Akerlof, M. Spence, and J. Stiglitz received the Nobel prize for their analyses of markets with asymmetric information. The framework of (Stoelhorst, 2008) for GD, shown in figure 6.1, bases economic evolution on the selection of information about what works and what does not. Common to these research streams is recognition of the fundamental role the concept of information plays in explaining the evolution of economic activity.

(Kallinikos, 2006) attempted to understand the complex character of technologically sustained information processes. He drew some important conclusions about the nature of information: it is self-referential and non-foundational. Self-referential means that information has value if it adds a difference to what is already known. (Borgman, 1999) stated ”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 means that informational differences emerge through comparison of two or more objects or items. They are not singular, but are relational entities. Due to its differential nature, information is hard to measure and conceptualize further. Nevertheless, the body of literature on the value of DINs and other IT has shown great progress regarding this issue. A significant amount of theoretical and empirical work has been produced to address the well-known paradox ”you can see the computer age everywhere but in the productivity statistics” (Solow, 1987).

The alternative to GD proposed in this chapter is a framework, labeled HF, which was suggested in chapter 2 for understanding, modeling and predicting the value of DINs. The HF describes a set of simple and fundamental concepts that describe how information flows are processed and from which evolutionary value is generated (e.g. economic evolutionary value). Our hypothesis is that the HF is not only applicable to DINs, but to other information networks as well. Irrespective of the technical aspects involved in the coding, transmission and decoding of information, digital networks allow humans to exchange information, just like any other transport, organizational, physical or biological network. Therefore, the HF applies to networks in general, digital or not, including economic information networks.

Of all the frameworks proposed to account for the value of DINs and IT, the HF was chosen for two main reasons. First, it is a framework developed purely upon the premises of evolutionary economics regarding the nature and value of information described in chapter 2. Second, the HF provides a more comprehensive view of the processes upon information. The latter is shown in chapter 2, where we compared the HF with two other reference frameworks on the value of IT (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004). This led us to the assumption, validated in this paper, that the HF could be an alternative to GD, addressing GD's key weaknesses regarding completeness and practical use.

6.4 Strengths and limitations of the HF

As mentioned in section 6.2, a critical point for frameworks such as the GD and HF is the ability to capture what is general and at the same time what is essential about economic evolution. For example, cooperative behavior is not captured explicitly in GD because it is assumed to be completely a product of Darwinian logic. Because GD leaves several relevant mechanisms obscured behind the mechanisms of variation, selection and retention, it has been seen as too general and vacuous.

(Mayr, 1961) pointed out that Darwinism is about explaining behavior and distinguished two forms of causation: ultimate and proximate. Ultimate causation assesses *why* a certain behavior originated and it is the form of causation addressed by GD. Proximate causation explains behavior in terms of *how* the behavior occurs. For example, how is a joint venture initiated between two firms? The HF can be placed somewhere in between these two forms of causation because it concerns which behaviors evolved (the *what*). As a result of a more proximate causation than GD, the HF is less abstract, identifying explicitly several mechanisms relevant for evolutionary economics that are not explicitly identified by GD:

1. *Artificial selection*. Artificial selection is defined as "human-directed evolution" (Conner, 2003), and its importance for economic evolution has been stressed by various economists. For example, (Commons, 1950) stated that political economy explaining institutional change must be constructed as an evolutionist theory of artificial or purposeful selection. The HF explicitly identifies artificial selection with the capability of selectibility.

2. *Culture*. As mentioned in section 6.2, the evolution of culture and how it influences economic evolution differ sharply from the details of biological evolution

(Nelson, 2005). The HF identifies the evolution and influence of culture with the capability of culturability, bringing culture explicitly into the economic evolutionary process.

3. *Cognition*. GD considers evolution as *blind*, and therefore does not identify explicitly any cognitive capabilities, such as self-reflection, reason, foresight or planning (Hodgson and Knudsen, 2006). However, the importance of cognition for economic evolution is widely recognized. For example, (Stoelhorst and Huizing, 2005) stressed the importance of intentionality on the speed at which new adaptive behaviors emerge. Contrarily to GD, the HF identifies explicitly three cognitive capabilities: decisability, modelability and perceptability.

4. *Cooperation*. Cooperation is considered a major factor of profitability and technological innovation in many industries (Dertouzos *et al.*, 1989). Often, social mechanisms promote cooperation even when the return-benefits are beyond cognitive limits. Otherwise, predictability is sufficient for cooperation to succeed (Iliopoulos *et al.*, 2010). However, GD does not account explicitly for cooperation or for the cognitive and social mechanisms that promote cooperation. The HF, on the other hand, identifies cooperation independently and explicitly with the capability of cooperatibility.

5. *Creativity*. In GD, *variation* is understood as simply a "source of change", thus apparently purposeless regarding (ultimate) goals. The exclusion of ultimate purposefulness in the *variation* process of GD limits it applicability to economic creativity (Schumpeter, 1947), which is typically assumed to be purposeful (Boden, 1997). In the HF, creativity is explicitly covered by creatibility which includes in its definition ultimate purposefulness.

6. *Self-organization*. Holarchies are nested hierarchies of self-organizing structures, the holons. The term *holon* reflects the tendency of holons to act as autonomous entities and yet cooperate to form apparently self-organizing hierarchies of sub-systems, such as the individual, the firm and the economic sector. Several authors stressed that self-organizing complex systems' dynamics might provide the conceptual framework within which Darwinism continues to evolve (Weber and Depew, 1996). Contrarily to GD, which does not account explicitly for self-organization, the HF captures explicitly self-organization using the holon theory. The holon theory contains an agency-communion duality stemming from the attempt of (Koestler, 1967) to create a model for self-organization in biological systems (Ulieru *et al.*, 2002).

GD is also known to be difficult to operationalize. The difficulty is aggravated by the fact that it requires a delimitation and characterization of natural selection acting upon the economic environment. The usefulness of the mechanism of natural selection has been questioned (Vromen, 2007; Campbell and Robert, 2005). Contrarily to GD, the HF is relatively easy to operationalize (see chapter 3).

The HF also has limitations. First, it investigates economic evolution only from an information perspective. In the literature on the entropic perspective for biological evolution, introduced in section 6.3, a reductionist focus on information has been questioned. (Weber and Depew, 1996), for instance, stated the relevance of energy flows for the evolution of capabilities, and (Pigliucci, 2007) pled for a theory of form or matter. In fact, if indeed there are five fundamental categories in nature (matter or form, energy, space, time, and information (Danchin, 2009)), then evolution (biological or economical) should be probably studied as a convolution of the properties of these categories.

The second relevant limitation of the HF lies in the level of formalization of the capabilities. The definitions of the capabilities are mostly based upon various previous independently-developed works. However, capabilities are essentially information processes, and therefore their definitions should be derived from a unique and fundamental theory of information. The quest for such theory is actually in progress: (Umpleby, 2007) stated "matter and energy have been the subject of scientific investigation for several hundred years, a scientific conception of information is relatively new".

6.5 Conclusions

The Generalized Darwinism (GD) initiative abstracts the current paradigm in biological evolution, the Modern Synthesis (MS), from its biological details so that variety generation, retention and selection, regardless of the very different ways in which they operate in different areas of application, provide an overall meta-theoretical framework universally applicable to various areas, including evolutionary economics. The two main criticism of GD are its abstractness and lack of completeness, with a failure to capture explicitly several relevant aspects in evolutionary economics, for example, the following:

1. Artificial selection

2. Culture

3. Cognition

4. Cooperation

5. Creativity

6. Self-organization

As an alternative to GD, we proposed a new framework, called the Holonic Framework (HF), to address the shortcomings of GD. In contrast to GD, the HF was not derived from biology, but from study on the value of DINs. The HF provides a more proximate account for economic evolution than GD, including the aspects expressly mentioned above. Additionally, in chapter 3, we demonstrated that the HF has a higher practical usability than GD. We finally state that the HF is not a full alternative or replacement for GD, but that both frameworks have complementary strengths and weaknesses, and should be seamlessly integrated in the future.

6.6 Future work

As a potential future implication of our work, the HF might serve as the conceptual framework to guide the development of Agents Based Modeling (ABM) economic models (Farmer and Foley, 2009). In ABM, the modeler designs classes of agents (a computational implementation of a holon), attributes these agents with certain capabilities, instantiates a population of agents, assigns initial and boundary conditions, executes the simulation for a duration of time periods, and examines the final state of the model. Broadly, an agent refers to bundled data and behavioral methods representing an entity constituting part of a computationally constructed world (Tesfatsion, 2005). Among ABM's strengths, modeling flexibility is the most important. In practice, this results in heterogeneity between the agents defined in the model, facilitating a representation of the individual and social behavior of the agents.

