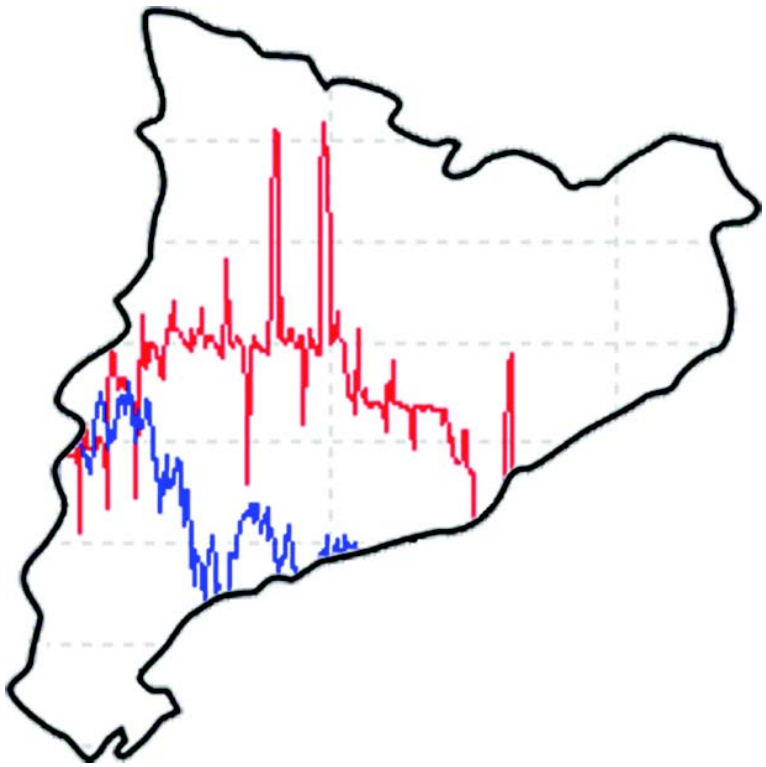
PROJECT INTERNET CATALONIA (PIC)

# THE NETWORK COMPANY IN CATALONIA

## ICTs, productivity, competitiveness, wages and returns in Catalonia's companies

### Summary of the final research report



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# Acknowledgements

Considering the complexity and dynamism of the study's subject matter, it happens all too often that social-science research requires a vast body of contributions. Such evidence is even more significant in research on knowledge economies and societies. There is no doubt that a specific, dynamic and relational spirit is required when attempting a complete approach to the incorporation of knowledge into economic activities and its social uses. Specific because the complexities of the current process of technical change cannot be understood without familiarizing oneself with technology, while moving on from a general conception to a more specific one, from technology to technologies. Dynamic, because technologies not only vary with time but also coexist in a variety of forms at any given moment. And relational because the effects of technological change cannot be analyzed in isolation from the particular context out of which it arises and develops. We shall therefore broach the subject matter of our study: changes in the main performance of Catalonia's corporate activities as a result of the uses made of information and communication technologies, with a methodological focus based on an economic and corporate analysis, and a necessarily multi-disciplinary sensitivity.

It is precisely in this spirit that, as investigators on the Projecte Internet Catalunya (PIC), we have periodically carried out meetings and discussions to analyze the various approaches to this broad investigation into technological change and its economic and social uses. We are most grateful to the project's directors, professors Manuel Castells and Imma Tubella, for their comments on, contributions to and support for this investigation here, and to all the researchers of the Seminari PIC, conducted under the framework of the Open University of Catalonia, for their valuable contributions and for the good will that they have always shown. Our special thanks then go to the following researchers: Eduard Aibar, Gemma Andreu, Rosa Borge, Eva Borràs, Jonatan Castaño, Agustí Cerrillo, Judith Clarés, Josep Maria Duart, Vincent Dwyer, Pere Fabra, Mireia Fernández, Marc Gil, Anna Graells, Imma Grau, Carolina Jiménez, Salomé Larrea, Paco Lupiañez, Julio Meneses, Josep Maria Mominó, Adoració Pérez, Maria Pujol, Meritxell Roca, Antoni Roig, Francesc Saigí, Josse Sánchez, Teresa Sancho, Gemma San Cornelio, Maximilian Senges, Carles Sigalés, Carlos Tabernero and Mireia Utzet.

We are also grateful to the UOC's professors and in particular to all those in Economics and Business Studies, for the solidarity they have expressed throughout the period of this investigation, which will have reached its fifth year at the half-way point of this year. We also wish to express our thanks to Anna Sánchez-Juárez and Isabel Carol, the project's coordinators, and to Noemí García and Cristina Magrinyà, for the help and management they gave. In addition, we wish to acknowledge our debt to the documentation service of the UOC library, in

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The investigation has additionally relied on the suggestions and observations made by a large group of university lecturers: lecturers and academic collaborators in Economics and Business Studies at the UOC, and also the lecturers Joan Tugores and Ramon Alemany, from the University of Barcelona; Luís Toharia, from the University of Alcalá de Henares; Eduardo Bueno Campos, from the Autonomous University of Madrid; Renato de Oliveira, from the Federal University of Rio Grande du Sul (Brazil), and Marshall van Alstyne, from the University of Michigan (United States). We are also grateful for the contributions made by professor Lluís Franco, the current presiding judge of Catalonia's Restrictive Practices Court.

On the other hand, mention should be made of the fact that this investigation would never have been successful without the contributions made by large group of people involved in various ways with the world of ICTs and corporate activities. At this point we ought to mention our indebtedness to a group of people who, above all, provided us with highly valuable comments and suggestions during the investigation's initial stage. Our thanks then to Antoni Farrés; Joan Coscubiela, Juan Manuel Tapia and Antonio Castán, from CCOO; Josep González and Albert Roca, from PIMEC-SEFES; Josep Maria Álvarez and Jaume Collboni, from UGT; Joaquín Trigo and Antonio Sáenz, from the Foment del Treball Nacional; Josep Morell and Xavier Carbonell, from Barcelona's Chamber of Commerce; Agustí Segarra, Carles Fradera, César López and Sara Sanz, from the Centre d'Innovació i Desenvolupament Empresarial (CIDEM), and Miquel Alabern, from the Consorci de Promoció Comercial

de Catalunya (COPCA). We also wish to mention the group of business people and professionals who helped us during the pilot stage of the questionnaire and clearly helped us gain a better understanding how Catalan companies make use of ICTs.

This investigation, for its part, relied on the invaluable collaboration of IDESCAT, especially during the drafting and pilot stages of the questionnaire. We thank its director at that time, Jordi Oliveres, as well as Enric Ripoll, Àlex Costa and the Subdirecció d'Assistència Tècnica Estadística (Statistical Technical Assistance Bureau) for their contributions and assessments.

We would not wish to close this collection of contributions to the investigation without mentioning the solid initial support given to the investigation by the president of the Generalitat, Jordi Pujol, who had believed, from the first meetings with the Project's directors, in the need for conducting an investigation with these features, a belief that was realised through the granting of financial and logistical support both to the investigation and to the dissemination of its results. We also express our gratitude to professor Gabriel Ferraté, first Rector of the Universitat Oberta de Catalunya (the Open University of Catalonia), without whose initiative, the initial research on knowledge economies and societies in which we have been immersed at our university, would not have been possible either. We would also like to mention the stake made in the project's continuity, through the financing of the investigation's second stage made by the government of President Pasqual Maragall, and specified by the Conselleria d'Economia i Finances (the Department of Economic Affairs and Finance of the Generalitat), under the direction of Antoni Castells, and by the Departament d'Universitats, Recerca i Societat de la Informació (the Department of Information-based Universities, Research and Societies) then under the direction of Carles Solà. We wish to express, at this point, and from the institutional perspective, our appreciation to the present Rector of the UOC, Imma Tubella, and to the present Chairman of the Science Committee at the IN3, Manuel Castells, as well as his current Research Vice-Rector, Eduard Aibar, for their determined and not always easy support for consolidating our university's research, a prime example of this being the Projecte Internet Catalunya. Finally we would like to express our gratitude to the present government of President José Montilla which, through the Conselleria d'Economia i Finances, under the direction of Antoni Castells, and the Departament d'Innovació, Universitats i Empresa (Department of Innovation, Universities and Companies), under the direction of Josep Huguet, have also given support to this investigation.

# Preface

## The Network Company in Catalonia. ICTs, productivity, competitiveness, wages and returns in knowledge-economy companies

### Description of the research

The research project *The Network Company in Catalonia. ICTs, productivity, competitiveness and returns in the knowledge economy companies* chiefly aims to analyse the changes to corporate activities linked to the use of information and communication technologies (ICTs). The main hypothesis that we wish to present is as follows: the consolidation of a new strategic, organisational and corporate-activity model, linked to ICT investment and use (network companies), substantially alters the behaviour patterns of corporate performance, in particular productivity, competitiveness, wages and profits. The empirical verification of this hypothesis, which has been extensively studied through the international literature currently in use, was conducted using a representative sample survey of Catalan companies, with a sample measure of 2,038 companies, stratified into activity sectors and company sizes.

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### With the collaboration of:

Institut DEP. The Institut d'Estudis i Professions collaborated in this research in providing the technical support requested by the ONE group. In particular, the Institut DEP joined the ONE research team in designing and validating the questionnaire and in creating the sample. The questionnaire survey, codification, filtration and verification of the surveys and first statistical processing were conducted by the Institut DEP, and always in accordance with the lines of action laid down by the research team.

### Collaborating institutions:

The Institut Català d'Estadística (IDESCAT) and the Centre d'Innovació i Desenvolupament Empresarial (CIDEM).

### With the support of:

The Generalitat of Catalonia

Research was begun in April 2002 and completed in 2007.

Barcelona, 20 April 2007

# Chapter 1

# The knowledge economy and network companies: research aims and methodology

**Joan Torrent and Jordi Vilaseca**

The paper below is a summary of a research project analysing how the link between digital technologies and strategies, organisations and value-chain elements in production activities becomes a determining factor in explaining corporate performance, in particular productivity, competitiveness and wages.[1] To back up this hypothesis we have carried out a micro-economic, empirical investigation into Catalan companies, based on data from a survey taken during the winter and spring of 2003. It is clear that the link between digital technologies with company activities and performance falls into a much broader context: the emergence of the knowledge economy and society.

1 . The complete report on this research project in Catalan is available at: http://www.uoc.edu/in3/pic/cat/empresa_xarxa/informe.html

## 1.1. From industrial to knowledge economy

Economic activity is currently going through a process of profound change. While there may be numerous reasons for this dynamic, there is a broad, academic consensus which ascribes the process to a three-fold interaction: a) a process of technological revolution, led by investment in and massive use of information and communication technologies (ICT); b) a temporally- and spatially-expansive dynamic within factor and product markets, or process of globalisation; and c) a new pattern in the norms of consumer demands and family and company investments.[2]

In this regard, it may be asserted that ITCs are consolidated as[3] general-purpose technologies and form the material basis of a new techno-economic paradigm[4] from which a process of industrial revolution emerges.[5] In fact, it has been agreed that this process of change, which is characterised by networking, investing, price decline and persistent use of ICTs, and by a growing presence of information and knowledge flows in the economic sphere, should be called the transition process, from an industrial economy to a knowledge economy.[6]

The knowledge economy is therefore consolidated through a new technical property: the application of new forms of knowledge and information to information-generating tools and the information and communication process.[7] There is currently more economic knowledge application than ever before in the generation of such knowledge. Here is an example by way of illustration. During the second Industrial Revolution scientific knowledge developed the internal combustion engine, which was progressively consolidated as a key production-scheme technology. In this case knowledge developed a technology which, once technically applied to the production process, radically changed economic activity. In the case of the digitisation process, we have technologies available that are based, as always, on the economic application of knowledge for developing products and services in a reproducible way. That being said, this is an innovation, and the impact of such knowledge is not limited to the technological side of production, given that ICTs also have an effect on the generation of that knowledge. In fact, ITCs are technologies and as such they constitute knowledge and, moreover, they broaden and extend the human mind. In other words, what we have is a so-

2. Kranzberg (1985); Mokyr (1990); David (2000); Castells (2004); Vilaseca and Torrent (2005b).
3. Bresnahan and Trajtenberg (1995); Jovanovic and Rousseau (2005); Albers (2006).
4. Dosi et al. (1998); Torrent (2004).
5. Crafts (2000); De Long (2001); Atkeson and Kehoe (2001); Baily and Lawrence (2001); Baily (2002).
6. Pérez (2002); Rodrigues (2002); Stehr (2002); Vilaseca and Torrent (2005b); Rooney, Hearn and Ninan (2005); Dolfsman and Soete (2006).
7. Castells (1996/2000).

cial stock of knowledge which uses knowledge as an input and contributes directly to the generation of knowledge as an output.[8]

In short, if we take a broad perspective on the technological process, understood as mankind's ascendancy over nature and the social environment,[9] we can see that ITCs do not just effect our ability to reproduce and control the environment but also provide us, more than ever, with technologies that directly act on our self-mastery capabilities or, more accurately, our generation of self-knowledge. In contrast to manufacturing base technologies, which affect manual labour, the application of ITCs to the production apparatus enhances and replaces mental work.[10] What then is the most outstanding conclusion reached in analysing such features that are intrinsic to digital technologies? It is clear that the productive application of ITCs present a high degree of association with the stock and dynamics of an economy's existing knowledge. In this regard, if we wish to analyse certain aspects that are linked to the ITC-led technological revolution, we shall have to focus our analysis on the economic dimension of knowledge.

If by knowledge we mean its epistemological definition, that is, the human and dynamic process of justification appropriate to a belief,[11] we can visualise the economic fact of its production, distribution, exchange and consumption, given that the act of knowledge is exclusively human and, as such, economically feasible. On the basis of reproductive capacity,[12] two types of knowledge may therefore be asserted to interact here in the economic sphere: explicit or observable knowledge and implicit or tacit knowledge. The first refers to knowledge that can be expressed through a formal and systematic language in such a way that it may be readily processed, communicated and stored. The second concerns knowledge that is essentially associated with work factors and based on technical and cognitive elements, such as practical experience, skills, qualifications and aptitudes, all of which are difficult to detail and, therefore, to specify.

How do ICTs affect observable and tacit knowledge production? The answer can be found in two ways.[13] The first has to do with the spectacular improvement in information-flow access and management. This has led to a notable relaxation in knowledge-dissemination barriers to entry and, ultimately, to a significant increase in the stock of observable knowledge. The second, and this is bound up with the first, concerns the improved opportunities of access and dissemination for elements affecting the production of tacit knowledge, which becomes observable in some

8. Torrent (2004).
9. McClellan i Dorn (1999).
10. Autor, Levy and Murnane (2003); Vilaseca and Torrent (2003).
11. Terricabres et al. (2001).
12. Polanyi (1978); Nonaka and Takeuchi (1995); Foray and Lundvall (1996).
13. Geuna (1999); Antonelli, Geuna and Steinmueller (2000); López Cerezo and Sánchez Ron (2001).

cases and in other cases changes the requirements, the theoretical and practical capabilities of the work force and the skills that are to be developed at the work place.

