Preface

At the end of 2002, among the EC initiatives aiming to build a favourable environment for economic growth and social cohesion, support for the adoption of Information and Communication Technologies (ICTs) was identified as playing a key role in driving the transformation of the European economy. Specific research and development efforts were directed at fostering ICT adoption on the part of enterprises and at increasing their use of ICT-based services, leading to improved business networking and greater competitiveness. However, the emergence of a 'digital divide' between large and small to medium-sized enterprises (SMEs) in the adoption of ICT technologies and ICT services caused concern. Thus, strategies for a greater inclusion of SMEs in economic and value-creation processes through greater exploitation of ICT became more urgent.

The question was widened to how ICTs can become an instrument of economic inclusion in the knowledge economy while strengthening the democratic processes upon which we are building the knowledge society. This means developing ICT-based solutions and models that support a participative society in which public and private organisations, professionals and individuals compete, interact, and collaborate for their own benefit and for the benefit of the organisations, teams, ecosystems and/or communities they belong to, in order to enable the participation of all players in the knowledge economy and in the information society.

In a cycle of online and offline consultations and workshops it was gradually recognised that the value of ICT went far beyond ICT services and the pure streamlining of production processes. A large part of the value of ICT adoption derives from its potential to exploit and integrate technological networking, knowledge networking, and socio-economic networking, enabling the dynamic creation of new connections, processes and cooperation between economic actors. It also became clear that a system enabling these multiple kinds of networking cannot be reduced to a technological platform of interoperable services, but should evolve into a process-oriented architecture that can support a knowledge-rich environment which is representative of the users and of their social and economic behaviour.

By extending the networking paradigm to the knowledge and social layers, the knowledge, the processes, and the economic activities working in cooperation and competition could be conceptualised as the organisms of an ecosystem by applying the ecosystem metaphor to their digital representation. It was through this experience of mutual discovery between the technical and the socio-economic spheres of research that the concept of digital ecosystem was born and coupled with the concept of business ecosystem to create the Digital Business Ecosystem.

Digital business ecosystems are designed to evolve under the pressure of economic forces and to adapt to local conditions. Adaptation and evolution are partly achieved by embedding specifically designed evolutionary mechanisms into their architecture and their structure, and partly through the participation of local stakeholders in the process of their development. In other words, digital ecosystems assume that the dynamic and self-organising properties can only go so far; technology is also constructed through the continuous formalisation of the knowledge and the processes that the socio-economic and cultural systems to which it is coupled express. When the technology, being constructed, becomes the medium that facilitates the formalisation and distribution of the knowledge from which the same technology emerged, the pace of transformation from the material to the knowledge economy accelerates,

justifying the characterisation of ICT as a catalyst for growth. The Digital Ecosystems research initiative claims that a further acceleration can be obtained when the ICT is further designed to favour certain processes, such as shared knowledge production and openness, and to deter others, such as the formation of monopolies. Knocking down the barriers to distributed cooperative work and shared knowledge production allows the synchronisation of dynamic social and communication networks over ever-shorter time scales, pushing the ecosystem metaphor towards a distributed cognitive system and a collective intelligence.

The intersubjective processes of knowledge formalisation and the necessity to include social behaviour and economic interactions in the ecosystem highlighted the limitations of several default assumptions that tend to be made in technical fields, such as the existence of an objective reality and the neutrality of the technology and architectural principles. The acceptance that social and power relations cannot be reduced to an objective logic, but are socially constructed, had led to research that intertwined ICT research with epistemology and social science. This analysis, in fact, anticipated precisely what we are starting to observe in recent phenomena such as those encompassed under "Web 2.0" or the Web Science Research Initiative.