ABM researchers argue pragmatically that agent-based tools allow modeling of cognitive agents with more realistic social and individual capabilities (hence, more autonomy). These capabilities include 1) ability to learn about one's environment (e.g. gather information, make use of past experiences, social mimicry, and experiment with new ideas) from a fixed set of options or from endogenously evolving spaces of options (e.g. strategies, performances, and preferences); 2) ability to alter expectations and preferences as an outcome of learning; 3) ability to exert some control over the timing and type of the actions; 4) ability to introduce structural changes in their methods on the basis of experience and information acquisition (e.g. in the learning method); 5) social communication (e.g. adaptively scripted messages); 6) social interaction patterns (e.g. trade networks); and others. At an abstracted level, all these capabilities are accounted for by the HF.

Contrary to neoclassical economic models, which make a system level presumption about the solution (an equilibrium state), in ABM the solution is found inductively. Rather than focusing on static or steady state paths, ABM looks for uncertain emergent properties of the agents' aggregate dynamics, often out of equilibrium. Convergence to a valid solution requires higher complexity in the definition of the agents, so that the system can develop over time solely on the basis of agents' interactions, without further interventions from the modeler (dynamical completeness). An advantage of this focus on the process rather than on ultimate equilibrium, is that modeling can proceed even if equilibria are computationally intractable or non-existent. Hence, with the HF and ABM, policy makers are now able to simulate artificial economies under different policy scenarios for a far wider range of non-equilibrium behaviors.

Finally, it is worthwhile noting that the HF is most likely applicable to domains other than evolutionary economics (e.g. policy making and biological evolution). We here want to highlight the field of strategic management. Strategy is the act of aligning a company with its environment, and is required because senior management cannot participate in all decision making and directly ensure the consistency of the myriad of individual actions and choices that make up a firm's ongoing activity (Porter, 1991). Perhaps the most important framework for strategy is Porter's *competitive-five-forces* framework (Porter, 1980). The competitive-forces approach views strategy as essentially determined by the industry structure (environment), and it helps firms to find a position in an industry from which it can best defend itself against competitive forces or exert influence in its favor. Porter's framework has been explored, contributed to and tested by many practitioners and theorists. Porter himself acknowledged a few limitations in his framework in (Porter, 1991). He recognized that the success of a firm should be centrally concerned with the creation and exploitation of its so called *distinctive competences*. To compensate for this limitation, a few streams of research developed (Teece *et al.*, 1997; Rumelt, 1984). From these perspectives, firms are heterogeneous with respect to their capabilities, and strategy is both constrained and shapes these capabilities. (Helfat *et al.*, 2007) mentioned that capability-based approaches continue to inform strategic management theory because they acknowledge the importance of time and historicity in economic decision making by referring to organizational paths; they explain why every organizational entity is equipped with specific resources and an identity; and they shed light on internal factors such as tacit knowledge, social complexity, organizational routines and competences (Freiling *et al.*, 2008). The HF identifies a set of capabilities that determine the evolution of holons. Therefore, it would be interesting as future work to position the HF within the literature on strategic management.

Chapter 7

A capability-aware business interoperability framework

Abstract: Interoperability refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged. Previous studies unveiled the costs of inadequate interoperability to be in the order of millions of euros per year. But existing research on interoperability mostly covers technical aspects, without caring for non-technical aspects that can also hamper closer relationships involving business partners. Along with technical aspects, research on interoperability should also involve business aspects such as organizational and operational abilities for enterprises to cooperate with its business partners with the objective to create value. This chapter describes a conceptual framework that identifies a new set of fundamental artifacts related with business interoperability. The novelty of our framework results from the unorthodox combination of theoretical backgrounds that we used: the fundamental nature of information, evolutionary economics and the body of literature on the value of Information Technology. The target group for this chapter are researchers investigating how companies can gain value through increased interoperability levels and bundling of core competencies.

This chapter was matter of publication in (Madureira *et al.*, 2011b, 2010b).

7.1 Introduction

A large body of literature exists spelling out the costs of limited interoperability in various fields. (Brunnermeier and Martin, 1999) uncovered the cost of interoperability barriers of IT systems used in the United States (US) sector of automotive manufacturing to be in the order of $1 billion per year. Another study estimated the cost of inadequate interoperability in the US capital facilities industry to be $15.8 billion per year (Gallaher *et al.*, 2004). A German miss-investment in a central police database costed directly more than €50 million, excluding the indirect dangerous consequences (Jochem and Knothe, 2007). (AMR Research, 2006) stated that $29 billion was spent in 2006 for application integration by IT professional services. (CIO Magazine, 2007) reported that 61% of chief information officers consider integration of systems and processes a key priority.

Definitions of *interoperability* have been reviewed in (Chen and Doumeingts, 2004). Broadly, it refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE, 1991). Most often, interoperability is discussed from a purely technical perspective, focusing on standards and IT architectures. A systematic analysis of business aspects associated with interoperability is currently lacking (Kotzé and Neaga, 2010; Legner and Lebreton, 2007). (Legner and Wende, 2006) introduced the term business interoperability, which denotes the "organizational and operational ability of an enterprise to cooperate with its business partners and to efficiently establish, conduct and develop IT-supported business relationships with the objective to create value".

Examples of business interoperability issues are business process compatibility, adaptability of business processes, leveraging legacy assets, support for business transactions and network security (Yang and Papazoglou, 2000). Although technological heterogeneity is a relevant challenge for seamless integration of networked organizations, enterprises often have found that there are also non-technical aspects that hamper closer relationships involving a large number of business partners. For example, lack of mutual trust, and responsibility gaps between businesses and intellectual property (ATHENA, 2006).

Without a framework capable to identify both technical as well as business and organizational aspects, it is hard to obtain the full potential of interoperability. The objective of this chapter is to explore business interoperability and to provide a conceptual framework which identifies a set of key concepts related with business interoperability. These concepts are fundamental dimensions upon which business interoperability should be designed and improved. Furthermore, this framework should be generic, and therefore abstracted from specific industries or economic sectors.

Since business interoperability involves the interplay between technological protocols (and standards), information systems and the economic value of IT, this chapter builds upon fundamental research developed within these three domains. The target group for this chapter are researchers investigating how companies can gain value through increased business interoperability levels and bundling of core-competencies.

In section 7.2, we provide a review of the state-of-the-art on interoperability and business interoperability in particular. In section 7.3, we describe our general theoretical approach for business interoperability, based upon the domain of *evolutionary economics* and the body of literature on the value of IT. In section 7.4, we describe the CaBIF, which is the main proposition of this chapter. Section 7.5 describes three illustrative case studies of the application of the CaBIF. In section 7.6, we provide an evaluation of the CaBIF, together with limitations and implications of our work. Finally, section 7.7 summarizes our major conclusions.

7.2 State-of-the-art

According to the ATHENA Interoperability Framework (AIF) (Berre *et al.*, 2007), developed within the Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications (ATHENA) project, interoperability takes place at four general levels:

1. Information/data
2. Service
3. Process
4. Business

In the information/data level (1), complementary data are either physically or logically brought together (Jhingran *et al.*, 2002). It refers to making different data models and query languages work together. Data might reside on different machines under different operating systems and data base management systems (Chen *et al.*, 2008).

The service level (2) defines interoperability between applications that are designed and implemented independently. Aspects involved are the identification and composition of various applications developed independently to function together. The term *service* also embarks functions of companies and networked enterprises.

Thus, it is more general in scope than just computer based applications. Therefore, a service could be defined as an abstraction and an encapsulation of the functionality provided by an autonomous entity (Berre *et al.*, 2007).

The level of process (3) defines interoperability between different alignment of services due to different business needs (Berre *et al.*, 2007). It refers to encapsulation of interdependent tasks, roles, people, departments, and functions required to provide a customer with a product or service (Klischewski, 2004). Examples of business processes are retailer-manufacturer and manufacturer-supplier cooperations (Greiner *et al.*, 2007).

The business level (4) refers to working in a harmonized way at the organizational level despite, for example, the different modes of decision-making, methods of work, legislations, culture of the company or commercial approaches, so that business can be developed between companies (Berre *et al.*, 2007; Chen *et al.*, 2008). For example, business interoperability might involve clarification of responsibilities between business partners.

These four interoperability dimensions influence each other. Cross-level issues are, for example, how processes ultimately generate value for organizations (Bartel *et al.*, 2007), alignment of IT services with business processes (Luftman, 2005) and problems of access to distributed datasets and application functions.

The AIF takes a multidisciplinary approach merging three research areas: 1) enterprise modeling to define interoperability requirements through model-driven architectures; 2) platforms to implement interoperability architectures; and 3) ontologies to solve semantic interoperability. The universe of discourse are enterprises and the IT systems they use. Figure 7.1 is a simplified view of the AIF which indicates two enterprises requiring and providing information, and the interoperability levels and areas needed for that.