On the other hand, there are countless examples of knowledge-based product and service transactions to be found in daily economic activities, from any digitisable commodities to capacity exchanges between economic agents. We may therefore assert that the interaction between ITC and knowledge prevents the latter from remaining solely a production resource. It is in this context that knowledge-based commodities acquire special economic features,[14] with both public and empirical properties, significant externalities, growing returns and network economies. In addition, as the generated knowledge becomes more readily transmissible, the marginal utility of its access tends to diminish, as do the barriers to exit for these types of commodity.[15]

In sum, the growing interaction between ITCs and knowledge allows us to consider the latter as a resource and commodity with progressive, economic significance. Accordingly, we can define the knowledge economy as that branch of analysis which studies the behaviour and facts that arise from the economic application of knowledge.[16] It should be noted in this regard that the knowledge economy's conception of its own resources and basic commodities goes beyond that of the traditional economic approach, which is more firmly rooted in the analysis of scientific and technological knowledge, to include an analysis of technical knowledge and capacities, irrespective of their ready transmissibility, among economic agents. In fact, since the second half of the 1990s, the expression of knowledge in economic activities has caused considerable change to several forms of economic-agent behaviour and has led to the appearance of new activities while transforming many of the old ones. It is precisely in this broader sense of interaction between ICTs and all current forms of knowledge that the knowledge economy becomes important, to the point where the above-mentioned resource and commodity become determining factors in explaining productivity and competitiveness levels and advances and, therefore, economic growth and material well-being within modern societies.[17]

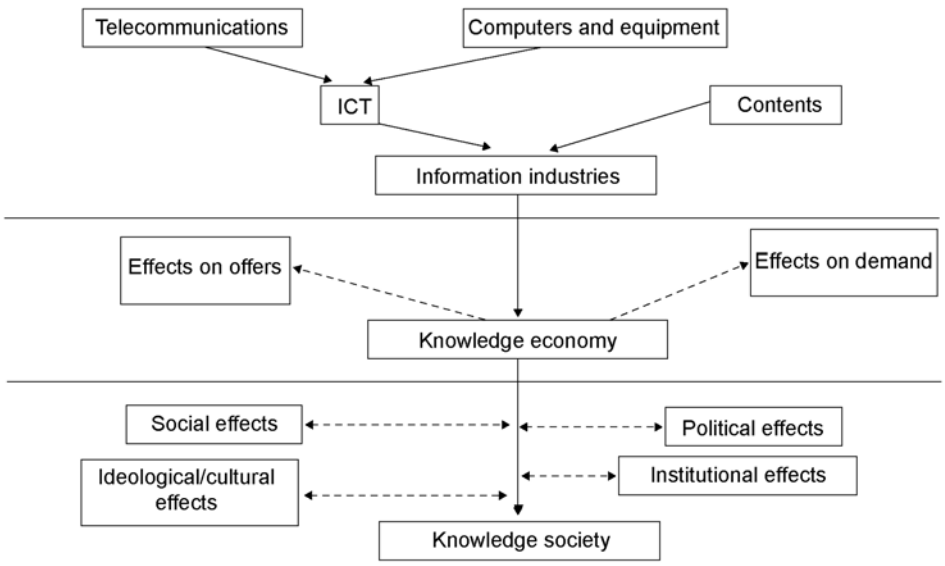
In fact, apart from the structural change that is presupposed on the appearance of a new productive sector which associates ICT-production goods and services with the traditional content industries, a gradual incorporation of knowledge into economic activities has become apparent in numerous ways over the last years. Through the high involvement of ICTs in the production of several important branches of activity, such as financial, commercial and

14. Shapiro and Varian (1999); Vilaseca and Torrent (2005b).
15. Torrent (2002).
16. Torrent (2004).
17. OECD (2003); Jorgenson, Ho and Stiroh (2005); Mas and Quesada (2005).

tourism-related services, and in companies and in certain capital-goods manufacturing industries, on the one hand. And on the other, knowledge resources have also been increasing their presence in production branches which are less intensive in their use of this input, such as certain textile-industry companies, for example. Knowledge has also appeared with new forms of distribution and consumption, changes in business relations and new financing methods. In other words, it is not just that the knowledge economy is based on companies at the digital heart of economic activity (the so-called dot.com or new economy companies) but the gradual productive incorporation of knowledge too reveals itself through changes in offers (new approaches to conducting business and working, to interaction between companies and to innovation, etc.) and changes in demand (new forms of consuming, changes in investing mechanisms or changes in external relations) of the economy generated by the intensive use of ITCs and their digital content.

On the social side, as could it not be otherwise, consolidation of the knowledge-based economy is causing significant changes to the whole network and to social relations. Changes to the labour market, ideological and cultural effects, institutional and political transformations and, in short, new forms of relations between individuals and their environment have all shaped some of the effects of the intensive economic use of knowledge on its sociological and institutional foundations. Figure 1 is a schematic representation of the interaction process between technology, society and the economy in the new context defined by the progressive significance of knowledge.

**Figure 1. A schematic representation of society, knowledge and the economy**




Source: Vilaseca and Torrent (2001)

From the economic-analysis perspective, the knowledge economy's consolidation raises new study aims and challenges. If we are to conduct a logical investigation into knowledge as a production factor and exchange commodity, we must bring with other focuses of interest into the equation. First, a behavioural analysis of economic agents, whether these are companies, consumers or the public sector. This approach leads us to a sectorial analysis of knowledge-intensive branches of production and to a study on connections with other branches of activity. Second, it is important to analyse the changes made on the sources of economic growth through intensive use of knowledge, as well as the connections with the other two basic production resources: capital and labour. Finally, we should not forget that this strategic and intangible resource changes some of the analytical requirements of economic development. In fact, the knowledge economy adds new dichotomies and contradictions to the traditional disparities of capitalism: the people, companies, sectors or economies that are connected or admitted to the global knowledge network *versus* the people, companies, sectors or economies that remain disconnected.

## 1.2. Digital technologies and value-chain changes in business activities

Where increases in productivity and competitiveness within a knowledge-based economy and global society essentially stem from learning (or unlearning) capacities, innovation, flexibility and the enterprising initiatives of economic agents, there can be no doubt that companies[18] constitute one of the economic agents that are most involved in this process of change. Everything seems to indicate that ICT use in companies is consolidated as one of the basic tools for adaptation to global, flexible schemes and networking production and demand. In other words, the knowledge economy moves to company activities on the basis of a two-fold dynamic: the centralisation of capital and the networking decentralisation of production activities, the consolidation of which the network company is a clear exponent. Let's look at this step by step.

As we were saying, company activities have demonstrated a significant transformation process in connection with the inrush of digital technologies and the growing presence of knowledge in the economic sphere. Network companies are the strategic, organisational and productive result of this broad range of changes. They appear through the networked decentralisation of each of the company's business units. In the words of Professor Castells (2001), they are "an organisational form constructed around a business project that results from the cooperation of the different members of various companies which operate within a network for a business project's duration and reconfigure their networks for each project to be carried out". Such an organisational model, which clearly differs from those based on company networks, pre-supposes a change in company management over to a variably-configured system of cooperation and competitiveness and arises from the decentralisation process of large companies and the inter- and intra-connection of companies of all sizes. However, this new company scheme, which refers to the model on which the activity is organised, is based on a powerful technological tool, ITCs. In this context, e-business refers to the way in which company activities are carried out. That is, through IT and telecommunications networks. According to Professor Castells (2001): "production activities, whose key operations, such as management, finance, innovation, production, distribution, sales and employee-customer relations, take place on and over the Internet or other IT networks, without prejudging the degree of connection between the company's virtual and physical dimensions". E-business is simply a different way to conduct business, based on an intensive use of information and communication technologies. Consequently, network companies,

18. By company we understand a set of dynamic resources and capacities organised under a specific strategy, taking on risk and aiming to gain profit. For a detailed and recent analysis of economics and company theory, see Valdaliso and López (2000); Ricketts (2002).

and therefore e-businesses, not only adopt every new production activity arising from the productive use of ICTs (or information industries) they also include traditional, production activities which incorporate ICTs and become networked as essential tools for chain-value generation.[19]

If we wish to analyse this important set of company-activity changes, understood here as the interrelated combination of a strategy and an organisation, we shall have to analyse how both the strategic and organisational model and the actual company activity have changed. This is exactly what we shall be doing in the next pages. First, we shall learn how the consolidation of the knowledge economy establishes a new organisational model of the companies which is based on external and internal business networking and, second, we shall analyse the principal changes that take place within companies and which are obviously connected with environmental changes.[20]

The development of company-activity organisational models towards networked structures must be set within the framework of studying the impact of technological innovation processes on company-activity strategy and organisation dynamics.[21] In this context, and in line with the theoretical development of the network concept, new investigations into company economics have gradually been abandoning the traditional exogenous concept of technology and focusing their analyses on the endogenous interpretation of technological progress.[22] Not only that, but with the consolidation of the knowledge economy, there is a noticeable shift of priorities in research on companies focused on studying intangibles and production orientation towards a global and changing demand. In other words, as always

19. Our analysis' basic economic tool is the value-chain of corporate activities (Porter, 1985). For the purpose of analysing the sources of competitive advantage, the value chain examines companies according to their strategic activities and analyses the behaviour of costs and the current and potential sources to product differentiation. This representation of the companies divides their activities up into two large groups, support activities which have a transversal character and primary activities which are properly speaking those of production and marketing. More specifically, there are three support activities. First, the company infrastructure, which includes general administration, organisation, accounting and finance activities and legal and tax activities, all activities that support the chain set. Second, human-resource administration, that is, research, recruitment, training, development and stay-payment activities. And third, technology development, that is, all activities oriented towards creating innovations. As for the primary activities, we differentiate between two operational activities, marketing and after-sales service. As for operations, we distinguish between supply activities, associated with receiving, storage and making primary materials and semi-finished products available for productive activities; production activities, which are those associated with converting resources into final products; and distribution and storage activities, and physical distribution of final products. We find that the commercial-area group has, first, marketing and sales activities, that is those relating to providing buyers with the means to buy products and/or to prompt them into buying them, such as advertising, sales forces and channels and prices. And, second, service activities, in other words those relating to service provisions for maintaining or increase the value of products, such as the installation, repair or adaptation of products.

20. Competitive forces are an analytical model for significant factors in the definition of corporate strategy, that is, the instrument which helps us provide companies with long-term orientation, while adapting the resources and capacities that are available to the environment. There are five of them: Suppliers' negotiation powers, clients' negotiation powers, the threat of substitute products, the presence of real competitors and, outside a product's actual market, the possibility of new competitors entering the market.

company economics analyses organisations and their management although it currently gives priority to new competitive elements, such as relations with the environment, the role of people and their knowledge and the decentralisation of production activities.

Technology has been traditionally regarded as a resource in the service of companies. From Adam Smith and the classical economists, technological innovation has been considered to be something exogenous to company activities. According to this notion, which classical company economics has reproduced, production improvements could only occur through increases in productivity; in other words, through a more efficient combination of production resources. This exogenous approach does not question the bases of company strategy or organisation, because it is understood that technology does not affect (is neutral to) the productive development of company inputs. For this reason, no technological innovation process may cast any doubt on the true essence of company activities, being based on division of labour and specialisation according to roles and hierarchies.[23]

On the other hand, the idea of company-activity networking is also linked to the concept of environmental relations and has its origins in the classical approaches to company economics.[24] With this classical experience, subsequent contributions have developed and applied the concept of activity networking, which is construed, however, as a network of companies in which one of the companies acts as an integrator of the roles that it has decentralised. Its principle is the reduction of transaction costs,[25] although the limited strategic integration of the various chain-value elements does not allow any advancement at higher levels of decentralisation.[26] Even so, the significant links that are currently found between digital technologies and the profound changes of company activities are hard to explain within the

21. Business-management general theory has been preoccupied for several years now with the technological impact on the organisation of corporate activities. See, *inter alia*, the works of Chandler (1962); Mintzberg (1984); Porter (1985; 2001); Piore and Sabel (1990); Navas (1994); Langlois and Robertson (1995); Johnson and Scholes (1996); Brynjolfsson, Renshaw and Van Alstyne (1997); Canals (2001); Vilaseca, Torrent and Cabañero (2002).

22. This approximation does nothing more than transfer over to company theory the view developed during the 1980s by economists such as Robert Lucas and Paul Romer. This endogenous view of economic growth interprets the progress of economic activities as a result of advances in factor endowments and technological changes, which is not independent of productive factors.

23. In Adam Smith *Wealth of the Nations* he had already verified that the productive efficiency of a needle-making factory could grow through the division of labour (specialisation) and use of better machinery. At the start of the 20th century, the theories of Frederick W. Taylor discussed achieving greater efficiency by using a similar specialisation model and making better use of tools and individuals.

24. Taylor (1961); Fayol (1961).

25. Costs linked to any economic transaction whatsoever, ranging from research and information costs to production and implementation costs and contract warranties.

26. For a detailed analysis of the introduction of technology, flexible production schemes and global competitiveness effects on the networking of companies, see, starting with the seminal work of Woodward (1965), up to the more recent works of Salas Fumás (1987); Piore and Sabel (1990); Milgrom and Roberts (1993); Langlois and Robertson (1995); Coriat (1995); Harrison (1997).

framework defined by the company network. While corporate designs have already been tending towards organisational flexibilisation for many years, the ICT outburst is diluting classical limits to activity decentralisation and enabling a design that is based on networking all the value-chain's elements.

In other words, the company environment's competitive development, under the heavy pressure of the globalisation process, involves a planning of strategies that require highly-decentralised organisations for achieving increasingly-higher levels of efficiency. Company organisations may be defined according to two basic variables: the technological complexity of activities and their transaction costs. It is often the case, in a highly-competitive environment, that companies need high technological complexity to obtain profits through cost reduction and product differentiation. These levels of complexity require collaborative (or decentralising) strategies to be implemented with other companies that put such technologies to more efficient use. This strategy, moreover, has an additional advantage: it enables companies to concentrate their production within the core of their business. In short, the overall efficiency (company plus collaboration with company having the technological expertise) tends to exceed that of an integrated company. This process takes us to the network of companies. Nevertheless, the intensive use of ICTs presupposes a qualitative jump in this technological decentralisation process, given that improvements in obtaining, processing and managing information and knowledge within all the elements in value chains enable us to consider an organisational structure based on networking all the value-chain elements. Indeed, the most important change to company activities within the knowledge economy is the fact that digital technologies allow the networked decentralisation of all lines of business along a variable, geometric system of all the organisation's value-chain elements. In other words, ICTs enable the step to be made from networks of companies to network companies, moving beyond the concept of technology as a resource and integrating it as a central element in company culture, which is translated into strategy and therefore into organisation.

In fact, we may even state that companies are a network, and that as such they have six principal features. First, network companies are only possible through an internal cultural change. Network companies are the result of a strategic and organisational change requiring a preliminary, internal corporate culture that places networking at the centre of its own definition. Second, network companies combine specialised assets, often intangible, under joint control. A strategic integration of suppliers and clients into the organisation leads us to a global perspective of all the resources used for achieving milestones and targets, under a common corporate culture. This strategic connection, which enables synergies between highly-efficient nodes, enables joint projects with greater complexity to be undertaken. Third, network companies stem from decision-taking that is based on knowledge instead of hierarchy. Using ICTs eliminates some of the routine tasks of work, so enabling workers to develop their own abilities to take decisions. This puts knowledge specific to the workplace at

the decision epicentre and progressively replaces hierarchical relations. This change transforms worker-company relationship and defines a new consideration model (as well as new contradictions) which focuses on controlling activities and taking decisions. Fourth, information and knowledge management in network companies is based on several direct communications that supply all of their nodes. ICTs reduce transaction costs to the point where the latter stop being the organisation's central criterion, to the advantage of knowledge and its nodal relations. Fifth, network companies are organised into multidisciplinary work teams of variable form. Specialisation based on knowledge and direct communications enables variable and specific multidisciplinary work teams to be set up for each business project, so breaking the traditional barriers of functional areas. Once the projects' strategic aims have been achieved, these teams are flexibly relocated to other projects. And, sixth, relations between members of network companies go beyond the traditional contractual ones which are based on price, functional features and service level. The high degree of strategic integration established by network companies shows the inadequacy of the above three elements, which characterise relations between two companies. New variables, such as the capacity to adapt to different corporate cultures and the confidence to share important information, are formed as significant to relations between the various networked business units.

In short, network companies presuppose breaking with the classical principals of corporate organisation and strategy. ICTs alter the design of the workplaces, the establishment of hierarchical relations and relations between the various components of corporate activities (areas and processes). The division of labour in network companies is based on the division of knowledge: workplaces are designed to have the human factor play an active role in their activities, so transforming hierarchical relations and setting decision-taking within the workplace. Establishing knowledge as a central element in corporate organisation and strategy is therefore only feasible where the relationship between the activity's components are networked, since the old forms of coordination based on pyramidal hierarchies prove to be unworkable.

We can furthermore assert that the actual strategic-definition process has undergone important changes over the last years. Strategies are conceived and designed in network companies through various nodes of corporate activities, so that an intensive use of ICTs is compatible with a flexible and networked strategic design. The requirements of a larger technological complexity, and achievements of a level of global efficiency, compel company officials to take account of decentralised knowledge in their strategic-design planning. It is not so strange then that the knowledge economy's agenda includes the increased strategic-integration level of suppliers and clients as well as activities for obtaining and managing information from (existing and potential) competitors and the threat of substitute commodities.

We may therefore conclude that networks are established within the knowledge economy along the organisational model of companies at an advanced stage in ICT use. In fact, while the firm or corporation is the unit of capital accumulation, property rights and strategic management, corporate activities develop within networks, so that global-economy response capabilities, ongoing requirements for innovation and regular changes in demand can now be dealt with. The advent and productive application of ICTs propel, promote and enable rapid development of these production schemes, for both internal and external company relations. Indeed, whereas corporate activities during the 1980s were organised on the basis of external decentralisation, with the appearance of outsourcing and other subcontracting models, this model has been coexisting since the 1990s with a new one, the network company, on the basis of internal decentralisation, which presupposes workplaces to be located within and without corporate organisations.[27] That said, there is nothing arbitrary about implementing this model. On the contrary, it continues to respond to the maximising logic of capitalism. As empirically demonstrated by a set of recently-conducted investigations,[28] productivity increase in significant groups of companies or activity sectors arise from the interrelation existing between digital technologies, knowledge and the establishment of the networked work force, strategy and organisation. This leads us to study the productive effect of e-business, which we shall immediate carry out.