The ability to participate in the shaping of knowledge and in technology production motivates a greater sense of ownership of the means of socio-economic development, leading to a more active and creative participation of smaller actors in social and economic processes, with corresponding greater autonomy and empowerment. Where the accumulation of power and control becomes concentrated into monopolies, the distributed P2P architecture of digital ecosystems enables them to self-correct by diffusing it again, in this manner preserving the socio-economic structure that made this emergence possible. In parallel, the processes of governance of the digital ecosystem infrastructures that are currently being studied and defined around principles of accountability, transparency, identity, and trust increase our awareness of a shared responsibility toward the common good that can be variously referred to as *res publica*, open source, or shared vision. These concepts point to a comprehensive and holistic strategy of socio-economic development catalysed by ICTs that balances self-organisation with self-awareness, and that relies on fundamentally democratic processes as an insurance to preserve the results to be accrued from research in the form of innovation, employment, and market exploitation.

The multidisciplinarity of Digital Ecosystems research

A vision of digital ecosystems able to evolve into distributed cognitive systems, engineered to embed mechanisms of evolution and adaptation to local needs and cultures, whose content is democratically and socially constructed, and that enable the economic participation of small producers of knowledge and services, is however extremely complex and ambitious. Intertwined research in ICT technologies and social science is required to improve the processes and operations of public and private organisations and to catalyse dynamic and remote collaboration and interaction between human and digital entities and systems in various structured and unstructured organisational settings, such as distributed information systems and collaborative environments composed of complex dynamic heterogeneous networks of human and digital systems. Multidisciplinary research will enable the sharing of knowledge and practices and the modelling of micro- and macro-economic contexts, which will drive productivity, sustainability, quality and effectiveness in structured environments while unleashing creativity, innovation, dynamic networking, and participation in unstructured settings, taking advantage of diversity and multidisciplinarity, and fostering the participation of all in processes of social construction and economic development.

The Digital Business Ecosystems research initiative, thus, requires the engagement of a research community composed of computer scientists, social scientists, linguists, epistemologists, economists, political scientists, system theorists, cognitive scientists, biologists, physicists, and mathematicians in a joint enterprise finalised to define collectively technologies, practices, paradigms, and policies that can produce tangible results as the basis for a gradual deployment of a network of digital ecosystems. The implication is that there is need to create working practises of interaction and feedback among scientists, decision makers and the entrepreneurial world; there is need to implement, demonstrate, deploy, and verify the impact of pilot implementations; and there is need to deal with issues related to governance and sustainability at the regional and global scales.

The ecosystem approach facilitates the operationalisation of regional policies in support of SMEs that are not based on direct subsidies in favour of individual SMEs but are directed towards the establishment of environmental and structural conditions that empower SMEs, communities, and individuals to participate in dynamic networked global co-operative business and value chains. Such SME development policies exploit the synergy between the Cohesion policy, the 7th Framework Programme for RTD, and the Competitiveness and Innovation Programme. *"Cohesion policies reinforce each other at regional level by providing national and regional development strategies showing how this will be achieved"*, as indicated within the EC Community Strategic Guidelines 2007-2013.

Achievements

In less than 5 years from the initial ideas, we can see that the initial vision is starting to become a reality and the first tangible effects can be perceived. Ideas that seemed odd in 2002 have now started to be accepted worldwide, and to be adopted by different research communities and in different policy initiatives. A thriving interdisciplinary research community is emerging in Europe, with research and academic institutions participating from India, Africa, South America and Australia. A new "science" of digital ecosystems is being formed, and a long-term vision and research agenda has been defined. The initial research results have been implemented and engineered within the first digital ecosystem platform implementations. The first regional digital business ecosystems have been activated. A large number of SMEs of such pilot regions are exploiting the ecosystem, increasing their competitiveness, proposing new services and forming new aggregations. An increasing number of European regions are including the Digital Business Ecosystems within their Regional Operative Plans as operational policy instruments for supporting SMEs and local development. A large network of regions aiming at implementing regional digital business ecosystems (REDEN, http://reden.opaals.org) has been established to create synergies within their local business ecosystems, i.e. networking their enterprise value chains, sharing solutions, applications, ideas and practices.