Various other frameworks have been developed, particularly in the 1990s, which frame interoperability, using more or less the same dimensions as the AIF. Among others, are ECMA/NIST, TOGAF, Zachman, ISO 10746, NATO’s C3 IF, IDEAS, Modinis, EFQM, ECMIF, EGIF, MITRE, INTEROP, C4IF and R4eGOV. In this chapter, we do not intend to provide an extensive review of the literature on interoperability. We suggest (Chen *et al.*, 2008) for an overview and comparison of the different frameworks.

We focus instead on the AIF as our main literature reference. The reasons for choosing this particular framework are threefold: 1) previous work on business interoperability (Legner and Wende, 2006) was integrated with the AIF (ATHENA, 2006), which suggests its suitability to deal with this topic; 2) the ATHENA project already

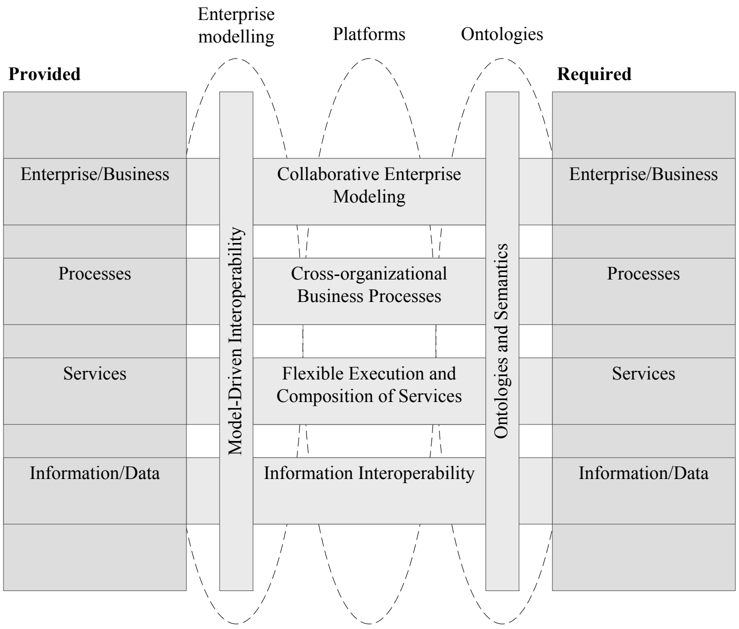


Figure 7.1: ATHENA Interoperability Framework (AIF)

defines a meta-model, the Cross-organizational Business Process (CBP) (ATHENA, 2005), capable to describe business process requirements. Our CaBIF relates directly to this CBP and the two may be integrated in future work; and 3) the AIF is well-established and often referred to in the literature (e.g. in (Chen *et al.*, 2008; Legner and Wende, 2006)).

(Legner and Lebreton, 2007) stated that interoperability is usually discussed from a purely technical perspective. A systematic analysis of strategic, organizational and operational issues associated with interoperability is currently lacking (Kotzé and Neaga, 2010; Legner and Lebreton, 2007). Similar observation was presented by (Aalst and Kumar, 2003), who mentioned that various mechanisms have been proposed for achieving interoperability of shared business processes, but that most of them focus on implementation details.

In this regard, (Legner and Wende, 2006) came up with a first framework that identifies a set of fundamental artifacts related to business interoperability. (Legner and Wende, 2006)'s Framework (LWF) is illustrated in figure 7.2. It identifies a set of *organizational design dimensions* and a set of *contingencies* which are factors that impact the organizational design. The organizational design dimensions and the contingencies are broadly identified by a set of *categories*, and each one is operationalized by a set of *perspectives/descriptions* which outline the key business decisions companies have to solve when establishing interoperable electronic business relationships.

LWF is based on two assumptions: 1) the maximum level of business interoperability does not necessarily represent appropriate levels for specific business interrelationship effectiveness; and 2) the appropriate level of business interoperability occurs if the design of inter-organizational relationships fits a certain set of contingencies. These two assumptions are grounded in the contingency theory (Donaldson, 2001). For example, whereas trust does not play a role in electronic invoicing scenarios, it is crucial in collaborative development in the automotive industry. Consequently, enterprises that seek maximum levels of interoperability while disregarding contingency factors, might be affected by lower efficiencies.

Business Interoperability (= Organisational design of the external business relationships)		
Category	*Perspective*	*Description*
Management of external relationships	"How do we manage and control external relationships?"	Interoperable organisations manage and monitor their external business relationships.
Collaborative Business Processes	"How do we collaborate with business partners?"	Interoperable organisations can quickly and inexpensively establish and conduct electronic collaboration with business partners.
Employees & Culture	"How do we behave towards our external business partners?"	Interoperable organisations promote relationships with business partners at an individual, team-based and organisational level.
Information Systems	"How do we connect with business partners?"	Interoperable ICT systems can be linked up to other ICT systems quickly and inexpensively and support the cooperation strategy of the organisation.
Contingencies (= Factors which impact the organisational design)		
Category	*Perspective*	*Description*
Cooperation Model (internal)	"What is the strategic intent of cooperating with external partners?"	Business strategy and cooperation model impact the required level of business interoperability.
Collaboration Space (external)	"Which baseline exists for collaborating with business partners?"	The collaboration space comprises proven cooperation models, processes and infrastructure which are available in the specific context.
Industry and general environment (external)	"Which environmental factors affect the external business relationships?"	Industry dynamics, legislation and other environmental factors determine requirements to business interoperability.

Figure 7.2: LWF framework

LWF identifies a set of *organizational design dimensions* and a set of *contingencies* which impact the organizational design. The organizational design dimensions and the contingencies are broadly identified by a set of *categories*, and each one is operationalized by a set of *perspectives/descriptions* which outline the key business decisions companies have to solve when establishing interoperable electronic business relationships. LWF is illustrated in figure 7.2.

To our knowledge, LWF is the only framework specifically developed to address business interoperability, and was already adopted by the ATHENA project (ATHENA, 2006). Therefore, in this chapter, we will use LWF as the state-of-the-art reference framework in business interoperability. In section 7.6.1, we evaluate our framework relatively to LWF.

7.3 Theoretical approach

In this section, we first relate business interoperability with the domain of *evolutionary economics*, and ultimately with the body of literature on the value of IT. This is done to motivate the specific theoretical background used to derive the CaBIF.

The two definitions of interoperability introduced in section 7.1 make clear that interoperability is fundamentally related with the concept of information (Legner and Wende, 2006; IEEE, 1991). Particularly, interoperability is a requirement to increase the value generated from information. Two views can be distinguished to account for the value of information (Bulkley and Van Alstyne, 2004):

1. 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 less informed economic system. 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 with a regression between the broadband penetration rate and economic growth.

2. 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 (Van 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 relatively coarse grained, being a black box transforming inputs into outputs. It helps in understanding the value of Digital Information Networks (DINs) as facts from observations. The evolutionary view is finer grained: modular input procedures can be rearranged to rearrange outputs. It helps understanding the value of information as procedures leading to changes in observations. Descriptions of economic systems are typically orders of magnitude larger in evolutionary economics than in orthodox economics. Thus, it is not uncertainty, but complexity and computational costs to generate and search an enormous state space of procedure possibilities that concerns evolutionary researchers.

The key assumption for the orthodox economic approach is that information can be directly observed as a production input. Therefore, information is seen as data (or a *thing* (Buckland, 1991)). As a consequence, the orthodox economic approach relates directly with the data/information level of the AIF. In contrast, the key assumption behind the evolutionary economic approach is that information cannot be directly observed. Only the processes upon which information is processed can. This assumption arises from the conceptualization of information as self-referential and non-foundational (Kallinikos, 2006). Self-referential means that information must be able to add a difference to what is already known to have value. Non-foundational means that information emerges through comparison of two or more objects or items (which are thus not singular, but relational entities).

The domain of evolutionary economics is therefore concerned with the study of procedures or intermediate processes that transform an economy and generate business value (Boulding, 1991). Thus, it relates directly with our process dimension of interoperability, which essentially deals with the same issue. In the context of interoperability, particularly in the AIF, business processes are the set of activities that deliver value to customers (Chen *et al.*, 2008; Berre *et al.*, 2007). Examples of business processes are coordination and control of process logic, i.e. the choreography and synchronization of activities and milestones between business partners (McAfee, 2005; Weigand and van den Heuvel, 2002).

Chapter 2 presented a first framework to account for the value of DINs built entirely upon the evolutionary approach mentioned above. This framework, labeled HF, identifies a set of fundamental capabilities which organizations use to extract value from DINs. Our hypothesis is that this set of capabilities constitute fundamental dimensions related with business interoperability. The CaBIF proposed by this chapter results from the inclusion in the AIF of the capabilities identified in the HF, as section 7.4 describes.