We have already mentioned that suitable technological assimilation has direct implications for company performance. We could summarise these by dividing them up into a first group of productivity improvements: better quality of the final product/service, cost reduction and larger production capabilities and into a second group of competitiveness increases: adaptation to client and supplier preferences, product and process diversification and innovation improvements. ICTs, as with any other technological development, also affect corporate activities, although their effects must be assessed as a significant internal and external restructuring.[29] Following this order of ideas, we may assert that corporate activities resulting from intensive use of digital technologies are structured around four key elements:

First, simultaneous work and a high level of information and knowledge exchange. We need only glance at our worktables or workplaces to notice how substantially the tasks to be carried out have changed over the years with the inrush of ICTs. Concepts such as flexible and

27. Apart from the networked decentralisation of corporate activities, the advent of the knowledge economy has not changed the other great result of capitalist development: the concentration of capital. Although our theses basically refer to changes in productive activities, this is an element that without doubt deserves more attention. Not only because the process of channelling savings towards investment is vital for developing productive activities, but also because the financial sector itself is established in a key productive branch of capitalist development.
28. Black and Lynch (2000); Bresnahan, Brynjolfsson and Hitt (2002); Arvanitis (2003).
29. Colet (1998); Cuesta (1998); Cortada and Hargraves (2000); Magreta (2001).

multidisciplinary work teams, simultaneous roles and information exchanges are on the agenda in today's corporate activities. Second, the possibility of gaining in scale without increasing in weight. This relates to the possibility of harnessing synergies, once the initial version has been realised. In other words, intensive use of digital technologies makes it easier to adopt a suitable dimension for each project, without having to concentrate all the investment and expenditure, yet again, into essential resources in order to carry it out. Third, outsourcing activities having less added value. This converts fixed costs into variable ones. And, fourth, changes in economic and financial valuations of corporate activities. The growing importance of knowledge and intangible assets has led to notable changes to methods and results in the financial valuation of each of these groups of assets, so undermining the traditional approaches to corporate assets.

The four aforementioned elements have consequently led to the application of central-structure reduction strategies, planning organisation charts and outsourcing elements with less added value. In addition to these organisational changes, digital applications also provide a new approach to dealing with activities that companies carry out. Function-based organisations are taking on a higher level of thoroughness and turning into dynamic, flexible and process-based organisations which aim to adapt to global and changing demands. In fact, the new orientation of demand towards the market means going beyond classical competitive variables, which are based on the differentiation of price, product and service, and presupposes a deep knowledge of demand for enabling production adaptations to clients' preferences. In this new context, the change and improvement culture carries on through innovation and becomes significantly integrated into the network-company framework, while fostering individual-initiative capabilities and ensuring that each person is capable of enterprise, team work and internalising the organisation's values. New companies are moreover characterised by a flexible production system which adapts to the changing dynamics of the market and by a management system that is coordinated and shared by all the organisation's creative value-chain nodes. It is evident that such new, networked company organisations provide solutions to old problems of allocation and efficiency. That said, we would be less than truthful if we did not acknowledge that such organisations generate new problems and contradictions relating directly to this need for flexible work and the possibility of individualising employment relations. We shall analyse all these corporate activity changes below in further detail.

We were saying earlier on that e-business is simply a new way to do business that is based on the intensive use of digital technologies and which we could summarise as the productive application of network companies. One way of examining all the changes that corporate activities are undergoing through intensive use of ICTs is to analyse each of their parts. As with our explanation of network companies, we shall also see below how value-chain elements in corporate activities are changing.

We shall begin by analysing organisational elements. The basic idea is that e-business is the appropriate tool for networking corporate organisations. To see this, we shall investigate the changes in parameters to the organisational design of corporate activities. Our starting point is the classical model, according to which the organisation of a company is based on four essential elements: workplace design, superstructure design, lateral links and decision-taking system design. As for workplace design, it is logical to assume that division of labour under the new knowledge-based economy is made according to the key economic-activity resource – knowledge – and not in response to other functionalities such as, for example, manual skills. This feature, the productive significance of knowledge, takes us towards another organisational trait in knowledge-based companies: workers progress from merely performing their work to controlling a good part of it. In fact, the logical consequence of locating knowledge at the centre of productive development and providing larger degrees of autonomy to work teams is a larger control of output by workers. This often creates tension within companies because the nature, with significant degrees of intangibility, with neither the production process nor the final product enabling the knowledge used or obtained to become at all observable. In other words, if flexible, multidisciplinary work teams with a knowledge-based production specialisation are the basic organisational core of network companies, the visibility of their production processes is much less, and therefore the possibilities of companies to codify their practices much smaller, than where the basic organisational core consists of the classical departments or functional areas, with a workplace division based on manual functionalities.

Another organisational element to take account of is the superstructure design, or rather the work group. At this point network companies are characterised by the department or functional area ceasing to be the basic unit of the work group and hierarchical relations no longer being solely pyramidal but networked too. This does not mean that company officials allow complete room for manoeuvre with operational work. On the contrary, technological possibilities enable strategic and tactical work, once the aims have been set, to monitor the performance of the operational work network with a certain independence from its internal organisation. As for lateral links, it is not at all unusual that communications and information management within the various organisational cores of companies have substantially changed with this reticulated structure. In network companies inter-node links are made point to point, that is, once ICTs are used there is nothing to prevent two people from different units being in communication. Finally, and on the matter of operational decision taking, we have already mentioned this is located at the work place, an obvious result of the intensity of knowledge-based work, organisation flexibility and hierarchical relations with higher levels of freedom. Therefore, from the company-organisation perspective, we have seen how the intensive use of digital technologies and knowledge can act as a catalyst for significant changes in work-place divisions, designs, relations and decision-taking. That said, a company is more than a strategic and organisational model, given that its management ap-

plies to a production process that combines inputs and generates outputs. However, it remains for us to analyse how digital applications and intensity in knowledge change the productive use of capital, labour and production practices.

Let us start with changes in capital resources and their principal use in companies: investment and financing flows. We shall maintain here that the origin of network companies is to be found in the change of capital markets. Despite the financial crisis of companies at the core of the new economy, the spectacular volatility of the stock market during the 1990s and start of the new millennium was not merely caused by speculation and exuberance but had a real basis as well: structural changes in finance markets. These could be summed up in three. First, they are global and interdependent markets, given that electronic transmission of securities is so significantly transforming the international finance system that everything seems to point to a shift towards a global and electronic network of capital markets.[30] In fact, online investment increases capital-market volume, promotes disintermediation possibilities, quickens response capacities and shows information and knowledge to be critical factors in decision making. The result is an increase in market volatility, since its complexity, size and speed generate a rapid action-reaction model for investors using telematic networks. The second element to be noted is the process of financial valuation. The break with the classical relationship between earnings and prices of shares (PER) shows how company valuation in financial markets is gradually moving away from book value. This is due to the interpretation that markets are making of intangible corporate assets, such as technological investment,[31] the combination of the latter with organisational changes, trademark policy, corporate image, efficiency and accuracy in management and the activity sector. In this regard, it should be pointed out that any action connected with ICTs has all too often received a premium (rising during growth and dropping during a depression), irrespective of the degree of risk and actual yields of the companies analysed. And third, we ought to mention that markets react to macroeconomic conditions and to political decisions. In such a context, information turbulence, which, together with ITCs, is effecting the (self-fulfilling) expectations of economic agents more rapidly than ever before, is one element that needs to be seriously considered if we wish to understand the actual functioning of financial markets.

Indeed these systematic changes in financial markets are having significant repercussions on the value-chain's determinant elements, the capitalisation process of corporate activities.

30. For a detailed analysis of systematic changes to financial markets, see Tugores (1997); Eichengreen (1999); Gupta (2000); McMorrow and Roeger (2004). As for the study on links between the new economy and financial markets, see, inter alia, Shiller (1999); Brynjolfsson, Hitt and Yang (2000); Garber (2000); Mandel (2000); Volcker (2000); Eichengreen (2003).
31. Some studies show that each dollar invested in installed computers proves to have a market value of five dollars for the company. See, Lucas (1999).

By investment and financing flow we mean the circular flow that describes the course of financial resources, from receipt to materialisation in functional elements. This circuit describes the mechanisms of converting savings into financing and, in turn, of financing into investment. Or, in other words, how it moves from its source to the application of corporate-activity production resources. What then is the impact that ICTs have on this process? To visualise this, we shall group three well-connected aspects together. First, we shall analyse the changes in the circular investment and financing flows of companies, and this shall take us to the second, an analysis of the structure and calculation of operational costs. We shall conclude this by looking at the financial components of corporate activities, with an analysis of corporate-management indicator and information systems.

The corporate financial circuit starts with the conversion of savings into financing through a series of intermediation mechanisms and institutions, whether indirectly through foreign financing or directly through holdings in the company's actual funds. Such financing applies to two types of destinations: investment in production elements (or, operational activities) and/or financing based on placing surpluses of liquid assets to other companies or individuals (or, financial activities). Both investment destinations aim at achieving incremental profits. These corporate financial surpluses are in turn a source of resources, which may be allocated to the direct financing of corporate activities (operational and/or financial) or used for financing other companies through, once more, the indirect mechanisms of allocating savings .

Having reached this point we may now maintain that ICT incorporation affects this circular, corporate investment and financing flow in three ways: it reduces operating cycles, improves the structure and profitability of financial activities and changes the functionalities of operational investments. In fact, the reduction of the operational cycle of corporate activities (or, cash-commodity-cash conversion process) can be explained by the acquisition of financial funds at a lower level of intermediation. This is related to the outburst of digital financial intermediation entities and their synergistic effects on traditional entities, which makes the channelling of savings into investment faster and more efficient. Furthermore, this change in the type of financing obtained helps avoid the need for additional financing and enables both a reduction in capital costs of financial funds to be reduced and an increase in available liquid surpluses. A faster, more efficient capitalisation of corporate activities is therefore combined with a change in the functionality of operational investments, and this has a greater effect on intangible elements. In short, network companies have new elements at their disposal which affect the composition and yield of investment decisions, as well as the manner of taking on, composing and structuring financial costs. All said, it changes the typology of links that exist in companies between source and productive application of financial resources.

Changes in investment functionality have another, more distinctive effect from the point of view of providing value to companies. This has to do with the incorporation of new production resources and the change in structuring production costs. New organisational models arising from ICT integration into companies allows optimisation of cost structures on the one hand, basically by the effective displacement of fixed costs to variable ones, and reduction of management costs on the other.[32] This situation is a direct consequence of the automation of information processes and the outsourcing of activities which offer no distinctive competence. ICTs and the network morphology of corporate activities have enabled such decentralisation of operative units, delegation of costs and assumption of risks for the performance of specific activities.

On the other hand, the productive development of knowledge-based companies clearly demonstrates the existence of productive intangible factors having increasing effects on product valuation but which have not, until now, been adequately integrated into corporate production tasks.[33] Furthermore, these intangible factors show a positive correlation with corporate productivity and allow a significant improvement in economic yield. And, finally, it is evidently confirmed that these intangible factors are clearly identified with infrastructures and organisational structures, with work and with the incorporation of ideas into production activities.[34] The main analytical problem raised by such an intensive use of knowledge is the increasingly significant use of production factors, the consumption of which features as an indirect activity cost. The challenge consequently presented from this perspective is that of searching for a cost model that enables adequate integration of the various elements involved.

This growth in intangible element investments takes us to a remarkable divergence between stock-market indicators and accounting indicators, which have been used for decades, in order to determine the development of corporate management and promote investment decisions. This paradox in business expectation indicators has created a need for devising new indicators which bring management information closer to the value perception that derives from financial markets. Network companies therefore find themselves in need of expanding their indicator systems for management. The route that is taken is as follows: starting from the more classical variables of situation, economic yield and internal finance, it works through extending information towards the sphere of the composition and yield of the human factor, quality, performance and relations with clients and suppliers, organisational efficiency and measure of technological efforts. The impact of ITCs on corporate activities has highlighted the need for measur-

32. Shapiro and Varian (1999).
33. Brooking (1997); Bueno (1998; 2002); Edvinsson and Malone (1999).
34. Brynjolfsson, Hitt and Yang (2000); Porter and Stern (2000); Vilaseca, Torrent and Castillo (2003).

ing other types of capital that are more intangible than physical, such as human capital (deriving directly from the work factor), structural capital (deriving from the organisational structure), relational capital (deriving from the relationship between economic agents, including suppliers and clients) and technological capital (deriving from innovation processes and the incorporation of technology into operational activities). In short, by observing the composition of the financial or production structure of companies which makes intensive use of ICTs and analyse the activities there that make up their value-chain and systems, we shall come to an important conclusion: network companies, as with any company, use both tangible and intangible resources. Thus, the massive incorporation of knowledge into corporate activities gives more of a leading role, and this means more direct involvement in obtaining results, to intangible elements.

If valuation in financial markets is the basic tool for valuing a company's profits, work continues to be the main source of productivity, innovation and competitiveness of networked corporate organisations. It is not unusual therefore that work acquires, yet again, considerable importance in an economy that increasingly depends on capabilities and skills for processing information and generating, applying and disseminating knowledge. However, this renewed importance is combined with the emergence of a new type of work: network work. We understand this to be the organisation of basic production in the knowledge economy.[35] Furthermore, the growing use of digital technologies as a tool for adding value to a production, referred to by growing amounts of knowledge, defines a new type of work that is based on three key pillars. First. Work in the knowledge economy requires a level of education, skills and particular abilities. Network work is based on initiative-taking capabilities and on recycling according to needs at the time. New flexibility-based abilities form part of the background where companies depend on work to develop innovation and competitiveness mechanisms required there by the global knowledge-based economy.[36] Such notable training requirements place ongoing learning and training in the workplace at the centre of the professional development scene.[37] Second, such new training-based and flexible work cannot entirely develop its capacities within a rigid and traditional financial and corporate environment. Network work is founded on level hierarchies, team-work systems and open and ready interaction between workers and managers, and between the departments and levels of organisational structures. And third, retention of talent has defined new remuneration policies, the most widespread of which is to pay a part of the consideration for work using instruments based on temporary salary deferrals and this moreover reduces company burdens.

35. Vilaseca, Torrent, Lladós and Ficapal (2004).
36. Osterman, Kochan, Locke and Piore (2002).
37. Ferraté (2002).

Such new forms of co-ownership and co-management all too often come with a price: a high level of needs and commitments with corporate projects, much greater than what is contractually required.

This new organisational formula leads us to the distinction between self-programmable work: trained and flexible work with self-organising capabilities and generic work: that of workers lacking specific qualifications and special skills which, moreover, can be performed using a combination of machinery, local work and external work. In this context, employment and wage stability are giving way to a flexibility-based production and work system so that autonomous, part-time and temporary work, as well as subcontracting and working for variable remuneration targets and models, continue to occupy more and more space within the employment world. In short, employment flexibility, variable work models, diverse work condition and individualisation of employment relations are systematic features of the labour market in the knowledge economy.[38]

Therefore, work changes in companies as a result of ICT use may be identified according to three elements: changes in job supply and demand (that is, in the gradual flexibilisation of employment), changes in the confluence between job supply and demand (that is, changes in the workplace) and finally changes in employment relations (that is, the gradual individualisation of relations between business people and workers). Despite that, employment changes are not only occurring in agreements to offers, demand and labour markets. The environment in which employment relations are set is also changing: ICT use and globalisation as a tool for disqualifying and risking work, new training needs, self-programmable work requirements and commitments, stress, reconciliation of employment and family life, lack of intermediation and wage-negotiation referents, with mechanisms intended for industrial societies, are some of the more significant examples of changes to organisations and institutions that affect the labour market.[39] Table 1 shows some of the main employment changes linked to the outburst of network work in the knowledge economy and compares these to employment characteristics in industrial economies.

38. Castells (2001).
39. Carnoy (2000).

**Table 1. Network work in the knowledge economy and work in the industrial economy**

| Employment characteristics | Knowledge economy | Industrial economy |
|---|---|---|
| Basic technologies and their employment incidence | Information and Communication Technologies (ITCs). Replacement of mental skills | Industrial application technologies. Replacement of manual skills |
| Corporate production and organisation | Made-to-measure/differentiated. Network company doing e-business | Standard. Company networks with Taylorist, Fordist or Toyotist organisation |
| Notable production factor | Knowledge and non-manual work | Physical capital and manual labour |
| Training required | Ongoing training and on-the-job training | Regulated and standard lifetime training |
| Skills | Innovation and flexibility | Experience and perseverance |
| Work type | Self-programmable | Generic |
| Remuneration | Flexible | Fixed |
| Work organisation | Network organisation: division of labour based on knowledge, multidisciplinary teams, working for objectives, networked links and decentralised decision making | Classical organisation: division of tasks, individual work and grouped into functional areas, pyramidal hierarchy and centralised decision making |
| Commitment | Greater than contractually required | Equal to or less than contractually required |
| Relationship with company | Individual | Collective, through trade-union intermediation mechanisms |
| Corporate value | Flexibility | Stability |

Source: Vilaseca, Torrent, Lladós and Ficapal (2004)

If economic activity is currently characterised by a massive incorporation of knowledge into production, distribution, exchange and consumption, it is logical to believe that one of the explanatory factors for growths in productivity and competitiveness is innovation. For a variety of reasons. Firstly, because innovation, by definition, involves economically applying every type of knowledge with the aim of creating new products and/or improvements in the process and/or improvements in corporate organisation. We can therefore assert that the economic application of knowledge (or, the knowledge economy) is synonymous with the innovation economy, in the sense that both base production development on the economic application of one resource: knowledge. Secondly, because the competitive environment, with a changing global production and dement, turns competitive innovation-based strategies into an indispensable resource in the path to maximising profits. Other competition strategies, such as differentiation in costs or low salaries, may not be appropriate in the global competitive environment. And finally, because the vicious cycle between ICT use and network work capacities makes it clearer when the aim is to apply knowledge to economic activity, or rather, the innovating process.