But, to a casual reader, due to its irreducible complexity and unusual assumptions, the Digital Business Ecosystem concept and strategy still looks exotic and unfamiliar. This book was therefore partly motivated by the desire to provide a comprehensive presentation of the DBE concepts by researchers, engineers, business people, regional development actors and European Commission officers from the many disciplinary viewpoints, characterising this emerging field of research and development.

Research Areas

Initiating a research area in Digital Business Ecosystems implied several courageous assumptions, which enabled a change of perspective. However, this also opened up a series of research questions, some of which are quite 'out of the box'. We will list and describe them briefly here.

New Value Systems and Business Models. The research, necessarily interdisciplinary, includes policy and social science, in addition to technology. This decision has been validated by the recent trends in Internet market innovation, driven by applications that are based on the interactions between people and between companies rather than only on technological advances: solutions based on network effects and their formalisation created by an architecture of participation. This suggests the potential for new business models at the intersection between the gift and the exchange economy. The open source phenomenon is an example of this. More broadly, what is the notion of public goods in the Knowledge Economy? How does openness compare to patents in stimulating innovation? How can we couple innovation to social dynamics? How can we amplify the synergies between social development and economic growth?

Evolutionary and Adaptive Software Systems. Complementing the coupling of social dynamics to the creation of economic value, the latter can also be increased through the optimisation of the digital technologies that permeate all facets of human experience. Why do applications and operating systems become intractably complex as they scale in size? How can we develop systems that learn from the behaviour of their users; systems that are adaptive, self-organising, and self-healing? How can we design system and socio-technical architectures that reflect a network of technical and economic processes and operations, and that have the ability to reproduce themselves recursively, creating, destroying, or reorganising themselves in response to external inputs and perturbations? Genetic algorithms have progressed to the level of distributed evolutionary architectures coupled to service-oriented architectures, but there is a snag. The definition of the fitness function is context-dependent. If applied to business models or service descriptions we run into the problem of semantic matching between offers and requests. In other words, evolutionary computing applied to business computing and service oriented architectures has been solved only in part. What remains to be solved is strongly related to the life of abstract entities in a digital environment and to their ability to represent business knowledge and services, i.e. to formal and natural languages.

Natural and Formal Languages. It is difficult for ICT services to support the firm in the presence of quickly shifting business goals because software development struggles to keep up with the pace of change of the business environment. More importantly, the greatest challenge remains to ensure that the formalisation of requirements effected by the software engineers corresponds to the requirements as understood by business users. A current problem in software engineering is how to operationalise the connection between business knowledge and requirements, expressed in natural language, with the software services that express such knowledge and satisfy such requirements, through the development of appropriate design-time and run-time software tools based on formal languages. Once this first

hurdle is solved, in order to make the service descriptions and specifications sensitive to the context in which they will be instantiated we will need to understand how the formalisation of the services and of the business knowledge can benefit from a formalisation of the context that could be likened to biological organisms and the ecosystems they inhabit sharing the same Periodic Table of the Elements. The progression toward common standards, itself a social process, is a simple practical example of this idea. In order to progress from software engineering as a social process to the self-organisation of digital organisms, and to integrate automatic generation of services from business process and workflow specifications with the evolution of service species under the same theoretical framework, we will need to dig deeper.

The Mathematical Structure of Logic as a Bridge between Biology and Software. In order for the virtual life of digital entities to emerge from the formalisation of the socially constructed business ecosystems, we need to understand, and ultimately operationalise along the time dimension, the deep connections between the algebraic structure of biological systems and the algebraic structure of logic. The same DNA molecule that carries hereditary information down the philogenetic tree is also responsible for the abstract specification of the cell metabolism, including all its proteins and regulatory cycles. There is strong evidence that the DNA code is related to the theory of Galois fields, the same theory that underpins Boolean algebras and quantifier algebras. The former is the mathematical expression of propositional logic, whereas the latter explains first-order logic (FOL). FOL, in turn, is the backbone of some of the new languages being developed by the OMG. Business rules and business processes can be related to specifications, which interface to transaction models for the run-time management and orchestration of service execution. One of the next challenges in computer science seems to point to the integration of the concurrent systems point of view with abstract algebra and temporal logics toward the definition of a new form of computing based on the concept of the Interaction Machine as the archetypical abstraction of a digital ecosystem.