The HF was chosen for two main reasons. First, contrarily to the large majority of existing studies on the value of DINs and IT, the HF was developed purely upon the premises of evolutionary economics regarding the nature and value of information. Consequently, the HF investigates the business processes which are of interest for business interoperability. Secondly, the HF provides a comprehensive view of the processes upon information. Chapter 2 compared the HF with two reference frameworks from the literature on the value of IT (Zand and van Beers, 2010; Bulkley and Van Alstyne, 2004) and its scientific value was identified.

7.4 Capability-aware Business Interoperability Framework (CaBIF)

This section describes the main proposition of this chapter, the CaBIF, which is a result of the integration of the capabilities identified by the HF in the AIF (see figure 7.3). AIF provides the general framework for interoperability, whereas the capabilities of the HF complement the AIF for a more specific account for business interoperability. Thus, the CaBIF is identical with the AIF except for the processes level, which is dictated mostly by the capabilities of the HF.

As described in section 7.3, our hypothesis is that the capabilities of the HF should be mappable to AIF's level of processes, to make it more specific and useful to address business interoperability. Business processes are the set of activities that deliver value to customers (Chen *et al.*, 2008), and the HF's capabilities are general processes that users of DINs use to generate economic value. The concept of *capability* that characterizes the HF is not strange to previous work on interoperability. For example, (Jochem and Knothe, 2007) stressed the importance of assess, plan and control the capabilities for interoperability according to the individual company specific business needs. Therefore, as figure 7.3 illustrates, the capabilities are placed on the AIF level of processes, as a specific set of processes relevant for business interoperability with implications on the levels of services and information/data.

An overview of case studies described in existing literature provides a first evidence of the importance of the capabilities for business interoperability. For example, a topic that has been thoroughly addressed is coordinatibility, which is a capability particularly relevant in supply-chain and logistics interoperability. In knowledge intensive organizations, training and education is important. Therefore, interoperability of IT systems supporting adoptability is crucial to achieve business value. The notion of virtual enterprise as a temporary alliance of enterprises that come together to

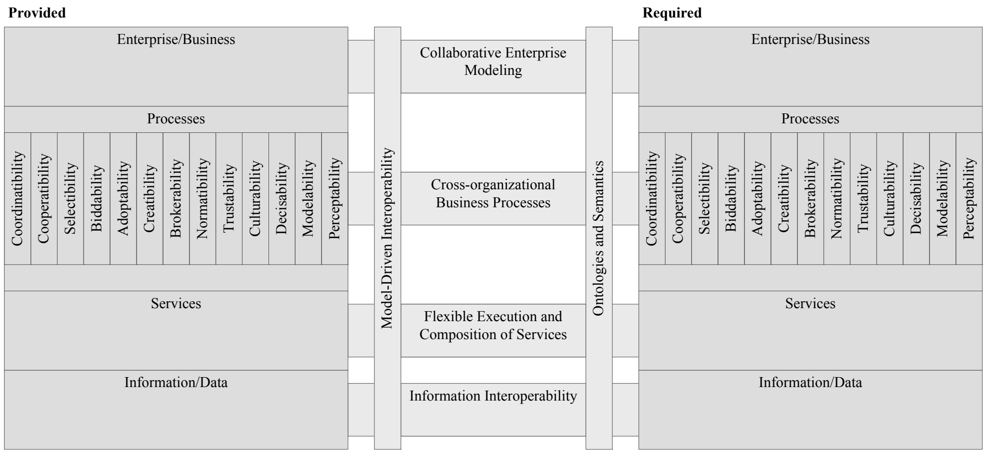


Figure 7.3: Overview sketch of the Capability-aware Business Interoperability Framework (CaBIF)

share skills or core competencies and resources supported by IT in order to better respond to business opportunities (Jochem and Knothe, 2007) is a manifestation of cooperatibility.

The CaBIF allows to guide interoperability at the services and information/data levels. For example, specific SCM packages could be chosen to support coordinatibility (Thomas and Griffin, 1996). Interoperability of Alert Management System (AMS) could manage cooperatibility among alert service agents. AMS are data mining systems designed to screen events, build profiles associated with events and send alerts based upon profiles and events (Grossman, 2005). Another technical scenario to support cooperatibility was described in (Jankovic *et al.*, 2007), in which actors need to define and accept business conditions before the beginning of any cooperation. Digital libraries are organized collections of digital information, essentially differing from the WWW by their ability to select information using meta-data for such a type of selectibility applications (Witten *et al.*, 2000; Paepcke *et al.*, 2000). In order to co-increase business value, companies need to model their internal processes and external contingencies. In order to support this instance of modelability, (Greiner *et al.*, 2007) suggests software packages such as ARIS, GraiTools, Mo2Go or METIS. The three case studies described in section 7.5 describe in more detail the value of technical support involving scenarios with other capabilities (selectibility, creatibility and biddability).

The HF hypothesizes that the capabilities are most likely not orthogonal, i.e. they

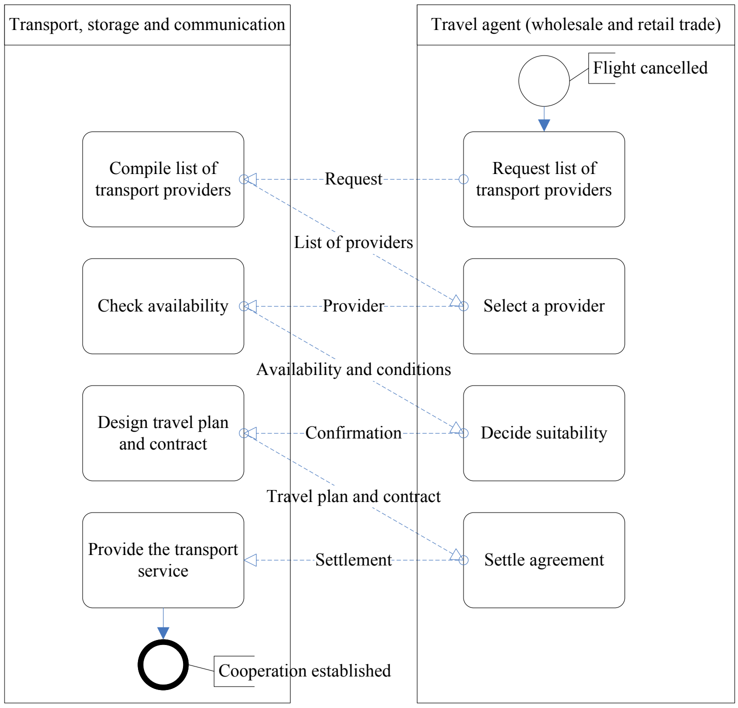


Figure 7.4: BPMN model of the flight scenario

have some overlap or inter-relatedness. The following simple business interoperability scenario illustrates this hypothesis. Due to a flight cancellation, a group of passengers is retained at the airport. The travel agent, belonging to the wholesale and retail trade sector, selects a hotel suitable for the passengers using a Web query. A transport company is selected and then contacted, and after some exchange of information, the travel agency and the transport company engage in a cooperative commercial relation. The transport company coordinates with the travel agent's insurance company to refund costs. Naturally, this scenario is abstracted of various interactions present in a real case. Figure 7.4 provides a high-level description of the requirements to support the cooperative relation between the transport, storage and communication sector and the wholesale and retail trade sector. The scenario is modeled using Business Process Modeling Notation (BPMN), starting with an event (flight canceled) and finishing with a cooperation established. Figure 7.4 shows that selectibility is necessary to achieve cooperatibility, illustrating the dependencies between capabilities. The travel agent uses selectibility to choose one of the transport providers. Thus, the overall success of cooperatibility depends on selectibility.

With the CaBIF in mind, a researcher interested in business interoperability has a suite of requisite process capabilities directly available to characterize how enterprises generate value. Due to their abstracted level, the capabilities first need to be proxied to be used. For example, selectibility could be proxied with how heavy an enterprise uses Internet information search engines. The second step is to identify the required services and information/data resources capable of supporting the capabilities. For example, Google Scholar is an important service for determining the creatibility of academic organizations. Therefore, using the CaBIF, one can immediately relate information/data assessments of Google Scholar (e.g. data structures) with academic value through the capability of creatibility.

7.5 Case studies

This section describes three explorative case studies that investigate different interoperability scenarios (Carpenter *et al.*, 2009; Moalla *et al.*, 2008; Guo, 2007). The goal pursued with these explorative case studies is to describe and structure complex interoperability scenarios, and illustrate the added value of CaBIF when analyzing them. With case studies one can investigate problems that need to be examined in specific real-world setting due to their complexity and interdependencies. Alternative research methods, such as surveys, are less suitable to pursue this goal (Yin, 2002). On the one hand, these case studies are general enough to be useful with the CaBIF. But they also deepen the examination of specific issues, which provide further insights on the application of the CaBIF. The case studies were selected on the reliability of the source to ensure that they could be verified by other researchers. Due to space limitations, the case studies are summarized and not described in depth. It was also guaranteed that the case studies contain not only technical aspects, but also behavioral and organizational aspects to ensure that the process and business levels of the AIF were having a role.