Economies have often tied long-term economic growth to technological innovation. This association of ideas answers the theoretical and empirical background that classical and modern economists have left us on this matter. The meeting point between the various existing tendencies tells us, logically, that economic growth has a two-fold foundation: accumulating production factors, such as capital and labour, and innovation in economic activity, or rather, technological progress. There are two sources to these facts. The first one is investment and the profitability of this investment, which are the bases of production-factor accumulation. The second one would be investment and dissemination of knowledge, which are the bases of technological progress. Nevertheless, there has not always been a consensus on the explanation for the sources of economic growth. Indeed, it used to be otherwise. The role of technological innovation in explaining economic growth has been the subject of intense academic debate that lasted up to the second half of the 20th century.[40] It has taken on a new lease of life since the outburst of digital technologies.

We have however come to a significant conclusion: innovation is vital for the economic future of people, companies or even nations. Furthermore, when we probe deeper into the analysis of the dynamic innovation process' determining factors, we find numerous issues that we had not initially taken into account. It is precisely the consideration of innovation as the intended application for each type of knowledge to economic activity that leads us to a broad view of innovating processes, to the point of considering elements missing in the traditional approach to economic growth, which only considers scientific and technological knowledge.[41] The view presented avoids such classical outlines and considers the economic incorporation of all types of knowledge, such as technical knowledge and the capacities of economic agents. We shall therefore consider both the elements of both formal and informal innovation. In addition, we shall also consider all of the actors in this process: from those that are directly involved in production plans to all the institutions and elements which, without being at the forefront, also carry some notable weight in explaining economic growth.

Therefore, on a basic level and with regard to the determining factors of innovation, we find elements directly linked to production factors, such as investment in education and scientific and technological systems, investment in physical capital and innovation financing, as well as aspects of company training and factor mobility. On the second level, we can consider a second set of components relating to technological aspects, such as technological dissem-

40. Cf. *Inter alia*, the works of Solow (1956; 1957; 2001); Romer (1986; 1994); Lucas (1988); Arthur (1994); Dosi (2001); Antonelli (2001); Torrent (2004).

41. At this point, keeping in mind the thoughts of Marx and Schumpeter, mention must be made, for their subsequent importance, of the broad visions of technological progress put forward by Rosenberg (1976) and a group of economists at Sussex University: Dosi et al. (1988); and Lundvall's approximation to national innovation systems (1992).

ination, technology costs and access, network work capacities and links between the economic creation and application of knowledge. And on a third level, institutions and the structure of markets also play an essential role in support policies and in promoting innovation, in such a way that these aspects, which figure under the heading of national innovation systems, are determining factors in explaining an economy's productivity and the competitiveness increases. We can distinguish two groups here. The first affects production-factor markets and competitive environments. Among these, we can distinguish labour market regimes, regulation of the environment, macroeconomic policies, the characteristics of financial markets and training policies. The second group affects strictly innovation policies, among which we may point out scientific and technological policy and the adaptation, promotion and redistribution policies of change.

In following this order of ideas, it is important to mention that the incorporation of ICTs into corporate development changes not only the determining factors of innovation but also the behaviour and nature of innovation. To verify this, we must be capable of identifying certain specific aspects that have traditionally had influential capacities during the justification of corporate innovation processes. As a starting point, we should analyse whether these variables, with the outburst of ICTs, still exercise their explanatory powers. Among these, there are factors within companies, factors tied to their environment, offer factors, demand factors and factors relating to company ownership. Second, it is important to set the innovation process within the company’s competitiveness strategy, so that identification must be made of its business strategy and, therefore, of what the competitive advantages would be where there is a desire for these to be exploited using such innovations. Third, it would be appropriate to discover the company's view on some of the potentialities of ICTs as innovation-stimulating tools. This comparison would have a two-fold perspective, ICT use as a means to innovation and ICT use as a means to overcoming current obstacles to innovation. And fourth, it would deal with identifying process, product, organisational and other innovations carried out through corporate activities. In short, we may conclude the cross-sectional view of value-chain elements to asset that ICTs are determining factors in the innovation process of network companies, seeing that they not only enable better interconnection with the agents involved in applying knowledge to production activities but also affect the nature of the innovation and orientate it towards the process.

Basic value-chain activities, on the other hand, relate to operations, marketing and after-sale services. As for the operations area, which include supplies, production and distribution, we should add that these are clearly affected by networking activities. There is no doubt that supply and distribution activities (as we consider suppliers or clients) take on a new meaning within the knowledge economy, since they go beyond the classical notion of operations that aim exclusively to make necessary resources available to the production system. Network companies and new ways of conducting business give a

new meaning to this role, while integrating business units, with a high degree of relating to and taking part in strategic designs. At the same time, production activities are being increasingly based on the idea of linking up products and services that have been produced by different components in the network. This set of changes to the operations system can be summed up as follows: intensive ICT use turns basic operational activities into a central decentralising tool for the company's activity lines and enables production to be directed towards the process.[42] In fact, the orientation towards demand required by the knowledge economy leaves hardly any room for manoeuvre to operational activities, which have to abandon their classical orientation of standard production focused on products and on entering new differentiated and made-to-measure production plans. The path for achieving this inevitably passes through accelerated and improved information flows as well as through a greater strategic integration of suppliers and clients. Finally, it offers numerous improvements in productivity (increased quality, improvements in the process, reduction in stocks and time etc.,) and in competitiveness (more adaptation to clients, more variety, better response capabilities etc.,) which have one basic objective: satisfying a demand, about which we need more information.

At present, therefore, company operations systems are gradually tending towards network-based designs. Concepts such as supply-chain management or added-value networks prevail within decentralised relations and in inter- and intra-company operation networks.[43] A basic feature of this system is that information and knowledge are definitively located as the production activity's main input, even before its physical aspects.[44] In this regard it is worth mentioning that organisational and technological improvements carried out in a balanced manner enable increases to be achieved in the system's flexibility, which will improve efficiency and make it possible for activities to be orientated towards the process and, in a personalised way, towards clients.

Such a decentralised notion of operational activities is reflected in a change of its strategic focuses. In fact, with the networking of economic activities, the aim is to consolidate cooperative relations with the various components of the logistics networks.[45] Efficient relations between these components are essential for consolidating sources competitive advantages. In this way, the idea of networking operations has consolidated this activity as a key corporate strategic element which, more than ever, is based on providing added value to clients and with long-term relations with suppliers. In short, we may assert that this strategic approach to operational activities, in

42. Brynjolfsson and Kahin (2000).
43. Angeles (2000).
44. Claycomb, Droge and Germain (2001).
45. Bowersox and Daugherty (1995).

conjunction with the processes which break integral corporate value-chains, makes operations following the central axis on which to decentralise the entire company.

In addition, the notion of networking operations presupposes that various business lines act together within a competitive framework. Networked management is based on the principles of association and cooperation, and requires, at the same time, very sensitive information on clients, current demand, information on sale points, strategic plans and similar information to be shared. Therefore, competitive relationships are presently being forged among operation networks rather than between companies. Integrating clients and suppliers into company operational activities gives rise to the notion of Supply Chain Management, from which the concept of logistics systems derives. This is understood as all tangible and intangible assets of suppliers, producers and consumers as well as the information and knowledge processes which connect these assets together. Three basic stages can therefore be defined in the development of operations towards a networked design. The first stage is based on each series of activities carried out independently while in the second stage these activities are integrated on an internal corporate scale and, in the third stage, they integrate suppliers and clients while creating activity networks.

In short networked designs of company operational activities attempt to achieve efficiency in their activities while reducing misappropriation and squandering, lowering terms and improving response flexibilities and lessening unit costs. Achieving these objectives enables companies to orientate themselves more and more towards the process and to increase production variety. In fact, reducing misappropriation and squandering is achieved by eliminating duplicity, by coordinating activities and improving quality. With regard to duplicity, it has been shown that there is a positive relationship between degree of centralisation in stocks, keeping them at critical points in the distribution process, and the levels of efficiency achieved in their management. As for activity coordination, this centres on the definition of valid information systems for all components in the network of operational companies, so that activities may have real-time, relevant and high-quality information available. The aim is none other than to eliminate unnecessary activities and to improve the delivery of products and services to final clients.

In view of all these mentioned aspects, ICTs play a principal role, since they are consolidated as a very useful tool for increasing operational-activity efficiency. This improvement in efficiency is based, among other things, on the possibilities of access to more efficient suppliers. We have one very clear example in the principal corporate technology used for integrating information into operational networks: the EDI system (Electronic Data Interchange). Its development towards an EDI-Internet system allows us to observe improved efficiency in running operational networks. ICTs applied to supplier and client relationships enable simultaneous relations between points, and the universe of companies capable of entering into this network is expanding for all those with access to the Internet and overcoming a large part of the asymmetry in these relations

between the agents in question. All these features allow improvements to client-service quality, efficiency of operational systems and, as a result, company productivity. To conclude then, intensive ICT use allows access to a network of increasingly efficient suppliers.

Finally, it is worth pointing out that ICT use with regard to distributors also allows last-step improvements to be made before reaching clients. At present it is not just efficient production of clients' requirements which is important, but delivering what is asked for at the appropriate time and to the suitable place. In this regard, ICTs applied to distribution improve this last stage, as they succeed in reducing incidents and increase efficiency levels of relations with distributors. It is exactly this productive orientation towards the process to satisfy global and changing demand that takes us to the second basic value-chain element of corporate activities: marketing and after-sale service. Changes arising from intensive ICT use are associated with significant changes in the circular flow of marketing, understood as the dynamic and repetitive process of market research, defining sales strategies and delivering goods to final clients. Having reached this point, we shall contend that the incorporation of ICTs into market research provides better knowledge of consumers, more readily incorporated into the creation of new products, which allows ongoing relationships to be established. In fact, as in the case of the other three corporate-activity value-chain elements, improvements in information- and knowledge-flow management allows us greater efficiency not only in researching demand but also in the actual running of the marketing area. With ICTs, network companies can incorporate knowledge of their markets more quickly and, ultimately, define hyper-segmentation strategies for their clients (*one to one*), even if it is more usual to use digitisation for establishing ongoing relations with their clients. Besides, we should not forget that with digital use, and above all thanks to the Internet, a new communications and marketing channel for clients has opened up, that is e-commerce.[46] By e-commerce we understand goods and services transactions carried out through telematic networks (the Internet, EDI or others) irrespective of the payment and delivery system.

**Table 2. Economic agents and digital exchanges**

| | Administration/ Management | Company/Business | Consumers |
|---|---|---|---|
| Administration/ Management | (G2G) Coordination | (G2B) Information | (G2C) Information |
| Company/ Business | (B2G) Relationship administration | (B2B) Comerç E-commerce | (B2C) Comerç E-commerce |
| Consumers | (C2G) Management administrative | (C2B) Comparation | (C2C) Auctions |

Source: In-house

46. Shaw, Blanning, Strader and Whinston (2000).

If we take account of the new interrelations that can currently be established between three basic economic agents (table 2), administration, company and consumer, more regularly-used consideration of e-commerce is the one that includes the exchanges among companies (business to business or B2B) and/or between companies and final consumers (business to consumer or B2C) carried out through telematic networks, although physical payment and delivery of products may be performed through non-digital systems.

So, as we have already seen, value-chain models recognise marketing and sales initiatives and after-sale services to be primary company activities. These are all tightly bound up with exchange relations, seeing that they refer to the manner, place and form in which companies make offers to clients and satisfy them with a set of supplementary services. The point of these activities is to give buyers offers with the greatest possible value, the purpose being that in the long term this will provide incremental profits. This understanding of marketing activities, sales and after-sales services is based on a market-orientation of companies, the basic principles of which are consumer orientation, coordination with the other chain-value areas and contributions to company growth and stability. Instilling these principles has allowed development of a new marketing concept, sales activities and related services, which promotes the establishment of firm, stable relations with clients. According to this approach, known as relational or relation marketing, long-term company profits are sought by building relations with clients that are based on mutual knowledge, confidence and commitment.[47]

ICTs, as endogenous elements to companies, become the keystone to instilling such an orientation. It is thanks to their use that companies are much closer to their clients. On the one hand, this is because such technologies enable large volumes of information to be quickly gathered, accumulated and analysed, for the purpose of creating knowledge that allows an understanding of the current and future needs of clients (consumer orientation). Besides, such information must be used for taking decisions and has to be capable of dissemination to the other value-chain areas that also require it (inter-functional coordination.) All in all, ICTs contribute to company initiatives becoming more suitable to market demands (contribution to the knowledge and/or stability aims). On the other hand, digital technologies also support the very process that we have just described and, at the same time, establish direct and interactive communications between companies and large audiences of potential clients.[48] Through these types of communications, clients become involved in company decisions and activities, while taking part, for example, in the development and decision making

47. Grönroos (2000).
48. Hoffman and Novak (1996).

of certain stages in the product-innovation process. In short, such greater cooperation provides confidence to and fosters commitment between the two parties, while establishing bases for a stable and long-lasting relationship.

It can generally be stated that ICT use has allowed improvements to the efficacy and efficiency of marketing activities, sales and after-sales services. It is not just with regard to their use in such specific fields as market research and analysis where, for example, we may observe that they enable quick and accurate detection of market composition. This allows new business opportunities to be identified while at the same time helps to discover the inefficiencies of various currently-implemented marketing strategies. It is because of the information and knowledge gathered from consumers, through the use of ICTs, that markets can be more thoroughly analysed. Such knowledge, on the one hand, allows homogeneous segments or groups of potential buyers to be identified while establishing the bases on which to implement market segmentation strategies. On the other hand, it enables the detection of new or unsatisfied consumer requirements and the response to these, by creating and developing new products and services.

Discovering that markets have segments of individuals with different needs, features and forms of behaviour can lead companies to develop different types of actions. These start with developing an innovation within the field of the product/service, in the event that a new or unmet demand is found, and end up with developing a differentiated marketing strategy especially adapted to each of the segments. The latter option becomes more frequent as it is shown that the current product or service offers the value wanted by clients but that the marketing mix through which it is marketed is not appropriate either because the client is not satisfied with one of the mix's variables or because it is found that larger profits may be obtained by adapting the mix to each of the segments.

The variety of features and forms of behaviour among clients along, and the possibility of dealing with them in an individualised manner, actually offer business opportunities for companies that are ready to resort to segmentation strategies while adapting their offer in accordance with each client's individual preferences (one to one marketing).[49] Sometimes the appropriate option involves marketing a product or service that is adapted to the requirements, features, tastes and needs of different consumers. They may even come to play a large role in the design and choice of their characteristics. However, on many other occasions, it is not possible to adapt or create a made-to-measure product/service, since this

49. Blattberg and Deighton (1991).

would lead to such a high increase in production and marketing costs as to be unworkable. On the other hand, there may well be marketing elements which, despite being supplementary to the basic offer, are duly valued by the market and may be provided in a personalised manner. In fact, companies may increase the global value of their products and services when they combine them with supplementary goods, services, information and knowledge. For example, when they adapt prices, communications or distribution methods to the individual preferences of each client.

On the other hand, ICT use for recording and managing information on clients, through complex CRM-integrated systems or simple client-data recording files, becomes extremely useful not just when companies decide to implement segmentation strategies but also in the integral development of the very process for sales. In general it may be stated that the intensive use of ICTs contributes towards improving the efficacy of sales activities, above all when the latter is developed by a sales team. It is because of the availability of information on clients that companies and, above all, their sales teams, are able to understand, anticipate and respond in a personalised manner to the needs of clients, in such a way that this is a first step to change simple transactions into milestones within a relationship process.

Each time it is therefore even more necessary for companies to define specific marketing strategies for each of the various markets and segments in which they act. In fact this becomes a notable requirement when they compete in both conventional and virtual markets at the same time. However, when companies market their own products/services in both these types of markets, it may seem logical for them to make use of a single marketing strategy, if we consider that each environment has specific characteristics and, above all, that the Internet offers a variety of possibilities for personalising offers, it may ultimately be more appropriate to design differentiated strategies for digital environments. However, the possibility remains that they will decide to market within virtual markets products or services that differ from those which they usually market within conventional environments. This decision is not especially based on the fact that there are products whose features make them more suitable for Internet sales (digital goods, search goods, etc.) Despite there being precise examples to support this argument, it appears that it is not the features of products per se which are determining factors for the e-business success, but rather the other aspects of their strategy.[50] In actual fact, it is through designing offers of products and services specific to virtual markets that companies are able to exploit the competitive advantages that come with this new environment.