Dynamic P2P Architectures and Autopoietic Networks. There are many fascinating open questions about how fully distributed and P2P networks can support local autonomy whilst guaranteeing consistency of coordinated distributed transactions in the execution of dynamically composed service workflows. How can we integrate business activities with an evolutionary environment that can support a distributed transaction model formalised through temporal logics to guarantee self-preserving and autopoietic networks? How can we plug in virtual vendors that can offer the same quality of service as the large enterprise retailers? How can we overcome the technological challenges for providing a large collaborative environment with a fully distributed architecture? How can we design the networks of the future to cope with heavy traffic, delegate, self-recover, and ensure consistency in the presence of millions of client-side events whilst avoiding centralised control? How can a distributed transaction model support the recoverability and consistency of asynchronous and long-lived transactions mediated by P2P networks?

The Evolution of Digital Ecosystems towards Distributed Cognitive Systems. The emergent web phenomena leverage user participation, but their ownership and governance is still centralised, for instance in YouTube, FaceBook, Second Life, BlogSphere, Google. Is this a transition phase or a long-term trend? Can fully distributed technological and 'power' architectures emerge? Does intelligence have to be distributed? Are these Web 2.0 phenomena a reflection of a new consciousness of collective intelligence, or collective identity? If the applications and infrastructures that support these Web phenomena based on social networking learn from the behaviour of their users, at what point will the collective intelligence of the users start interacting with the intelligence of the network? What do we mean by collective intelligence and what does it have to do with regional socio-economic development? How can we foster the participation of new actors? How can we operationalise the processes of formalisation of knowledge through social tagging, i.e. how can we go beyond simple tagging? Where do new forms of knowledge meet new forms of language to create new forms of cognitive processes? How can we develop languages that express the economic activities and capabilities of economic and social actors as well as aspects of socio-economic and micro-economic interactions (licenses, business and revenue models, reputation frameworks, organisational structures and aims)? How can these new formal structures and social processes enable dynamic, networked, and cooperative business processes, crowdsourcing and global cooperation? How can we develop ICT instruments and formalisms that enable the description and identification of products, services, human talent, technologies, ideas, and that incorporate business relations and knowledge through formal and/or social semantics, supporting dynamic, distributed, social, and business networking construction processes and economic development? How can we integrate technologies and economic models that support innovation ecosystems that mediate the interactions between the human and digital dimensions in a context of dynamic self-organisation of socio-technical and economic systems, integrating research efforts in ICT with social and economic sciences?

Who Will Run the Digital Business Ecosystems? Who are the stakeholders? What is the power balance? What are the rules? Who sets the rules? How can the local rules of the digital ecosystems vary between ecosystems, while still allowing global interaction among ecosystems? How can we build trust? Who is accountable? How do we go about developing a governance framework? How do we bootstrap and then preserve the autopoietic properties of digital ecosystems? Can

we define structural features of the digital ecosystems that will make the emergence of oligopolies naturally difficult while fostering an inclusive economic dynamic, without having to make recourse to top-down regulatory policy? It is clear from the foregoing that Digital Business Ecosystems research is not just about software services and technology platforms, but reflects the richness and the complexity of social and economic relations. In the rest of this book this integrative point of view is elaborated from many different disciplinary perspectives, as follows.

The Sections of the Book

In Section 1: "Science: New Paradigms", the authors look at the more theoretical aspects of Digital Ecosystems research. Following a broad-sweeping discussion of the scientific foundations of Digital Ecosystems, the main concepts of biological ecosystems are presented in the second article of the section, together with their applicability to evolutionary and agent-based architectures. The third article then looks at ecosystems from the point of view of language and linguistics. The fourth and final article of the section looks at business ecosystems and organisations.