7.5.1 Boeing's Electronic Market place

An Electronic Market place (EMp) is a common information space, where e-business information exchange is enabled to allow B2B Electronic Market (EM) functions to be presented with certain information exchange efficiency and/or financial costs in use (Guo and Sun, 2004). The development of EMp was highly influenced by the development of interoperability technologies (Warfield, 2007). For example, influenced by community-oriented SCM systems integrating heterogeneous firms for inter-enterprise information exchange (Beheshti *et al.*, 2007).

A key function in EMp is the capability to quickly search electronic catalogues for products, buyers, and sellers, prices, and matching offers with purchases (Bakos, 1998). This function is identified in the CaBIF as selectibility. (Wang and Archer, 2007) identified selectibility in EMp as an aggregation and match-making market-oriented functionality. Obviously, the reduction of cost and time in building selectibility will attract more businesses to participate in EMp transactions.

Boeing is an aerospace company specialized in aviation technology and products. Boeing started using EMp technologies in the middle of the 1990s. Initially for promotion advertisement only, but they quickly shifted to on-line sales. Boeing developed not only its internal EMp at boeing.com, but also co-founded an industrial consortium EMp at exostar.com.

An historical analysis presented in (Guo, 2007) shows that an important event in the development of Boeing's selectibility function for EMp was the introduction of an intra-firm search engine based upon Electronic Data Interchange (EDI), which happened on 10/12/1997. EDI is a structured transmission of data between organizations by electronic means, without human intervention, accomplished through a specific set of standards (Senn, 1992).

The value of the CaBIF for Boeing's case study is three-fold. First, the CaBIF helps identifying a key business process involved, focusing the interoperability analysis. In this case, the capability involved is selectibility. Second, the CaBIF allows to structure the technical constraints and requirements at the services and information/data level. In this case, to be interoperable with Boeing's EMp selectibility, the consortium's EMp needs to implement or be compatible with EDI. Third, the CaBIF identifies core competencies from different organizations, and therefore, facilitates their bundling. In this case, the bundling of selectibility from two different EMps.

7.5.2 CAD/CAM distributed collaborative design

Computer Aided Design (CAD) computer tools support design and design-documentation in many applications such as automotive, shipbuilding, industrial and architectural design. CAD is just one part of the whole Digital Product Development (DPD) activity within the Product Lifecycle Management (PLM) process (Saaksvuori and Immonen, 2008). Another part are Computer Aided Manufacturing (CAM) tools, which use computer software to control machine tools and related machinery in the manufacturing of workpieces (Martin, 1992).

CAD tools are frequently mentioned to liberate designers, giving them new ways to envision their work and become more creative (Lawson, 2002). For example, architect Ian Ritchie used a CAD system to help design his innovative gallery in the Natural History Museum in London, and claimed that he would not have tried the 3D complex forms that he used without CAD assistance (Lawson, 1994). Thus, a key function of CAD systems is to increase creativity, a capability covered in the CaBIF by creatibility.

Interoperability between CAD and CAM tools is relevant when communicating CAD designs to CAM manufacturers. Interoperability becomes even more vital for collaborative design approaches, when a complex product is done by more than one designer, geographically dispersed and using different CAD/CAM tools according to their expertise. (Moalla *et al.*, 2008) described a case study that shows how to enhance interoperability between designs using heterogeneous CAD/CAM models. Their solution allowed to enhance creatibility, among other capabilities.

The technical scenario described by (Moalla *et al.*, 2008) consists of SolidWorks as the CAD tool and Esprit as the CAM tool. To interoperate SolidWorks and Esprit, (Moalla *et al.*, 2008) used a Model Driven Architecture (MDA) based approach. Their goal was to get a common shared data model, capable to account for specific functionalities of each tool. Additionally, a Product Process Organization (PPO) meta-model was used as middle-ware for exchanging product information.

This case study illustrates the value of the CaBIF from the same three perspectives mentioned in the Boeing's case. First, the CaBIF helps identifying the main business process involved (creatibility) focusing the interoperability analysis. Second, the CaBIF allows to structure the technical constraints and requirements at the services and information/data level. In this case, the technologies involved are SolidWorks, Esprit and PPO. Third, the CaBIF identifies creatibility as a core competency of the organizations involved, suggesting these organizations to be interoperable with others that share the same core competency.

7.5.3 Virtual organizations

A Virtual Organization (VO) is an aggregation of autonomous and independent organizations connected through a network and brought together in response to a customer need (Faisst, 1997). VOs arise due to the dynamic and opportunistic nature of modern markets, together with shrinking response times and volatile demand, leading to increasingly short-lived business opportunities (Carpenter *et al.*, 2009). An example of a VO is the Upper Austrian Cluster of Automotive Excellence (Crosswork, 2004).

VOs require fast configuration speed to capitalize business opportunities. Therefore, interoperability in VOs is a crucial subject. Most often, VOs are based on a decentralized approach without social control, which suggests the use of agents-based technology to provide deliberative goal-driven reasoning, automate goal decomposition, process refinements, interaction protocols and so forth (Carpenter *et al.*, 2009).

The overall goal is to create a composite service to respond to a service request (McIlraith *et al.*, 2001). The agent that decided to outsource a service, makes a Call For Proposal (CFP), for example, using the Iterated Contract Net Protocol (FIPA, 2011). An agent interested in the CFP submits a proposal, i.e. bids, to supply a necessary service. The bid is typically in proportion to the perceived return on investment for the opportunity. Therefore, a crucial process in VOs is biddability.

This case study was described in (Carpenter *et al.*, 2009), and the implementation of various interoperability scenarios was tested using Java Agent DEvelopment Framework (JADE). An example of a scenario was a water tank constructor who can construct specific types of water tank if provided with certain components, which have to be provided by other agents. Agents recognize that a component that they can provide is likely to be useful for the type of product produced and offer it.

Contrary to the two case studies presented in section 7.5.1 and 7.5.2, this case study shows how the CaBIF can be used to guide the design of interoperability simulation models, rather than full technical implementations. Once again, the CaBIF allows to identify biddability as a key capability involved in the scenario. Therefore, as a general requirement, a JADE interoperability simulation model requires the implementation of biddability, and the services and information/data levels capable to support biddability.

7.6 Discussion

7.6.1 Analytical evaluation

In this section, we evaluate the conceptual merits of the CaBIF relatively to LWF (see figure 7.2). LWF identifies a set of *organizational design dimensions* and a set of *contingencies* that impact the organizational design. The organizational design dimensions and the contingencies are broadly identified by a set of *categories*, and each one is operationalized by a set of *perspectives/descriptions* that outline the key business decisions companies have to solve when establishing interoperable electronic business relationships.

The contingencies correspond to exogenous factors to the organizations involved in a business relationship, which do not relate directly with the IT infrastructure from the perspective of information, but affect the organizations as a whole. Examples are industry dynamics, legislation and business strategy. Generally speaking, contingencies are assumed to be exogenous and taken as static but, in the long run, contingencies can be influenced by the processes supported by IT infrastructures. For example, adoption of IT standards can shape industry dynamics (Baldwin and Clark, 2000).

In addition to contingencies, LWF identifies a set of endogenous organizational design dimensions. Examples are the levels of trust between organizations, agreements on common terminologies, cultural differences and IT infrastructures. The first goal for a practitioner of LWF is to identify the organizational design dimensions and contingencies that characterize an organization. Grounded in the contingency theory (Donaldson, 2001), the second goal is to fit the organizational design with the set of contingencies for optimum levels of business interoperability.

Previous research has extensively related organizational design with information processing capabilities (Tushman and Nadler, 1978; Galbraith, 1974). On the one hand, organizations must develop information processing capabilities to cope with the uncertainty of external contingencies. On the other hand, organizations can fruitfully explore information capabilities to create appropriate configurations of work units. Particularly, a wide body of research, including our HF, related organizational design with IT capabilities (Huber, 1990).