50. Poon and Joseph (2000).

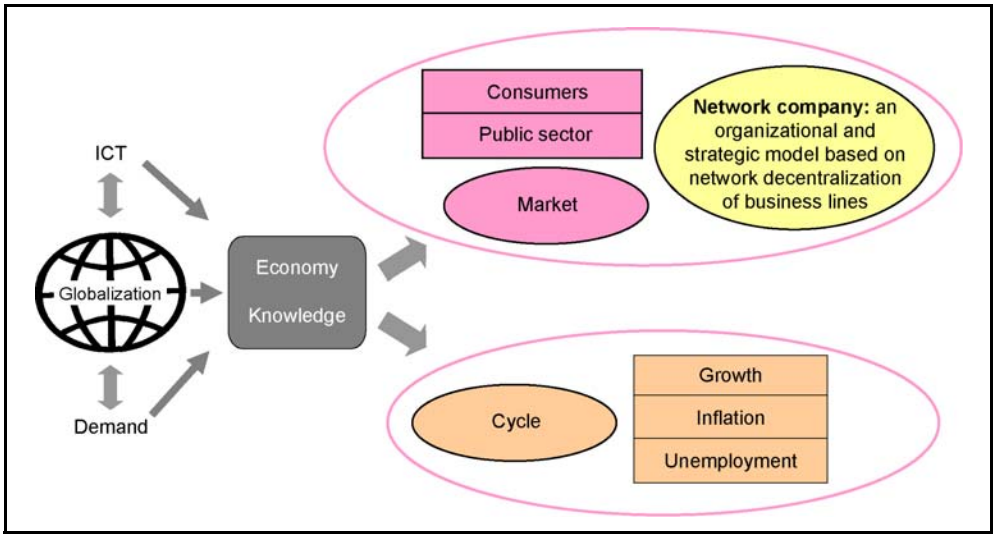
In this context, it is becoming increasingly common for companies to use the Internet to offer their product catalogues and to set up dialogue with stakeholders. This makes it a well-accepted medium, practically consolidated, within the field of marketing communications. Notwithstanding that, the Internet is still an emerging environment in product and service sales, particularly with regard to e-exchanges of companies with final consumers. There is a tendency, despite that, for business figures generated by e-commerce to continue to rise, although the gap between exchanges with companies (B2B) and B2C can be maintained. This is because the first type of commerce is driven by the virtual environment allowing more efficient performance of acquisition and supply activities and because it is not so conditioned by final-demand elements that often fall outside the control of companies.

## 1.3. Research aims and methodology

As we have already mentioned above, the primary aim of this research is to analyse the changes to company performance resulting from the combination of digital technologies and traditional production-activity elements in Catalonia. These transformations, which mean notable changes in the two basic corporate-activity inputs (capital and labour), as well as in corporate practices and the determining factor for long-term growth: innovation, should be empirically verified on the basis of a general hypothesis. As can be gathered from figure 2, ICT convergence, the economic globalisation process and changes in the patterns of demand of economic agents have led to a broad change in economic activities, which we group under the heading of the knowledge economy and which from the economic-analysis perspective may be approached both from the economic-cycle (macro-economy) point of view and from the market point of view, that is, the interaction of economic agents (micro-economy). It is precisely the study of corporate economic agents that this research is focused on. Figure 2 outlines the main determinants of the knowledge economy and the conceptual analytical framework within which economic science has tackled these issues.

Despite the efforts made by various public and private institutions, there is not enough secondary information available to describe the important changes being generated by ICTs in all the economic and corporate activities. While we have significant information available on the penetration of ICTs into companies and some of their more direct uses, there are currently no reliable and representative statistics that deal with how ICTs are changing the entire body of strategies, organisations and production practices or which explain corporate activity performance. In this regard, the research presented below generally aims to gather, structure, analyse and interpret reliable information that is sufficient for gaining an awareness and understanding of the effect of ICT uses, first of all, on their interdependence with production strategy, organisation and practices and, second, how such links change the performance of Catalan companies which use ICTs in relation to those organisations that do not. With this analytical aim, the basic hypothesis we hope to verify is that the gradual generalisation of the knowledge economy changes corporate activities, and that this is carried out through computer and telecommunication networks, or e-business, and defines a strategic and organisational model based on networked decentralisation of business lines, or network companies. In fact, consolidation of network companies takes shape as a basic determinant for productivity, competitiveness, wages and profits.

**Figure 2. The knowledge economy and the network company**




Source: In-house

At this point we should point out that the aim of this research is analytical, although we do not wish to underestimate the descriptive value of information that has been gathered, among other things, as it is useful for in-depth studies of a phenomenon that does not cease to be significant for being new. It therefore aims to make an analytical contribution through verifying the hypotheses put forward in response to the changes of corporate strategy, organisation and practices that result from ICT use and how such changes affect performance in the case of Catalan companies. Nonetheless we are also interested in publishing some of the descriptive results of this research on network companies. Because of the originality of the data obtained, their comparative value, the wealth of information on Catalan companies and the changes of their value-chain elements and their performance we think it is fully advisable to publish and analyse these initial descriptive results. And to establish as well the corporate-performance explanatory models that include networked corporate activities as a dependent variable. It should be noted here that this report is a summary of a research project, the *Projecte Internet Catalunya, PIC Empreses*, which aims at presenting the general public, through a novel approach, with an analysis of the changes in the strategic, organisational and production practices of Catalan companies and a study on the role that these changes play in explaining their performance. Naturally, the panorama described under this research forms only a part of a much broader project, the *Projecte Internet Catalunya (PIC)*, which analyses changes in society, schools, universities, autonomous and local administration and the audiovisual and health sectors. We refer back to the research reports of the project's other investigations to form a broad panorama of sectorial, social and institutional changes in Catalonia.[51]

51. See, http://www.uoc.edu/in3/pic/cat/

We made an empirical verification of the working hypotheses, using the data of a staff survey, formulated as a structured, one-hour-long questionnaire, on a representative sample of 2,038 Catalan companies, stratified according to activity sector and size. The overall significance of this sample was around +/–2%, while the partial significance of sub-samples by the sector and size was around +/–5%. Field work was conducted between the months of January and May 2003. We may already assert from this sample that roughly one third of the companies showed an average or advanced level of ICT use while the remaining two thirds showed low use. Therefore, most of the companies surveyed did not make intensive use of ICTs, although they did show an acceptable level of equipment. However, we also studied, in addition to company ICT use, certain features of Catalan companies, such as the effect of digital technologies on their main inputs and value-chain elements, as well as study of the role played by network company consolidation in explaining productivity, competitiveness and wages.

The questionnaire, somewhat complex, included 128 questions, which were subject to an initial pilot stage (33 interviews). The questionnaire was answered by companies or managers with a comprehensive view of their entire activities and was generally well received. It relied on the collaboration of the staff interviewed, always in person. Furthermore, the study was presented as a non-commercial research by the Universitat Oberta de Catalunya, under the guarantee that its statistics would be confidential, its analysis fully independent and the results obtained freely published. Even so, we completed the data obtained from the questionnaire using the economic and financial information of the sample companies that was available to the general public in the Commercial and Companies Registry and which we obtained through the SABI (Sistema Análisis de Balances Ibéricos) programme. The purpose of including these new variables was to complete the rather qualitative information from the questionnaire with published and relevant data, using quantitative and registry indicators on the evolution of corporate development.

Once we codified the responses to the questionnaire and the analysis of its contents, we created a database containing values from the questionnaire's resulting items plus values obtained from financial and quantitative information. Starting from here, we devised new variables, some out of the initial ones and others by combining their variables and making indicators. Here we ought to mention that to achieve representativeness of Catalonia's economy, and having attained a sample overweighting of several production sectors, for the sake of making a further specific analysis, we re-weighted the database according to certain grossing-up factors in order to represent the world being studied, that is, all Catalonia's companies. In this regard, the analysis conducted from the little more than 500 variables analysed, making up an array of 1 million data on Catalonia's companies, was

carried out according to usual social-science research methodology. In other words, a descriptive and frequential analysis, contingency tables analysing associations between different variables, some data-reduction and conglomerate establishment techniques and, finally, some regression analysis, such as the ordinary-least-square model or other discrete-choice models which aim at establishing the determining factors for specified independent variables.

To simplify drafting and make it easier to read and understand this research, we have made certain associations that ought to be mentioned. As for company sizes, these are initially stratified into 5 typologies: companies with 5 or fewer workers, from 6 to 9 workers, from 10 to 19 workers, from 20 to 99 workers and from 100 or more workers, the following correlation has been made. A company is a micro-company where it has 5 or fewer workers. A company is small where it has between 6 and 19 workers. A company is medium sized where it employs between 20 and 99 workers, whereas, finally, a company is large where it has over 100 workers. We have also simplified the way productive sectors are dealt with. Following the indications of international bodies, in particular the OECD classifications, we initially made use of seven productive sectors: information industries, low-technology industries, low medium-technology industries, high medium-technology industries, high-technology industries, less intensive knowledge services and intensive knowledge services. We have reduced this grouping to 6 sectors, information industries, low-technology industries (which correspond to low-technology industries), medium-technology industries (which correspond to low medium technology industries) and high-technology industries (which include high medium and high technology industries) and less intensive and intensive knowledge services. Table 2 shows the association between the division of production activities according to technological intensity and in knowledge, considered in this research for the purposes of understanding in a better way the digital technological impact on the knowledge economy, and the traditional division according to productive branches of the Catalan classification of economic activities.

The document that we accordingly present below is made up of 3 chapters. After this introduction, where we have revised the general framework defined by the knowledge economy and transition process towards network companies, we shall make a detailed analysis below of the main performance situation of corporate activities and their connections with digital-based innovation processes. We shall therefore deal with the analysis of the explanatory determining factors for the productivity and competitiveness behaviour of Catalan companies. We shall first consider, in each chapter, the state of the art of scientific literature on this matter, in order to analyse straight away the explanatory models of the efficiency and competitiveness determinants of Catalan companies. There will be a summary, at the end of the document, giving the main results identified by the analysis.

**Table 2. Summary table of production activities according to technological intensity and knowledge**

| Economic activity according to technological intensity and knowledge | Traditional economic activities |
|---|---|
| Information industries | ICT sector (IT, telecommunications, microelectronic and optoelectronic teams and services)<br>Training, R+D+i, publishing and knowledge-dissemination activities<br>Digital-contents industries |
| Low-technology industries | Agro-alimentary industries<br>Textiles<br>Wood, cork, furniture, recycling and other manufacturing industries<br>Primary sector activities<br>Other industrial activities not contemplated and construction |
| Medium-technology industries | Metallic products, non-metallic minerals, and metallurgy<br>Energy, rubber and plastics industries and shipyards |
| High-technology industries | Aeronautics and space<br>Pharmaceutical products<br>Medical surgical equipment and orthopaedic devices<br>Machinery and equipment<br>Transport material<br>Chemical industries |
| Less intensive knowledge-based services | Commercial activities<br>Hotels and restaurants<br>Postal transportation and activities<br>Other services not contemplated |
| Intensive knowledge-based services | Financial intermediation, insurance and real estate<br>Company services<br>Social and health services<br>Association activities |
| | |

Source: In-house

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# Chapter 2

# Company-productivity facts and sources in Catalonia

**Joan Torrent, Pilar Ficapal and Ángel Díaz**

One of the main manifestations of gradual consolidation in the knowledge economy, which bases its running on the massive incorporation of knowledge into activities, is the significant increase in productivity that, on both microeconomic and macroeconomic levels, has been observed since the second half of the 1990s. This bullish upturn in product growth per capita and in sectorial and company efficiency has been accompanied by an intense academic debate over the sources and sustainability of this growth. Although it would seem that, from the theoretical point of view, a consensus has been reached on the sources of economic growth, in practice the problems relating to correct productivity measurement continue to be serious. As Professor Gordon, one of the principal researchers on productivity, has stated: "There is no macroeconomic scale more important for the future development of an economy as productivity growth, nor is there anything so difficult to predict".[52]

This difficulty arises for at least three reasons. First, because of the high percentage of employment in the services. It is no secret that official statistics work well when the commodity to be measured is a tangible market product and measurable in both physical and monetary units. Nevertheless, official productivity metrics starts to stagger when measuring output is made more difficult. This happens to services in general, and to public services in particular, and we can no longer say when this tertiarization of the economy combines with a gradual intangibilisation of economic-transaction commodities. Second, insofar as companies progress in forming production and network work, the problem of understanding productivity increases throughout the value-chain of reticulated and globalised organisations becomes increasing difficult. Third, the mismatch (temporary phase shift) between technological revolutions and their impact on production. The history of technology has shown us repeatedly that temporary leaps between invention discoveries, their productive dissemination and subsequent productivity increases can be high. In the specific case of digital technologies, everything seems to indicate that we are under the effects of the first in a series of various innovation cycles which will establish the bases for important productivity increases for the future. Nonetheless, statistical and productivity-measurement improvements would suggest a quantitative leap in efficiency increase of a significant set of economies since the second half of the 1990s,[53] a leap that would be linked to massive ICT investments and to production and organisational changes based on economic-activity networking. This productivity increase makes up a chain that stretches from the productive core of economic changes up to the other activity branches. In sum, investment and ICT uses together with productive and organisational restructuring would explain a good part of the growth in work productivity in countries, regions, sectors and companies throughout the world.[54]

52. Gordon (2003).
53. Jorgenson, Ho and Stiroh (2005).
54. OECD (2003).

We already know that one of the most notable economic indicators in explaining long-term economic growth is work productivity, understood as products per person employed or, preferably, per hour worked.[55] Work productivity may rise as a result of an increase in available capital per hour worked (intensification of capital use) or through a greater degree of economic efficiency, measured by increases in total factor productivity (TFP). In this regard an acceleration in total factor productivity would be a clear indication of the existence of a new economic substrate, since not only would productivity increases be explained by increases in factor endowment but we would also have a significant leap in the overall efficiency of the economic system Nevertheless, and in contrast to work productivity, TFP cannot be measured directly and it is difficult to estimate in practice. In fact, economic growth models containing some technological innovation have demonstrated that one of the explanations for the productivity paradox, that is, the low significance of capital per capita in explaining economic growth appears precisely with total factor productivity. This product-per-capita component is usually attributed to a wide selection of elements ranging from the effects of technological innovation not directly linked to production factors (disembodied technical change) to institutional elements guaranteeing microeconomic efficiency and macroeconomic stability.

From the point of view of corporate activities, one of the most widely accepted indicators for measuring the capacity of companies to attain positive, long-term incremental performance is their potential to maximise the quantity of transaction-commodities (and, consequently, their market value) with a specified amount of production factors (and therefore a specified value of productive consumption). In other words, the capacity of companies to minimise input costs used for generating a specified output level. The rate of company productivity becomes a suitable measure of corporate capacity for long-term efficiency, and establishes itself as an indirect approach to creating values arising from their production activities.

The productivity index, as a microeconomic measure of efficiency achieved per company in performing its productive activities, is influenced both by the nature of the factors used and by their weighting in production-structure configuration. In this regard, we may evidently consider a priori that the productive application of ICTs, whether in tangible capital (tangible technological infrastructure, that is, equipment and facilities) or intangible capital (intangible technological in-

55. The explanation is quite simple. In calculating productivity according to occupation, (GDP/employed) directly influences the average number of hours worked per employee. In fact, we can break down the (GDP/hour worked) ratio = (GDP/employee) * (employee/hour worked). In a setting where part-time work is becoming increasingly important, product use per employee would involve a clear bias towards a drop in productivity figures, given that, according to this measure, all the employees would be working the same hours, and this would make the denominator increase and so reduce the ratio.

frastructure, that is, IT applications) and/or primary material (information and knowledge) can have an impact on the value of the above-mentioned indicator.

This direct ICT impact on productivity benefits is not, however, the only effect of this factor on the productive-efficiency process. In fact, an horizontal effect may arise between ICTs and the other factors used by companies (embodied technical change). In this regard there is some empirical evidence of the reciprocal effects that appear with ICT use, together with other factors in the sphere of productive corporate activities. On the one hand, it is demonstrated that specified corporate investments, such as research and development, favour the emergence of ICTs for productive use, and through this they are built up into principal innovative-strategy elements, with clear, positive synergies from the point of view of increases in product creation and process improvements. On the other hand, it also seems empirically proven that investments in ICTs by companies generate parallel investments in associated resources, usually intangible and related to the requirements of new professional skills and competencies (human capital) and of new organisational forms guaranteeing efficient use of these technologies (organisational capital).

Mention should finally be made, on the last point, of the evidence that effective use of productive ICT factors requires organisational adaptation. In other words, from production and organisation work methods to all levels of organisation. Such adjustments are not automatic or immediate, in that they are only obvious if periods of time are considered that are more than just short term. We can find the explanation for this gradual change in various productive and organisational components in the assumptions made by learning-based organisational models, according to which the introduction of digital technologies into organisations generally involves an approximation, learning and testing time in their more efficient use for a specific production activity. In this way everything seems to indicate that a clear sequence of possible ICT relations takes shape with the corporate productivity rate, which we may summarise as the following process: investment should first be made in ICTs, for the purpose of improving productive factor efficiency; then, investments should be made for acquiring knowledge of the efficacious and efficient use of such technologies; and finally, the company's organisational structure should be adapted to the new production reality.