Section 2: "Economic and Social aspects" begins with an article on business and technology clusters of small firms and their increasingly dynamic role in the globalising economy. The second article addresses the challenge of developing a governance framework for Digital Ecosystems that can sustain the plurality of decision processes surrounding their social, technological and regulatory aspects. The third article is more economic in flavour and discusses a cost-benefit analysis framework for Digital Ecosystems, partly based on initial results from the participating regions. The fourth article focuses on knowledge, sustainability and scalability in open source Digital Ecosystems. The fifth and last article of the section discusses a regulatory framework for Digital Ecosystems organised around the concept of trust.

Section 3: "Digital Ecosystem Technology" is almost entirely focussed on architectural aspects. From distributed information and ecosystem-oriented architecture the section includes articles on DBE services, on Business modelling languages, on the dynamic and scale-free topology of the run-time environment, on distributed infrastructural services, on a negotiation environment, and finally on a simulation framework that can equally visualise the Evolutionary Environment and SME networks.

Section 4: "Case Studies of Technology Transfer and Digital Ecosystem Adoption" is focussed on DBE adoption. The first two articles discuss regional development. The third and fourth articles are case studies from the Regional Catalysts of the DBE Integrated Project. The final three articles are new and emerging regional experiences of direct or indirect relevance to Digital Ecosystems from India, Ireland and Brazil, respectively.

The final section, Section 5: "Digital Ecosystem Projects Cluster", gives an overview of the Digital Ecosystems Cluster of research projects funded by the European Commission.

Acknowledgements

The *DBE book team* wishes to express their recognition to Ramon O'Callagan, Miguel Vidal, Jesús Gabaldón and Antonella Passani for their hard work in writing the introductions to different sections.

The following persons also provided valuable background material, critical feedback, or stimulating discussions for specific chapters of this book: Evangelia Berdou, Alan Hooper, Paul Krause, Robin Mansell, Daniel Schreckling, Frauke Zeller.

The book is the result of extensive research driven by the DBE research community within the projects funded by the 6th Framework Programme of the European Union. It benefited from inputs and feedback provided by researchers under the cluster "Technologies for Digital Ecosystems", presented and developed in Section 5. The book also benefited from collaboration with the following institutions: Instituto Tecnológico de Aragón, University of Central England, London School of Economics and Political Science, Imperial College London, Heriot-Watt University, University of Kassel, University of Tennessee, Monash University, Technical University Ilmenau, University of Lecce, University of Surrey, Tilburg University, IESE Business School, Waterford Institute of Technology, Fachhochschule Salzburg, Indian Institute of Technology Kanpur, T6, CENSIS, TechIDEAS, Soluta, Intel Ireland, CREATE-NET, and the Regions for Digital Ecosystems Network (REDEN).

Part of the content of the DVD attached to this book was produced within the activities of the projects of the "Technologies for Digital Ecosystems" cluster, which decided to provide their deliverables under a creative common license, specifically: DBE, OPAALS, SEAMLESS, EFFORT, PEARDROP, ONE.

The tag cloud that is on the cover of the book was designed collectively by the DBE community by the definition of the tags and their relevance. The Picture on the back cover page was designed by Bertrand Dory and Anne English, Intel Ireland. The overall layout, graphics and desktop publishing were done by Paolo Antinori.

This book would not have been possible without the knowledge, the research, and the previous work of hundreds of scientists. Among them we would like to mention the project CYBERSYN and the FP5 project FETISH. We would like to express a special tribute to some persons whose ideas have been fundamental for building the vision expressed in this book: H Maturana, F Varela, F Flores, S Beer, G Bateson, L Lessig.

The DBE project provided part of the financial support for the editing of the book, as part of the project dissemination activites. The DBE and OPAALS projects are gratefully acknowledged.

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