(Legner and Wende, 2006) did not explicitly relate their organizational design dimensions with information processing capabilities. However, following the line of reasoning above, these dimensions should be mappable to a set of information capabilities such as the ones identified by the HF. The reasons are two-fold. First, from LWF's perspective, the organizational design dimensions should be dependent on IT, otherwise they do not have relevancy for interoperability. Second, from the CaBIF's perspective, the capabilities of the HF apply to information networks in general, and therefore are not exclusively supported by IT infrastructures. The added value of the CaBIF should therefore rely mainly on the following conceptual differences between LWF's organizational design dimensions and the HF's capabilities:

1. *Management of external relationships*. This category covers all aspects of realization, implementation and monitoring of cooperation relationships, and has been highlighted as an important factor by several authors (Daft, 2004). This category is fundamentally covered with the notion of cooperatibility in the CaBIF. Examples of pertinent aspects for this category are selection of business partners and contractual agreements. The HF proposes that the capabilities depend on each other. Therefore, the CaBIF is capable to account for

the dependency between cooperation and selection of business partners with the dependency between cooperatibility and selectibility; and the dependency between cooperation and contractual agreements with the dependency between cooperatibility and normatibility.

2. *Collaborative business processes*. This category deals with resource conflicts and coordination effort across businesses. For example, clarification of responsibilities between business partners. This category is fundamentally covered with the notion of coordinatibility in the CaBIF.

3. *Employees and culture*. Generally speaking, business interoperability can not be ordered or imposed to someone. Partnerships often rely on trust and on a climate of mutual cultural identification. The CaBIF covers this category with trustability and culturability. As an example of the effect of IT on corporate culture, managers have been using Workflow Management Systems (WMS) to strengthen organizational values (e.g. customer orientation) (Doherty and Perry, 2001). Therefore, to increase their effectiveness, WMS type of systems should be made interoperable.

4. *Information systems*. This category encloses the interoperability factors related with information as data. For example, if the interaction is done by fax, phone or e-mail communications, or if standards are used (Papazoglou *et al.*, 2003). This category is covered in the CaBIF with the information/data level, which was already identified in the AIF.

Summarizing, LWF fails to identify several relevant dimensions for business interoperability which are identified in the CaBIF: selectibility, biddability, adoptability, creatibility, brokerability, normatibility, decisability, modelability and perceptability. On the other hand, the CaBIF fails to identify the contingencies of LWF. This is caused by the HF's focus on the process level rather than on the interface between the organization and its external contingencies. In this regard, LWF is complementary to the CaBIF.

Relatively to the AIF, the CaBIF provides a much richer and specific account for aspects relevant to business interoperability. For example, whereas the AIF does not account for trust as a factor limiting business interoperability, the CaBIF accounts for it with trustability. The limitations of the AIF regarding business interoperability have been identified in (ATHENA, 2006), which adopts LWF as ATHENA's business interoperability framework.

7.6.2 Implications

Fundamentally speaking, interoperability issues are related to how information is conceptualized. Most of the existing research discusses interoperability from a purely technical perspective, assuming that information can be directly observed as a production input (e.g. data such as an ontology) (Legner and Lebreton, 2007). From the business perspective taken by this chapter, information is conceptualized differently, as non-foundational and self-referential (Kallinikos, 2006). From this perspective, the value of information is captured with a specific set of process capabilities identified in chapter 2. The domain of evolutionary economics also relies upon a non-foundational and self-referential conceptualization of information, and how information generates economic and business value (Boulding, 1991). Therefore, business interoperability can benefit from evolutionary economic research.

LWF didn't identify several relevant dimensions for business process interoperability which are identified in the CaBIF. Therefore, the CaBIF provides a rich new ground to guide business interoperability framework. Additionally, the CaBIF is based upon the capabilities of the HF, which were derived by observing how DINs generate value. A similar approach can be taken by researchers to validate or modify the CaBIF's current interoperability dimensions, or to add new ones. Contrarily, LWF was derived following the design-science approach, and is based directly on the review of different research streams and approaches to interoperability (Hevner *et al.*, 2004). Therefore, LWF is biased by previous interoperability research, which can now be compensated by CaBIF's novel methodological approach.

Existing interoperability studies generally address routine processes, such as coordination aspects in supply chain management. Some even define interoperability specifically from a coordination and control of process logic point of view, i.e. the choreography and synchronization of activities and milestones between business partners (McAfee, 2005; Weigand and van den Heuvel, 2002). However, processes with an evolving ad-hoc nature are very important in the global networked economies. For example, large-scale emergencies create sudden and profound change of events, leading people to respond with activities that range from planned to improvised, conducted both by established and ad-hoc organizations (Mendonca and Wallace, 2007). The CaBIF also provides an account for this type of processes, which therefore can now be addressed.

7.6.3 Limitations and future study

We identify three main limitations of the CaBIF. First, our contribution to the CaBIF focuses on the process level of business interoperability, thus at the interface between the organizations and their IT infrastructures. The interface between the organizations and their external context is not addressed. Examples of external factors affecting business interoperability are industry dynamics, legislation and business strategy. In this regard, LWF is more advanced than the CaBIF, identifying explicitly a set of external factors with the notion of contingency. Therefore, from this perspective, LWF may be used to enrich the CaBIF.

Second, we have not explored the concepts of holon and holarchy in the CaBIF. These two concepts provide a rich conceptual framework for multi-level, hierarchical networks (Koestler, 1967), which added value has been already recognized in the context of IT. For example, (Peters and Többen, 2005) described how the holon theory is applied to SCM and how insights from there are achieved for higher efficiency and effectiveness; (Cheng *et al.*, 2004) adopted the holon theory to develop a holonic information coordination system to support agile manufacturing activities; and (Adelsberger, 2000) proposed coordination mechanisms developed within economic frameworks to design manufacturing holonic multi-agent systems. In the public sector, for example, the holon theory could be useful to address the complex challenges currently posed to enable interoperability across the various levels and domains involved (Gøtze *et al.*, 2009).

Third, as mentioned in chapter 2, the HF bases its notion of *value* in concepts originating from the physical sciences (e.g. entropy). By relying on the HF, the CaBIF assumes the same notion of value, and proxies it with the set of capabilities. In this context, business value corresponds to shifts in a system from states of higher entropy to lower entropy. These shifts are achieved using the capabilities of the HF with the goal of increasing the complexity and order of the information associated with the organizations involved in business relationships. Additionally, this notion of value assumes that these organizations have some form of agency that incites them to decrease their entropy. This agency is easy to recognize in humans, organizations and biological entities, but difficult to associate to IT devices. However, several scenarios of interoperability only involve IT. Examples include scenarios for home automation and industrial manufacturing. For this type of scenarios, the notions of business value and capabilities are difficult to identify, and thus, the CaBIF has limited use. A notion of value for technical interoperability therefore needs to be developed and integrated with the notion of business value already identified in the CaBIF.

7.7 Conclusions

Interoperability enables value-creation and businesses to evolve. Although there is a large body of research on interoperability from a technical perspective, research from a business perspective is currently lacking. Therefore, there is a wide gap that decouples technical solutions from business goals. This chapter contributes to fill this gap.

Recurring to a state-of-the-art framework from the literature on the value of Digital Information Networks (DINs) and IT, labeled Holonic Framework (HF), we extended an interoperability reference framework called ATHENA Interoperability Framework (AIF) with a set of thirteen fundamental dimensions for business interoperability (also called processes or capabilities), which led to the main proposition of this chapter: the Capability-aware Business Interoperability Framework (CaBIF).

The CaBIF, as this enhanced AIF is called, contributes by letting practitioners focus on topics that are relevant, not just for being interoperable today, but also on the long run. Our analytical evaluation of the CaBIF, led us to conclude that the CaBIF identifies several new relevant dimensions for business interoperability when comparing with previous research. Using three case studies from existing literature, we illustrated how the CaBIF can be applied to predict and create business value from interoperability. Finally, we discussed several implications and limitations of our work.

Chapter 8

Conclusions

8.1 Main findings

The existing studies on the value of Digital Information Networks (DINs) can be grouped into three classes: 1) macro-economic type of studies using general equilibrium theories and/or input-output tables; 2) econometric type of studies not addressing the issue of causality; and 3) econometric type of studies addressing causality deterministically. The first class of studies provides speculative conclusions, due to the underlying theoretical assumptions (e.g. markets in equilibrium). The second class of studies provides elusive conclusions, because they do not account for the fact that causality between DINs and economic growth generally works in both directions (e.g. richer countries have more advanced telecommunication infrastructures). The third class of studies is limited because they use aggregated statistical deterministic relations between DINs and economic value, which provide few insights on how the actual value of information networks spreads across economies.

The most recent literature on the general value of IT (including hard- and software) takes more insightful and refined conclusions by depicting the value of particular subcomponents of IT. The major difference between these specific studies on the general value of IT and the literature on DINs lies in how information is conceptualized:

1. The orthodox economic approach (followed by the studies on the value of DINs) 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 sys-

tem and a less informed economic system. Thus, this approach assumes that information can be directly observed as a production input, and therefore information is seen as data. Additionally, this approach assumes that information has purely productive value, neglecting other forms of value (e.g. sociological).

2. 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. Thus, the assumption behind the evolutionary economic approach is that information can not be directly observed due to its self-referential and non-foundational nature. Only the processes upon which information is processed are measurable. This approach is aligned with the more refined studies on the value of IT, including organizational theory and management sciences literature.