We shall therefore adopt short-term productivity as an approximation to the profit-earning potential capacity of companies. And we shall analyse the effect of ICTs, through their Internet uses and equipment, on the behaviour of products per unit produced by Catalan companies. With this aim we shall pay attention to two differentiated measures of productivity rates: total factor productivity, seen as the relation between output and input levels of work, capital, consumption of materials and outsourced services: and work productivity, measured through the gross added value of companies per employee, seen as the added value generated in companies per unit of work.

Throughout this chapter, then, we shall consider the role played by ICTs in explaining corporate activity efficiency in Catalonia. We shall verify this causal relationship through two approaches. First, that of productivity facts, with which we shall verify the effects of capital intensification per worker and of TFP on explaining work productivity. Or, in other words, the extent to which the endowment of factors, and the efficiency with which they are combined, determine the long-term growth potential of companies. This approach will allow us to verify whether the impact of digital technological changes is actually causing improvements in efficiency in the production network, so that we can observe the transformation process linked to the consolidation of the knowledge economy. Second, that of productivity sources. This is an area in which we can consider the physical, technological, organisational, training and employment-relations determinants in explaining work productivity. In other words, we wish to verify even the point at which investment in physical, human, technological, organisational and institutional capital and its complementary features determine the growth potential of the private productive network in Catalonia.

## 2.1. ITC, knowledge and productivity: conceptual framework and empirical evidence

There is an extensive body of literature today on the link between technology, productivity, economic growth and corporate efficiency. In fact, thanks to the seminal works of Marx and Schumpeter,[56] economic analyses have closely linked long-term economic growth and, as a consequence, material progress in society, to technological innovation. We may therefore assert that the meeting point between the various trends of thought on economic growth in the light of technological innovation demonstrates that progress in economic activity has a two-fold basis: on the one hand, accumulating productive factors, such as capital and labour; and on the other, innovation in economic activity, or rather, technological progress. There are two sources to these facts. First, investment and its profitability become the foundation for factor accumulation while second, investment and dissemination of knowledge form the basis of technological progress.[57] Nonetheless, there has not always been a clear consensus on the explanation for the determining factors of long-term economic growth which, understood through productivity, as an indicator of efficiency in the output and input relationship, basically attributes advances in the levels of an economy's material well-being to a combination of productive-factor endowment and technological progress. In this context, as well as that of the debate on productivity sources, there has been an intense academic and scientific debate on the contribution of technological innovation to economic growth. Having lasted for a large part of the second half of the 20th century, the debate has taken on a new lease of life with the advent of ICTs and the innovation dynamics that have arisen from that.[58]

The mandatory starting point in the modern theory of economic growth in the light of technological innovation was established by the seminal *Solow-Swan model*.[59] This approach to economic-growth sources is based on the theory that sustained long-term product increases may only occur where there is technological innovation, which is interpreted here as exogenous to economic activity. Without such an innovation process, accumulations of capital would face diminishing returns, and this would lead to falls in productivity. In contrast, with technical changes, improvements associated with technology would counter the unfavourable effects of decreasing returns on factor accumulation and as a result we would obtain an advance in profit per capita, produced by these same technological improvements and by the additional accumulation of capital that makes them possible. This model, based on an aggregate function of production, which satisfies classical concavity suppositions (increa-

56. Marx (1863/1883); Schumpeter (1934).
57. de la Fuente (1992; 1998); Torrent (2004).
58. Vilaseca and Torrent (2006).
59. Solow (1956); Swan (1956).

sing marginal products, decreasing marginal productivity, constant returns to scale and factor-dependent production) and is of the Cobb-Douglas type. In other words:

$$Y_t = A_t K_t^{\alpha} L_t^{(1-\alpha)} \quad (1)$$

Where $Y_t$ is the level of income for period t, A(t) is the measure of the accumulated effects of technical changes in time, $K_t$ is the endowment of capital in period t and $L_t$ is the endowment of work in period t. Taking logarithms, differentiating and bearing in mind that the elasticity of capital and labour in relation to production are, in competitive suppositions, the involvement of these factors in national income, we then reach the basic formula for growth-accounting exercises:

$$\Delta \ln Y_t = \alpha (\Delta \ln K_t) + (1-\alpha) (\Delta \ln L_t) + \Delta \ln A_t \quad (2)$$

Through the theory of constant returns to scale, we can translate this into the intensive terms:

$$\Delta \ln y_t = \alpha (\Delta \ln k_t) + \Delta \ln A_t \quad (3)$$

Where $y_t = Y_t/L_t$ i $k_t = K_t/L_t$. The only non-observable scale in this formula is $\Delta \ln A_t$, so that, by difference, we may calculate the contribution of technological progress to the per-capita increase in income. This is precisely the calculation exercise that Solow [60] used on the US economy for the 1909-1949 period. Given that the capital per hour worked in the private non-agrarian sector increased to an annual average rate of 0.68% during this period, and that the product per hour worked made it an annual rhythm of 1.8%, a simple calculation, with *α* (that is, the involvement of capital in national income) equal to 0.33%, gives us corroboration that the contribution of technical progress to the growth of per-capital income in the USA for the period under the analysis came to 87.5% of the total. In fact, the term $\Delta \ln A_t$ is normally known as the growth in total factor productivity (TFP), or also the growth in multiple factor productivity. These results, and others like them,[61] were very surprising, in the light of conventional economic theory, which had always linked long-term economic growth with factor endowment, and raised a clear question with researchers: what are the bases of A? A consensus was reached around the explanation that what this residual factor was capturing were the effects of the technological progress. In this context, the empirical corroboration of

60. Solow (1957).

61. Abramovitz (1956); Kendrick (1956); Jorgenson and Griliches (1967); Kuznets (1971); Denison (1986); Jones (1988); Solow (2001).

the residual factor's importance in explaining economic growth, at the expense of the factor endowment, would come to be termed *the productivity paradox*.

However, other interpretations for this residual factor soon arose, which highlighted once more the importance of factor accumulation, or the errors in their metrics, and, consequently, the principal role of the savings and investment process as a driver of long-term economic growth.[62] One of the notable contributions was that of Hicks,[63] with a growth model which, rejecting neo-classical theories, considered the growing returns and market structures of monopolistic competition. The basic conclusion of this interpretation was that neo-classical models *a la Solow* underestimated the importance of capital endowment in economic growth. Another contribution to be considered is that of Schulz[64] which, for the first time, emphasised the importance of human-capital investment. According to this approach, the undervaluation of factor endowment in explaining growth is understandable because in traditional work measures (number of employees or work hours) no consideration is given to the quality of human efforts, which progressively increase in direct relation to investments in education and health. These various interpretations of the residual factor established the bases of what would much later be called the *endogenous economic growth theory.*

In this context, these theories were pondered regarding sources of technological progress, which was no longer regarded as "manna from heaven". So investment in research and development, innovation, external technological commerce are now considered to form part of the determining factors of growth. This allows technological progress to be considered with a process of further investment and, therefore, reconciles the two interpretative trends in economic growth, the neo-classical explanation of factor endowment and the residual-factor explanation.

In fact, it can be asserted that there are two major families of endogenous growth models which we can group under the title of *learning-by-doing models* and *human-capital models*. In form, many of these models are nothing other than mere changes in some of the exogenous-model theories. Learning-by-doing models are characterised by their emphasis on technical progress being an almost accidental result of other economic actions or activities. This has a two-fold basis: on the one hand, as a result of the growing returns generated by the intensive use of knowledge; on the other, owing to accumulated experience in investment and production activities. In fact, according to this approach, learning raises productivity, therefore familiarisation with the productive process of the economic

62. Salter (1960).
63. Hicks (1965).
64. Schultz (1961).

agents concerned improves economic-activity efficiency. As a result of this, the technological progress incorporated into the growth models is no longer exclusively a function of time but rather depends too on the acquisition of knowledge, of learning based on accumulated practice and experience.[65] In this sense, an experience index could be accumulated investments. Another important supposition of this development is the fact that knowledge endowment has public-property characteristics. That is, once developed, a technology then becomes incorporated into the economic-activity series (or knowledge spillovers). In this way, a set of models have been developed that incorporate the growing-returns theory into productive function.[66]

In contrast, in human-capital models, technological progress is the direct result of economic-agent investments into training and researching, and this is a costly process. In this context one of the principal sources for economic growth is current knowledge endowment and the volume of resources invested in training and/or research and development. In fact, these models are based on the view that the work factor may incorporate different levels of training and require various abilities and competencies.[67] Moreover, these models do nothing more than to raise a model *al la Solow* with the incorporation of a new productive factor, human capital or qualified work or even to extend consideration to a set of notable economic-activity functions.[68]

On the basis of an empirically-verified fact: with the accelerated rate of economic-growth and productivity progress in the USA since the second half of the 1990s, there has been an important academic dispute among productivity and economic-growth researchers over analysing the economic impact on consolidating a knowledge-based economy, and in particular the role of ICTs. In this regard, the rate of product growth per worked hour within the non-agrarian private sector in the USA showed a significant leap, seeing that it had progressed from growing at rates around 1.5% between 1990 and 1995 to an increase of 2.7% between 1996 and 2000. More up-to-date data confirm this important upward turn, though with slight temporal variations. A first stage that went from the fourth quarter of 1995 to the second quarter of 2000 (2.6% on average), a second stage of weakening (0.7% average increase between the third quarter of 2000 and the third quarter of 2001), a spectacularly bullish recovery around the end of 2001 until 2004 (progressing at 4% on average), and a new stage of greater moderation in 2005 and 2006, with average growth slightly over 2%).

65. Arrow (1962).
66. Romer (1986).
67. Lucas (1988).
68. Romer (1990).

In this context, and based on several initial contributions,[69] which ascribe considerable importance to ICTs in accelerating work-productivity growth in the USA, professor Gordon,[70] one of the main researchers into productivity, made an in-depth analysis of this and pointed out that work-productivity acceleration in the USA was attributable almost exclusively to the ICT sector. This undermined the arguments for synergic effects of ICTs on the rest of the economy and, as a result, the arguments in favour of there being a new knowledge-based economy. Nevertheless, another well-known productivity researcher, Professor Nordhaus,[71] came to exactly the opposite conclusion, using up-to-date data and better output measures: almost half of the work-productivity acceleration in the USA was a consequence of ICT use by other productive branches of the economy that had no links to the digital goods and services production sector. In fact all such work, which is based on an aggregate productive function with technological innovation to explain work productivity, differentiates factor accumulation and TFP into two components: that associated with the ICT sector and the rest of the economy. So a certain consensus has been reached on ICT investments as the principal explanatory element for capital intensification in the USA. There is also, moreover, an academic agreement on much of the economic system's efficiency improvements being attributable to ICT-sector production. Nevertheless, disputes remain over the other TFP component, the synergic effects of digital technological innovation towards all productive branches of the economy.

In this regard we may state that between 25% and 50% of work-productivity acceleration in the private, non-agrarian sector in the USA during the second half of the 1990s is attributable, depending on the work, to the intensification of ICT capital, and close to 25% in addition to TFP is directly linked to the production of digital goods and services. In contrast, and during these first moments of the analysis on the impact of ICTs on the potential growth of the US economy, there has no clear consensus in the literature. At this point we should distinguish two positions. The first, which we call the sceptical, and which is led by Professor Gordon,[72] considers the acceleration of TFP in the second half of the 1990s to be ten, on the grand scale, in cyclic effects relating to the spectacular increase in ICT investment. The decline in work productivity towards the end of 2000 and beginning of 2001, and the initial empirical results on the microeconomic level, which ascribe almost all of the productive increase to the computer, semi-conductor, software and telecommunications sector, give credibility to this approach.

69. Jorgenson and Stiroh (2000; 2001); Oliner and Sichel (2000); Whelan (2000).
70. Gordon (1999;2000).
71. Nordhaus (2001;2002).
72. Gordon (2000).

Even so, subsequent sectorial and empirical studies[73] have opened this perspective up and shown an important acceleration of productivity in sectors which, such as finance, retail and wholesale commerce and several manufacturing industries, use ICTs intensively. The idea of such work is specifically as follows: those sectors that invested more in ICTs during the 1990s are the ones that have shown the most substantial increase in productivity. This approach, which we call favourable, considers a substantial part of the advances in work productivity to be structural and to extend progressively to all branches of activity, especially to those making intensive use of ICTs. Nonetheless, the basic question is whether these effects are cyclical or structural or, in other words, whether they are linked to the spectacular advance in digital- and software-equipment investment and whether these synergic effects will continue for the time being.[74]

Finally, we must point out that a new and recent set of investigations on the impact of ICTs on work-productivity growth in the USA has verified the favourable approach in the sense that ICT investment and use presupposes an undoubted improvement in the intensification of capital, both in the ICT sector and in the sectors that make intensive use of these technologies and, also and even more notable, an increase in TFP, likewise in the ICT sector and the sectors making intensive digital investment and use. In this sense the sceptical view[75] has finished by re-considering its initial approach and confirmed that the analysis of the impact of the digital technological revolution on the advance of work productivity in the USA brings us good and bad news. The bad news has to do with the unusual confluence in this investment's period of extraordinary growth with extraordinarily positive shocks, both in the macroeconomic sense (growth of stock markets, low inflation and reduced unemployment) and in the microeconomic (spectacular growth in ICT demand, the Internet outburst and Moore's law). Therefore, the temporal concurrence of all these factors makes the second half of the 1990s exceptional with regard to the work-productivity increases and their sources.

However, there is good news which is basically linked to a certain extension of the synergic effects of digital investment and use with regard to other production branches, such as new retail commerce, financial services and other manufacturing industries of high added value. It concludes here that it will be highly difficult to maintain digital-investment growth rates at around 30% for the coming years, although we must bear in mind other types or investment and organisation improvements that are more closely connected to institutional frameworks

73. Stiroh (2001); Baily and Lawrence (2001).
74. FMI (2001).
75. Gordon (2003).

and to the capacities of economic agents and not so directly linked to digital investment. We may therefore state that the initial scepticism has taken on three basic directions. First, the recent investigations into the impact of ICTs on work-productivity growth suggest a favourable connection where this relationship combines with institutional impulses.[76] Second, ICTs make several productive sectors more efficient in production. The impact of the internet and software and IT services on companies has been recently demonstrated, above all, in the financial and commercial sectors.[77] Third, historical comparison shows us a clear parallel between current increases in work productivity in the USA and advances of this scale during the 1920s. The two are the result of an accumulative and dynamic process of new-technology investment and use.[78]

On the other hand, and in the light of the significant importance of digital data for the economy in the USA, a growing set of investigations has extended the analysis to other world economies. Based on the initial work of economists with links to the OECD,[79] the international analysis of the impact of ICTs on productivity growth has been essentially focused on two perspectives: a first set of studies estimates the ICT contribution to capital dependence using the conventional theory on economic growth[80] accounting: another analytical focus, however, studies the role of productive sectors, such as both the ICT sector and other activity branches which use ICTs, in explaining economic growth.[81]

The first approach shows us how investment in digital technologies (capital dependence based on ICTs) has made a remarkable contribution to the economic growth of an important group of countries. In fact, we can point out that the USA is not the only country to have benefited from the expansive effects on the growth of per-capita returns on ICT investment. We ought to mention the cases of Canada, Australia and Finland in particular, even if the other large countries analysed, especially the four large ones of the European Union (Germany, the United Kingdom, France and Italy) have made a less significant contribution in the ICT sector, although this will grow in time. This leads us to acknowledge that a significant consolidation of the ICT-productive sector is a necessary, although insufficient, condition for the effect of digital technologies on economic growth. The cases of Australia and Canada suggest that the spread of ICTs plays a major role in these technologies' contribution to economic growth, without this having to be accompanied by a more developed internal digital sector.

76. Gordon (2004c).
77. Gordon (2004b).
78. Gordon (2004a).
79. Schreyer (2000); Scarpetta, Bassanini, Pilat and Schreyer (2000).
80. Schreyer (2000); Colecchia (2001); Colecchia and Schreyer (2001); Daveri (2001); Roeger (2001).
81. Pilat and Lee (2001); van Ark (2001); Central European Bank (2001); van Ark, Inklaar and McGuckin (2002).

The second work family takes us closer to the contribution of the ICT sector and digital-use intensive sectors to productivity growth and GDP for a group of countries. As to the increase in work productivity,[82] it has been corroborated that the contribution of the ICT sector and its intensive-use branches have been outstanding in the countries analysed since the second half of the 1990s, whether through an important contribution of the productive sector of digital technologies (in Finland especially) or the notable contribution of intense uses of ICTs (USA, Denmark and the United Kingdom). As for TFP, the evidence is mixed. On the one hand, countries with a significant relative weighting in the ICT sector, such as Finland, Ireland and the USA, have shown an important upward trend in this economic efficiency indicator during the second half of the 1990s, although other countries with a representative ICT sector, such as Japan and the four large members of the EU, have shown almost imperceptible advances in TFP. Notwithstanding this, other countries with a relative weighting with the low ICT sector, such as Australia, have shown a notable acceleration in TFP, which suggests that because there is a developed ICT sector there is no need to accelerate TFP.

To sum up then, we may conclude this review of international empirical evidence on the contribution of ICTs to economic growth and on work productivity based on four basic assertions. First, the strong increase in investment in digital and software equipment in the USA explains much of the bullish upturn in economic growth and productivity in that country. In fact, capital dependence and TFP, linked to ICT investment and production, have been the underlying element in the trend improvements of productivity in the USA. Furthermore, evidence has also been growing, from the sectorial perspective, relating to the fact that productivity improvements progressively extend to the other activity branches, in particular in the financial, commercial, transport and intra-corporate service sectors as well as in other manufacturing industries.

Second, since the second half of the 1990s a group of OECD countries have also shown significant improvements in the trend progress of productivity. Moreover, conclusive evidence has been found regarding the fact that investment in ICTs explains much of the economic growth of the countries analysed, in Australia, Finland and Canada in particular. The sectorial approaches also confirm the importance of ICTs in explaining GDP and productivity growth, and also demonstrate the progressive importance of synergic effects on the intensive use of these technologies (especially in Denmark and the United Kingdom). Third, the evidence that relates to improvements in the overall efficiency of the economic system (TPF), as a consequence of the intensive use of ICTS, is mixed. Some countries, such as

82. Pilat and Lee (2001).

Finland, Norway, Sweden, Ireland and Australia have shown notable improvements in efficiency during the second half of the 1990s, although no appraisal was made of the advances in basic efficiency indicators in Japan and the four main EU countries. Fourth, measuring problems, especially the accounting-interpretation differences of ICT investments, the calculation of price deflators and the lack of recent statistics, as well as the link between ICTs and work-force skills and the residual consideration of usual economic efficiency indicators, could have led to an underestimation of some of the results obtained on modest TFP advances in some countries.

In short, we may conclude by asserting that there is a growing body of conclusive evidence for investment in digital technologies explaining a large part of the increase in economic growth and productivity of some countries. Moreover, the sectorial approach confirms that intensive ICT use has a certain synergic effect on the rest of the system of production, which leads us to maintain that there are new elements behind the recent acceleration of TFP since the second half of the 1990s. Two key questions, nonetheless, still need to be answered. First, does the bullish upturn of TFP components that are not physically related to inputs have its origins in synergic effects and networked externalities arising from ICT investment? Second, is this acceleration cyclical or structural?

In other words, international empirical literature gives us evidence of the macroeconomic impact of ICT investment on productivity progress and economic growth as well as on the efficiency of the general economic system. That said, this literature does not definitively explain the causes for these effects, or whether efficiency improvements would last for any time. The solution to these two questions probably depends on incorporation as analytical tools for other factors, such as institutional effects of capacities of economic agents, and also on the expectation that the digital revolution's effects will extend effects to a growing number of productive branches. Nevertheless, one thing is for sure: innovation, the digital investment of which forms a basic component, will be the key to explaining economic growth and productivity during the coming years. In this sense, an even more recent set of investigations[83] has demonstrated, using new output, input and price-comparable measures, the growing importance of digital-investment and use in explaining aggregate and sectorial productivity, both in the capital-intensification component and in TFP. In fact it confirms the advance of the synergic effects of ICTs, often associated with human and organisational capital, on improvements in efficiency of the entire economic system and, therefore, the gradual consolidation of a new knowledge-based economic substrate. It is this exercise that we will be conducting below on the Catalan economy's private production network.

83. Greenan, L'Horty and Mairesse (2002); Timmer, Ypma and Van Ark (2003); OECD (2003); Mas and Quesada (2005); Jorgenson, Ho and Stiroh (2005); Mas and Schreyer (2006).

## 2.2. Digital change and corporate efficiency in Catalonia

We have already mentioned above that the approach to the facts on productivity allow us to measure the impact of ICTs on factor endowment and the efficiency with which these combine. In fact, as we have seen in the previous section, the available empirical evidence suggests to us that any verification of the movement towards a new economic and corporate configuration has to be understood through the impact that digital changes bring about on the efficiency of the entire economic system (TFP). This is exactly the exercise that we shall be performing below. We wish to verify, in the case of Catalan companies, whether the investment and use of ICTs have any favourable impact on the efficiency component of the growth potential (PTL) of our productive network. If we follow the current literature and what we have just seen in the formula (3), we can specify a model in levels (formula 4), that is, for each year in which we have information, during which work productivity depends on capital intensification (capital ratio per worker) and on the efficiency with which the inputs are combined. That is:

$$\text{Ln } y_i = \sum_{i=1}^{n} \beta_1 \text{ Ln } k_i + \beta_2 \text{ Ln TFP}_i + \varepsilon_i \qquad (4)$$

Where work productivity , $y_i = Y_i/L_i$, capital intensification (work capital ratio) $k_i = K_i/L_i$, and the economic efficiency indicator ($\ln A_i$) is represented by the PTF formula. The sub-index i represents the company and the component $\varepsilon_i$ represents the error term. We should point out that the only unobservable magnitude to this formula is $\ln PTF_i$, so that, the first exercise that we must carry out is the calculation of this variable. To do that, and following the methodology used by corporate literature, based on productive function, we may calculate the total factor productivity in each company, as stated in the formula (5):

$$\text{Ln TFP}_i = \text{Ln VEN}_i - s_{ki} \text{ Ln } K_i - s_{li} L_i - s_{ii} \text{ Ln } I_i \qquad (5)$$

Where $VEN_i$ represents the company's sales revenue; $s_{ki}$ is the share of capital costs over total company costs; $K_i$ is the company's current capital endowment; $s_{li}$ is the share of expenses in man power over total company costs; $L_i$ represents expenditure on company staff; $s_{ii}$ is the share of intermediate running costs over the total cost; and $I_i$ represents the volume of intermediate running costs in the company.

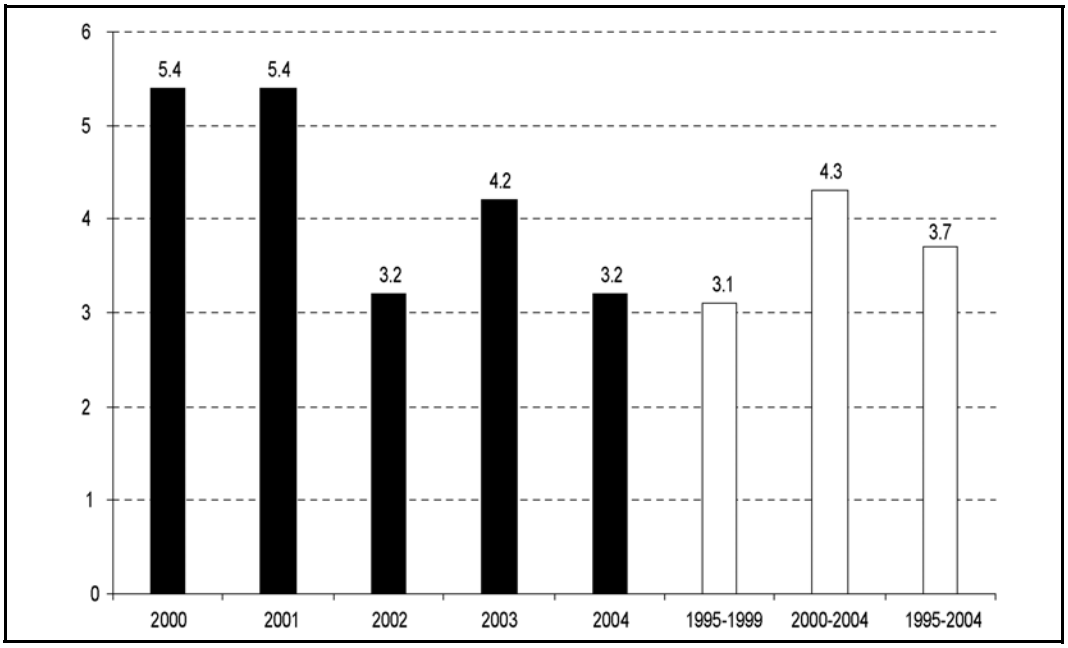
This section has a two-fold aim. We shall calculate the total factor productivity on the one hand and on the other we shall estimate the contribution of this variable, together with the capital intensification, in explaining work productivity. As for the data, we have completed

those for the year on the basis the survey, reported in 2003, with a temporary series included in the period 1995-2004. We therefore have a company panel, with a time horizon of ten years, which will enable us to understand the impact of ICTs on corporate efficiency, from the beginnings of the productive consolidation of these technologies, and to go beyond the analysis in levels and analyse the development of the variables that make up the model. Although we had information available for the financial year of 2005, it was not incorporated into the explanatory model owing to the unavailability of complete data for all the companies in the sample.

In this respect, as we shall immediate see, it should be mentioned that the main limitation to this approach is that in incorporating a selection of companies according to their use of ICTs, the datum available only for 2003, we had to assume that there was a constant development of this variable. So, for example, where companies showed, according to the results of our data, advanced ICT use in 2003, such consideration has been maintained throughout the series of available years. Therefore, the level of ICT uses obtained for 2003 remains constant throughout the sample years. In contrast, for the other variables, whether we use them to calculate the TFP or to determine work productivity, have been obtained from the available data deriving from the Commercial and Companies Registry. A second serious limitation we should point out is the lack of available relative-price indicators. The approach followed then, year on year, is taken under nominal terms. Finally, note that in the first approach, in the estimation of the work-productivity determinants, no indicators measuring the impact on quality of work have been incorporated. This features in the TFP measurement.

The calculation exercise for the efficiency indicator in combining Catalan company inputs (TFP) shows us very significant results. First, we must mention that the TFP of Catalan companies grew in nominal terms and during the period 1995-2004 at an annual rate of 3.7%. If we then divide this ten-year period into two sub-periods, 1995-1999 and 2000-2004, we can estimate an acceleration of efficiency growth in Catalonia's private production network. In fact, during the 1995-1999 period, the TFP of the private sector in Catalonia grew, in nominal annual average terms, by 3.1%, a lower record than the increase achieved for the 2000-2004 period, which was entered as 4.3%. It should nevertheless be appreciated that this acceleration arose, above all, during the first years of the second period. Thus, in 2000 and 2001, the TFP of Catalonia's private production network progressed along rates approaching 5.5%. This acceleration slowed down during the subsequent financial years (figure 1).

**Figure 1. Total factor productivity (TFP) in Catalonia's companies. 1995-2004** (nominal annual average growth rates)

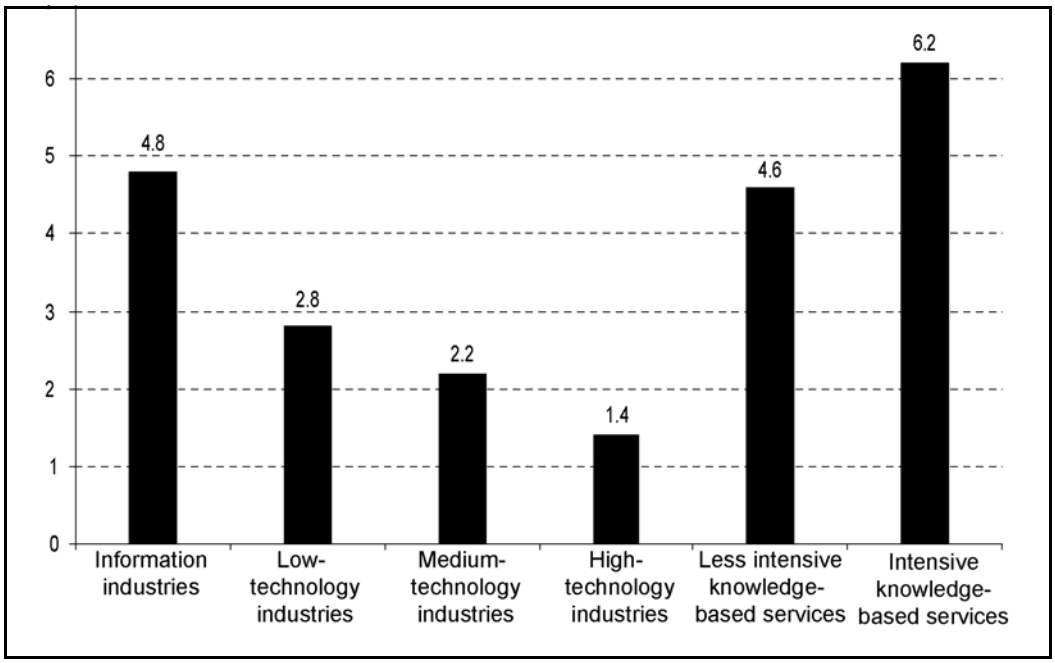



Source: In-house

Sectorial analysis demonstrates that efficiency acceleration in Catalan companies is explained by a better combination of inputs in the production process with intensive technology- and knowledge-use activities.[84] Indeed, the sectorial distribution for the entire production network in six major branches of activity is as follows: a) the core of digital change or information industry; b) industrial activities, divided up into sections according to technological intensity. low, medium or high technology industry; and c) service activities divided up into sections according to knowledge-use intensity: services less intensive in knowledge and knowledge-intensive services show that acceleration of TFP has been consolidated on the basis of efficiency improvements in knowledge-intensive sectors, especially in the information industry and in intensive knowledge-use services (figure 2).

84. OECD (2002).

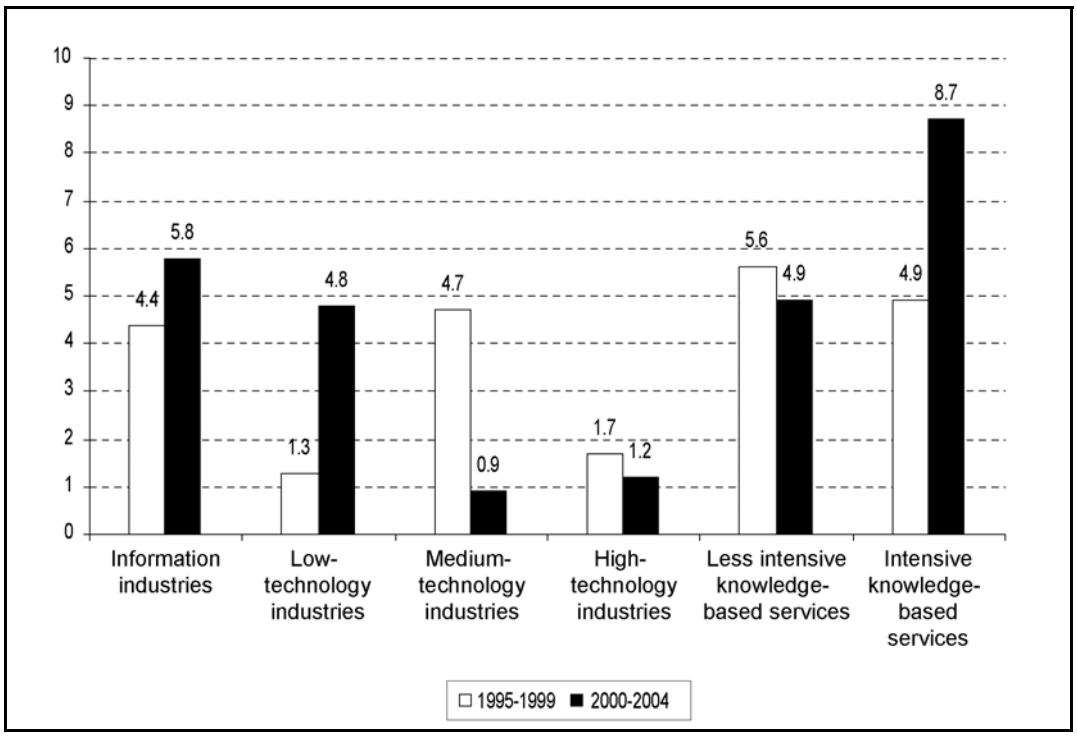
**Figure 2. Total factor productivity (TFP) in Catalonia's companies, by activity sectors. 1995-2004** (nominal annual average growth rates)




Source: In-house

In fact, analysing TFP sectorial components provides us with an important dimension for the factors that drive its dynamics. So, we must first point out that the sectorial aggregate which triggered this increase in aggregate efficiency of Catalan's private sector was services. Intensive-knowledge services have shown, during the 1995-2004 period, an average rate of TFP annual growth of 6.2%, 1.2 percentage points above the growth shown by services less intensive in knowledge (4.6%) and 2.5 percentage points over the average for all Catalan companies. As for industry, note the decline in its efficiency growth as its technological intensity increased. In the 1995-2004 period, therefore, the total factor productivity showed a nominal annual average increase of 2.8% in low-technology industries, of 2.2% in medium-technology industries and of 1.4% in high-technology industries. Finally, note the significant efficiency increase in information industries. The productive core of the digital change process has shown an average TFP increase of 4.8% during the period referred to, 1.1 percentage points over the Catalan average. In addition, analysis by sub-period demonstrates that these differences have become accentuated over time. Indeed, during the 2000-2204 period, the average efficiency growth in information industries and knowledge-intensive services was high (5.8% and 8.7% respectively). By contrast, the rate of progress in total factor productivity in medium- and high-technology industries did not exceed the annual average of 1.5% (figure 3).