In order to provide a finer-grained view of the processes enabled by DINs, and to account both for mechanistic views of the value of information networks in line with orthodox economics and with more sociological views, this thesis followed the evolutionary economic approach. The evolutionary economic approach concerns the study of procedures or intermediate processes that are dependent on information and that transform an economy. To account for the fact that the value of DINs can be depicted at several levels of analysis (e.g. individual and at the country level) and that these levels mutually interfere and co-evolve, this thesis uses the concept of holon to refer to an entity that is part of and makes use of multi-level networks for exchange of information.

Holons process information to evolve. Evolution can be seen as an entropic process. Entropy is a measure of randomness in a system. Holons strive to stay organized and distinctive, or even become more organized and distinctive, and thus try to lower their entropy. For that they need a steady inflow of energy and information. The notion of *value* used in this thesis therefore corresponds to evolutionary shifts from states of high entropy to low entropy.

The main proposition of this thesis, the Holonic Framework (HF), describes a set of simple and fundamental concepts which describe how information flows are processed and from which evolutionary value is generated. Irrespective of the technical aspects involved in the coding, transmission and decoding of information, digital networks allow humans to exchange information, just like any other transport, organizational, physical or biological network. Therefore, the HF applies to networks in general, digital or not, and to multiple levels of analysis (e.g. biological, economical and political). For two main reasons, the HF is more suitable to study evolution than current frameworks in the literature. First, it is a framework developed purely upon the premises of evolutionary economics regarding the nature and value of information. The evolutionary economic approach views information as procedures to change the nature of an economic system, and therefore is aligned with the view of evolution as caused by processes using information. Secondly, the HF provides a more comprehensive view of these processes.

The conceptual linkage between the HF and evolution in different domains allows us to demonstrate that the HF is capable to account for various forms of value in addition to the traditional economic ones (e.g. productivity and growth). However, this linkage provides a fundamentally different approach for theory building in these domains. In this thesis, we focused in three domains in particular (policy making, biological evolution and evolutionary economics), but other domains (e.g. strategic management) could have been chosen as well.

8.2 Contribution to theorists

In chapter 1, we concluded that this thesis aims to contribute to the literature on the value of DINs from three perspectives: 1) by contributing a framework capable to provide an overarching and holistic view of the processes enabled by DINs which generate evolutionary value; 2) by contributing a framework capable to link macro with micro-levels of analysis; and 3) the framework should be capable to account for other forms of value, in addition to the traditional economic accounts of value.

As stated above, the specific literature on the value of DINs does not identify the intermediate processes from DINs to economic value. In chapter 2, the main proposition of this thesis, the HF, was compared with two references frameworks from the literature on the general value of IT: the MIT framework (Bulkley and Van Alstyne, 2004) and the DUT framework (Zand and van Beers, 2010). We concluded that the DUT framework fails to identify eight of the 13 capabilities identified in the HF, whereas the MIT framework fails to identify four capabilities. Therefore, we confirmed the first objective of this thesis, not only regarding the specific literature on the value of DINs, but also regarding the literature on the general value of IT (including hard- and software).

In chapter 2, we found that the capabilities identified in the HF are multi-level, in the sense that they are meaningful and can be observed at various levels of analysis (e.g. biological and economical levels). In chapter 3, we operationalized the HF with Eurostat data both at the individual-level and enterprise-level, in order to draw conclusions about the capabilities identified in the HF. As such, we confirmed the second objective of this thesis of designing a framework capable to link different levels of analysis.

In chapter 2, we also argued that by following the evolutionary economic approach, the HF is capable to account for more sophisticated measures of value in comparison with the MIT and the DUT frameworks. In chapters 4, 5 and 6, we provided substance to this claim by showing the contribution of the HF in three specific domains: policy making, biological evolution and evolutionary economics. This approach underpins how the HF is capable to account for other forms of value than the traditional economic ones (e.g. productivity), and therefore confirms the third objective of this thesis. Furthermore, this approach is by itself a relevant theoretical contribution of this thesis: the study on the value of DINs is a practical way to build theory in several domains, namely policy making, biological evolution and evolutionary economics.

In chapter 4, we described a novel framework, labeled Capability-aware Policy Framework (CaPF), that can be used to analyze policy making and influence policy changes. The CaPF was derived by integrating the state-of-the-art reference framework in policy making, the Advocacy Coalition Framework (ACF), with the HF. We concluded that the CaPF has true operational value from a case study on the development and implementation of an electronic identification management system in Austria. The conceptual value of the CaPF goes beyond the value of the ACF in six different ways.

In chapters 5 and 6, we discussed the conceptual value of the HF by comparing it with the current paradigm for biological evolution, the MS. Generalized Darwinism (GD) abstracts the MS from biology to provide a conceptual ground for evolutionary economics. However, the MS is under scrutiny in biology and its application to economy provides too limited explanatory power. In chapter 6, we showed that the HF is an alternative conceptual ground for evolutionary economics. Additionally, we showed that the HF is capable to account explicitly for several aspects relevant for evolutionary economics which are not explicitly accounted for by GD (e.g. cooperation, cognition and self-organization).

Finally, in chapter 7, we achieved the secondary objective of this thesis, which was to derive a framework capable to address business interoperability with the ultimate purpose of increasing the value generated by DINs. We integrated the HF with an interoperability reference framework called ATHENA which led to the main proposition of chapter 7: the Capability-aware Business Interoperability Framework (CaBIF). The CaBIF contributes to the ATHENA framework by identifying a fundamental set of requisite process capabilities to characterize how enterprises generate business value. Our analytical discussion led us to conclude that the CaBIF identifies several relevant dimensions for business interoperability that are lacking in (Legner and Wende, 2006)'s state-of-the-art framework.

8.3 Relevant implications for the research domains

Our literature review and analysis gave us the insight that macro-economic studies using general equilibrium and/or input-output tables are speculative. Thus, no scientific ground can be guaranteed for claims such as (Katz *et al.*, 2009): "the economic impact of broadband development over a ten year period in Germany amounts to 968000 additional jobs". Additionally, any study that does not account for the direction of causality between DINs and economic value should be interpreted cautiously. Finally, economic studies based upon Cobb-Douglas production functions might be fundamentally inadequate to capture the behavior of the capabilities enabled by DINs. Therefore, new functional forms have to be developed to account for those effects. (Briscoe *et al.*, 2006)'s $n \log(n)$ law might be a good starting point.

This thesis identified a fundamental new set of mechanisms which guide the policy process, not accounted for in the current reference framework in policy making, the ACF. Our case study on the development and implementation of an electronic management system in Austria allowed us to validate the importance of two capabilities in the innovation process: brokerability (already accounted for in the ACF) and trustability (not accounted for in the ACF). Future work should confirm the importance of the remaining capabilities and study their interrelatedness. Additionally, it would be interesting to investigate the ability of the CaPF to fully predict policy outcomes.

Within the biological evolutionary research domain, the MS never actually went through a paradigmatic shift, relying on augmentations without overthrowing any of the previous foundations (Gould, 2002). The HF might contribute to the development of a new paradigm for biological evolution. The reasons are two-fold: 1) the HF is not based upon the MS or its foundations: Darwinism and neo-Darwinism (Pigliucci, 2007); and 2) the HF accounts for various aspects in biological evolution not explicitly accounted for by the MS.

Within the domain of evolutionary economics, this thesis provides a fundamentally different approach to conceptualize the evolutionary economic process. From a theoretical perspective, the added value of the HF in comparison with the initiative GD was clearly demonstrated. From an operational perspective, contrarily to GD, the HF can be easily linked to empirical data. In future work, the HF can be used to guide the development of evolutionary economic simulation models using Agents Based Modeling (ABM) (Farmer and Foley, 2009). Finally, the application of the HF to the domain of strategic management (organizational evolution) should be investigated.

Finally, this thesis demonstrated that business interoperability should be fundamentally grounded on research on the value of DINs. Additionally, we have identified fundamental dimensions for business interoperability that should be accounted for in future work.

8.4 Contribution to practitioners

Together with its theoretical contributions, this thesis also has the potential to be applied in practice within the short-term. Firstly and most obviously in the domain on the value of DINs and general IT. The business demand to understand, manage and promote IT is evidenced by the number of studies on the topic led by market firms. Backed up by its scientific support, the HF can be directly used to underpin the value of DINs and IT and to influence policy and management options.

Also within the public sector several initiatives have been initiated. In this thesis, we used the Eurostat's surveys on ICT use by households and enterprises. In the Eurostat statistics, some of the capabilities were impossible to operationalize and others were operationalized in a limited way. Therefore, the Eurostat surveys should be redesigned from a more conceptual perspective to provide a better account for the value of DINs and IT. The HF is well-positioned to provide the conceptual ground for such revision.

The second domain in which this thesis can be applied within the short term is policy making. The Advocacy Coalition Framework (ACF) has been applied in several countries and to several issues: climate change, Internet censorship, workers' compensation and rehabilitation, metallurgical development, education, tobacco tax, forest policy, waste management and incineration, steel policy, sports, tax, national security, conservation policy, unemployment and paid leave policy, pharmacy policy, public finance, think tanks and professional forums, coastal flooding policy, planning policy, estuary development, land use, nuclear energy, drug policy, domestic violence, roads policy, coastal water policy, transport and mineral policy, industrial pollution policy, antitrust policy, communications policy, airline deregulation, public lands policy, economic policy, nuclear power, water policy, energy and oil policy, auto pollution policy, nuclear waste policy, nuclear security policy, watershed management, hazardous waste policy, estuary management, air and transportation policy, reclamation policy, etc (Colorado, 2011). Given its conceptual strengths in comparison with the ACF, we expect that our Capability-aware Policy Framework (CaPF) will provide additional value to address policy issues such as the ones in the domains listed.

8.5 Limitations and future work

While the HF is purely a theory of information, physics recognizes the existence of five fundamental categories in nature: information, matter/form, energy, space and time (Danchin, 2009). Not a single one of these categories can be entirely described by the convolution of the remaining categories, although relations between them have been established (e.g. Einstein's relation between energy and matter). Therefore, in future work, the HF should be extended and interrelated with theories of matter/form, energy, space and time. For example, in organizational theory, time is recognized to have an important role. Historicity implies path-dependency and irreversibility (Dosi, 1993). Generally speaking, events are inter-temporally related and to a certain extent possibly self-energizing (Arthur, 2000). Actions are surrounded by other actions with time lags regarding their effects implying organizational flexibility and inertia (Rumelt, 1984). From an energy point of view, we established a connection of the HF with the fundamental laws of thermodynamics. (Frenken and Boschma, 2007) described a framework that is sufficiently general to systematically investigate a number of stylized facts in economic geography, and thus could provide an extension to the HF to address the spatial dimension.

The second important limitation of the HF lies in the level of formalization of the concept of capabilities. The definitions of the capabilities was mostly based upon previous multiple and independently developed work. However, capabilities are essentially information processes, and therefore their definitions should be derived from a unique and fundamental theory of information. The quest for such theory is in progress. (Umpleby, 2007) stated that matter and energy have been subject of scientific investigation for several hundred years, but a scientific conception of information is relatively new. While mathematical formulations are recurrent in traditional physics, it is questionable if mathematical formulations are possible in domains related with information, because of the own nature of information (Kallinikos, 2006). Most of the research in social sciences still uses purely verbal representation of social phenomena which has the downside of making it harder to investigate causal relations going from assumptions to implications and scientific knowledge to build up (Ostrom, 1988). With the advent of powerful and accessible computational tools, a more formal representation is emerging for information-related phenomena, making the assessment of consistency, generalization and other desirable properties easier.

The third relevant limitation of the HF lies in the fact that it does not account for environmental effects. In some senses, the HF may learn from the MS and GD, but the practical utility of the theory of natural selection is questionable at the level of generality in which it is defined. Perhaps an useful account for the environment should be domain-specific. For example, Michael Porter's famous framework of the five environmental forces that shape the competitiveness of a firm could be used to characterize the environment for an organizational instance of the HF (Porter, 2008). As an example from the biological realm, (Karr, 1987) described a set of metrics that reflect individual, population, community and ecosystems which could be integrated with the HF to characterize a biological environment.

The last important limitation to mention concerns the operationalization of the HF. Although we based ourselves on one of the world's best sources of empirical data on the value of ICT, the match between the conceptual and operational definitions of the capabilities needs to be improved. Some of the capabilities were impossible to operationalize (brokerability and culturability) and others were operationalized in a limited way. Looking into other data sources is an obvious way to improve our empirical results (e.g. the UN Statistical Commission). Even better would be the understanding and construction of a targeted measuring and data-gathering campaign to further validate and quantify the importance and completeness of the capabilities identified by the HF.

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List of acronyms

ABM	Agents Based Modeling
ACF	Advocacy Coalition Framework
AI	Artificial Intelligence
AIF	ATHENA Interoperability Framework
AGE	Applied General Equilibrium
AMS	Alert Management System
ATHENA	Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications
B2B	Business To Business
BIF	Business Interoperability Framework
BPMN	Business Process Modeling Notation
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CaPF	Capability-aware Policy Framework
CBP	Cross-organizational Business Process
CFP	Call For Proposals
CIO	Chief Information Officer
CRM	Customer Relationship Management
DINs	Digital Information Networks
DMS	Document Management System
DNA	Deoxyribonucleic acid
DUT	Delft University of Technology
DPD	Digital Product Development
EDI	Electronic Data Interchange
eIDM	Electronic Identification Management

EM	Electronic Market
EMp	Electronic Market place
ERP	Enterprise Resource Planning
ES	Enterprise System
EU	European Union
FTTH	Fiber To The Home
GD	Generalized Darwinism
GDP	Gross Domestic Product
HF	Holonic Framework
ICT	Information and Communication Technology
IT	Information Technology
JADE	Java Agent DEvelopment Framework
KM	Knowledge Management
KMS	Knowledge Management System
LWF	(Legner and Wende, 2006)'s Framework
MDA	Model Driven Architecture
MES	Modern Evolutionary Synthesis
MIT	Massachusetts Institute of Technology
NACE	Statistical Classification of Economic Activities in the European Community
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
OFX	Open Financial Exchange
PIM4SOA	Platform-Independent Model for Service-Oriented Architecture
POP*	Process, Organisation, Product and Other
PLM	Product Lifecycle Management
PPO	Product Process Organization
RBV	Resource Based View
RF	Reference Framework
SCM	Supply Chain Management
SIS	Strategic Information System
STOF	Service Technology Organization Finance
TCE	Transaction Cost Economics
UK	United Kingdom
UN	United Nations
US	United States
VO	Virtual Organization
WWW	World Wide Web

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Samenvatting

De wereldwijde aandacht voor de aanleg van Digitale Informatie Netwerken (DIN) komt voort uit de overtuiging dat zij van toegevoegde waarde zijn op economisch, sociaal en milieu vlak. De huidige wetenschappelijke pogingen om deze overtuiging te staven komen echter tot speculatieve, ongrijpbare of beperkte conclusies. In dit proefschrift stellen we een nieuw raamwerk voor dat de waarde van DINs tot uitdrukking brengt. Binnen ons raamwerk is het mogelijk om iedere vorm van waarde te bepalen, dit in tegenstelling tot de bestaande literatuur die zich vooral richt op conservatieve prestatie maten zoals productiviteit. Ter illustratie gebruiken wij ons raamwerk om de evolutionaire veranderingen in beleidsvorming, de economie en de biologie te verklaren. Aan de ene kant onderbouwen we middels deze aanpak hoe DINs waarde genereren in deze drie domeinen. Aan de andere kant leveren we een aanzienlijke theoretische bijdrage die beschreven wordt in relatie tot zowel het Advocary Coalition Framework (het modernste referentiekader in beleidsvorming), als het Initiative Generalized Darwinism (in evolutionaire economie), als het Modern Synthesis (het huidige model voor de biologische evolutie). Ten slotte draagt dit proefschrift bij aan de zakelijke interoperabiliteit met als uiteindelijke doel het vergroten van de met DINs gegenereerde waarde. Uit empirisch oogpunt wordt ons werk ondersteund met een uitgebreide Eurostat dataset over het gebruik van ICT in ondernemingen en huishoudens en een casestudy van een Oostenrijks elektronisch identificatie managementsysteem.

Curriculum Vitae

Specialization

Telecommunications/IT

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Scientific research done on the value of digital information networks and IT, business IT interoperability, policy making, evolutionary economics and biological evolution

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Delft University of Technology, Netherlands, MSC in Telecommunications, September 2004-November 2006, evaluated with $\approx 8.5/10$

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Internships

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Distinctions

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Nominated for the Netelcom award 2008 chaired by Willem Vermeend, former Dutch minister of social affairs

Fundação para a Ciência e Tecnologia (FCT) scholarship for the TU Delft MSc thesis project, highest rated proposal for Portuguese MSc scholarship grants in the area of Electrical Engineering and Computer Sciences, 2005, ≈15000€

Patents

Proxy-bridge for connecting different types of devices, Archi Delphinanto, Frank den Hartog, Franklin Selgert and António Madureira, US Patent Nr. 20090303926, October 2009

Lecturing

Delft University of Technology course ET4034- Enterprise Networks and Business Models, 2007-2011

Management

Supervised independently two TU Delft MSc students in their graduation final project

Various supportive roles within research projects