**Figure 3. Total factor productivity (TFP) in Catalonia's companies, by activity sectors. 1995-1999 and 2000-2004** (nominal annual average growth rates)



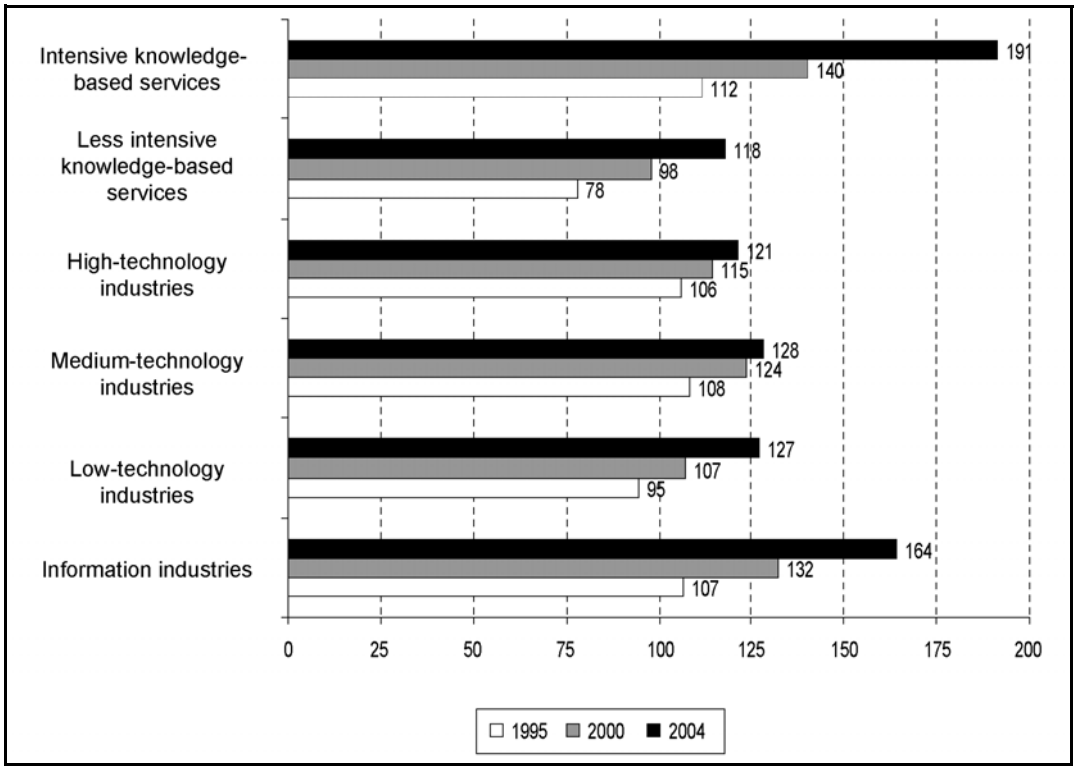

Source: In-house

In the light of the data obtained, which demonstrates a notable improvement in efficiency, both in companies forming the digital core of the Catalan economy and in knowledge-intensive services, denoting, in part, clear synergic effects on the TFP of those of its technological, training and organisational components which are not associated with productive factors, the dynamics experienced in the industry does not cease to surprise. In fact, contrary to what we could expect *a priori*, the accelerated efficiency of the Catalan industrial network shows itself in the less intensively-used branches of technology. To probe deeper into the analysis of this situation, we have carried out an approach to the development of productivity levels in the various activity sectors considered. So figure 4 represents the development of TFP levels of the six major production branches into which we have divided up the company group, while indexing the average Catalan value for 1995 as a percentage. We have used this exercise to try and understand the level effect on efficiency dynamics, so its starting point is considered in TFP development. In this way, it is possible to verify whether the acceleration of TFP occurs in low or high starting-point circumstance. The data obtained confirm that: a) information industries and knowledge-intensive services show a much accelerated dynamic for the TFP which is combined with a starting point that is higher than that of the Catalan average; b) services that are less knowledge intensive also show a very positive trajectory

of the TFP, although the lower nature in the Catalan average of its starting point undermines the final results obtained. In fact, in 2004 the average value of the total productivity level of the factors in this branch of activity was less than those recorded by the industrial network's branches; and c) as for industrial sectors, we can observe two differentiated dynamics: on the one hand, the significant acceleration of low-technology industries is noteworthy, and highly notable if we take account of the fact that from a lower starting point in the Catalan average, it achieved a final record in 2004 that was clearly favourable; on the other hand, the trajectory of medium- and high-technology industries should be pointed out which, despite showing a starting point higher than that of the Catalan average, accelerated their efficiency level with less intensity than the industrial production branch that makes less intensive use of technology.

We can summarise this sectorial verification exercise between the level and dynamics of total factor productivity in Catalonia's private production network during the 1995-2005 period by stating that: a) despite branches making intensive use of technology and knowledge; that is the information industry,. the high-technology industry and knowledge-intensive services, start with an initial efficiency point that is higher than the Catalan average in 1995, this is not a necessary condition for subsequent productivity acceleration, just as the results of low-technology industries show; and b) despite the productive branches that are less intensive in technology and knowledge, that is, low- and medium-technology industries and services that are less intensive in knowledge, generally, start from an initial efficiency point that is lower than know-intensive productive branches, this is not indicative of a lesser TFP acceleration, as the dynamics of the services that are less intensive in knowledge show. So we can therefore state that the initial productivity situation does not form a necessary and sufficient condition for establishing accelerations subsequent to this indicator. This situation is probably related to the mainstreaming of the change process linked to the consolidation of the knowledge economy, in which it is possible, irrespective of the level of technological intensity and initial knowledge, to achieve clear efficiency improvements. In fact, as the available empirical evidence suggests, corporate efficiency improvements are not just linked to technology intensity and initial knowledge but positive synergies also arise there in the TFP improvement process which becomes established when technology and knowledge associate themselves with appropriate productive, organisational and institutional changes. For the purpose of our investigation this result advises against the sectorial approach which moreover is defined *ex ante* to the verification of the data, but which, nonetheless, has been useful for us in verifying that corporate efficiency improvements in the decade between 1995 and 2004 are associated with the digital core of the new economy and with the extension of certain synergic effects towards other branches of activity, in particular the knowledge-intensive services.

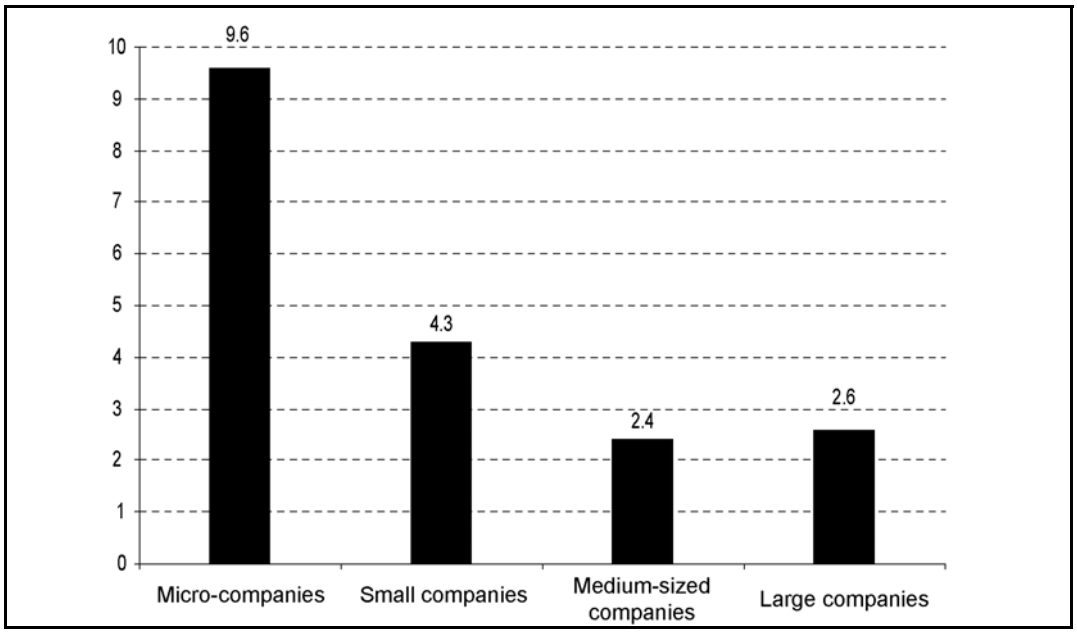
**Figure 4. Total factor productivity (TFP) in Catalonia's companies, by activity sectors. 1995-2004** (Index number: Catalonia value 1995=100)




Source: In-house

Another outstanding aspect to companies regarding efficiency dynamics is size. Industry assumptions have traditionally demonstrated that economies of scale which are linked to a larger size guarantee improvements in the efficiency of the production network. The data obtained for the 1995-2004 period suggest exactly the opposite. In fact, if divide up our sample of available companies according to their size (micro-companies: 5 or fewer workers; small companies: from 6 to 19 workers; medium-sized companies: from 20 to 99 workers; and large companies: 100 or more workers) we discover that improvements in the efficiency of Catalonia's private production network have taken place with much more intensity in micro- and small companies. We must highlight in particular the strong growth in efficiency, during the period under analysis, achieved by micro-companies and small companies (9.6% and 4.3% respectively), records that are clearly higher than those attained by medium-sized companies within Catalonia's production network. In contrast, both medium-sized companies (2.4%) and large companies (2.6%) showed an efficiency increment below that of medium-sized Catalan companies and, in real terms, if we discount the GDP deflator, they are very meagre (figure 5).

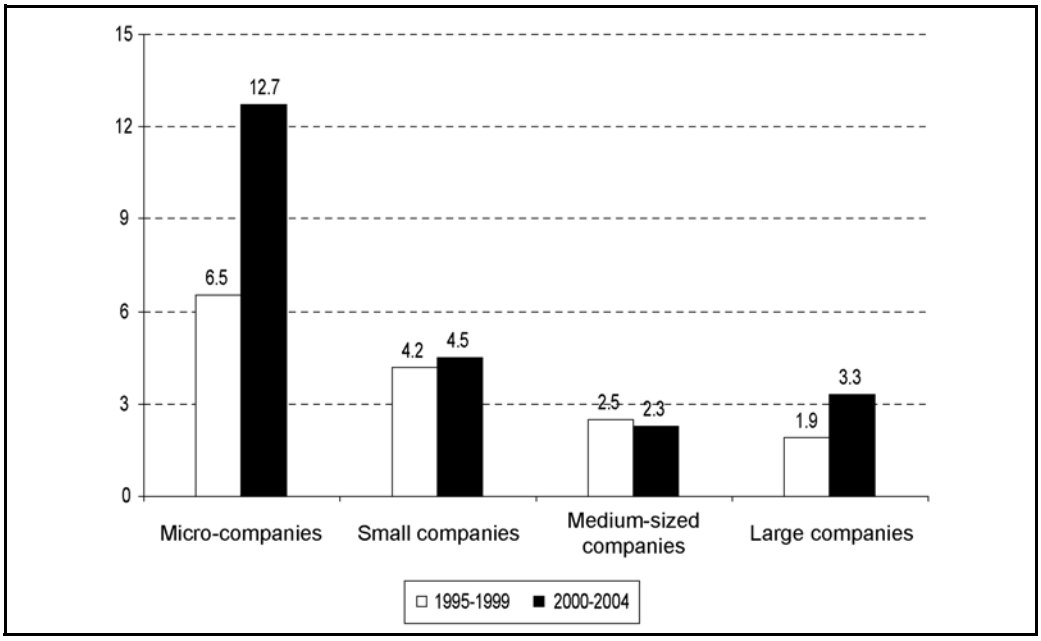
**Figure 5. Total factor productivity (TFP) in Catalonia's companies, by size. 1995-2004**
(nominal annual average growth rates)




Source: In-house

As in the case with the productive sectors, interesting results arise when distinguishing between the two reference sub-periods. So, as figure 6 makes clear, we can observe a very notable acceleration in efficiency in the small-sized companies of our productive network, with a nominal average increase in TFP for the 2000-2004 period of 12.7%, compared to that of 6.5% for the 1995-1999 period. In fact, and in view of the practical maintenance of total-factor productivity rates in small companies (from 4.2% for the 1995-1999 period to 4.5% for the 2000-2004 period) and medium-sized companied (from 2.5% to 2.3%) and considering the most efficiency acceleration in large companies (from 1.9% to 3.3%), we can assert that it is micro-companies which are chiefly responsible for the efficiency acceleration with which the factors are combined in the private productive network in Catalonia's economy during the 1995-2004 period.

**Figure 6. Total factor productivity (TFP) in Catalonia's companies, by size. 1995-1999 and 2000-2004** (nominal annual average growth rates)



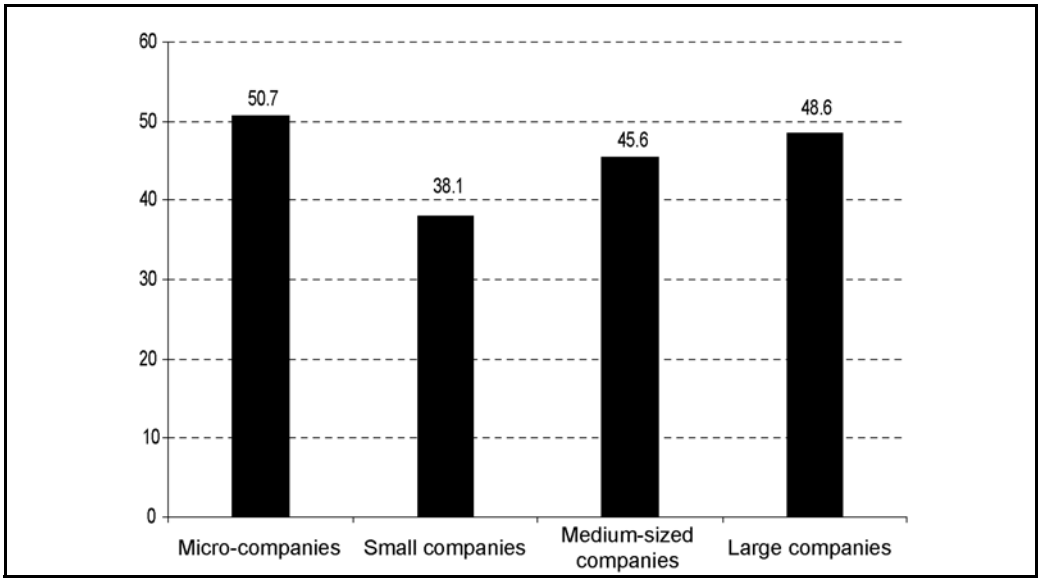

Source: In-house

Thus, after this TFP parameterisation exercise for the entire private production network in Catalonia's economy, it is well demonstrated: a) the importance of the digital core in the new economy; b) the extension of certain synergic effects towards other branches of activity such as knowledge-intensive services; and c) the prevailing role of micro-companies in explaining advances in microeconomic efficiency, we are now ready to deal with the true aim of this section: analysing the determining factors in the growth potential of corporate activities. To do this, and with the aim of parameterising evident work productivity, we shall have to create a GVA (gross value added) per equivalent full-time worker. The companies' gross value added has been calculated on the following profit-and-loss account basis: production values have been approximated using the total net amount of turnover, other operational revenues, variations in finished-product stocks, work performed for intangible fixed assets and taxes relating to production, less the consumption of goods. To valuate these intermediary consumptions, consumptions of primary materials and other supplies as well as work carried out for other companies and external services have been calculated. The equivalent full-time worker indicator has been created bearing in mind the share of full- and part-time work in companies.[85] In fact, based on the percentage structure of part-time workers, workers under this working-day mode have been treated in full-time equivalent terms.[86] So while TFP gives us an explanation for technical effects on work productivity, the latter takes account of the effects of both technical efficiency and capital intensification.

The descriptive data featuring in figure 7 show that the apparent work productivity in Catalonia during the 1995-2004 period was positioned, on average, at 44,000 euros per worker, with an

annual increase of 4.1%. Depending on company size, the average level of apparent work productivity describes a convex parabola with a minimum at the small company size (38,100 euros). As for the other sizes contemplated, all show a value in excess of the aforementioned, while the two extremes stand out: micro-companies with 50,700 euros, have the highest productivity in the private production network, and slightly above that reached by large companies (48,600 euros during the 1995-2004 period). Notwithstanding that, as can be gathered from figure 8, the segmentation into two reference sub-periods, 1995-1999 and 2000-2004, can also give us remarkable results. First, it must be highlighted that large companies reveal, in the second reference period, a productivity level (52,600 euros) which slightly overtakes now the value of micro-companies (51,900 euros). Second, mention should be made of the significant upturn equal to the level of apparent work productivity in small and medium-sized companies.

**Figure 7. Apparent factor productivity (AFP) in Catalonia's companies, by size. 1995-2004** (thousands of current euros)

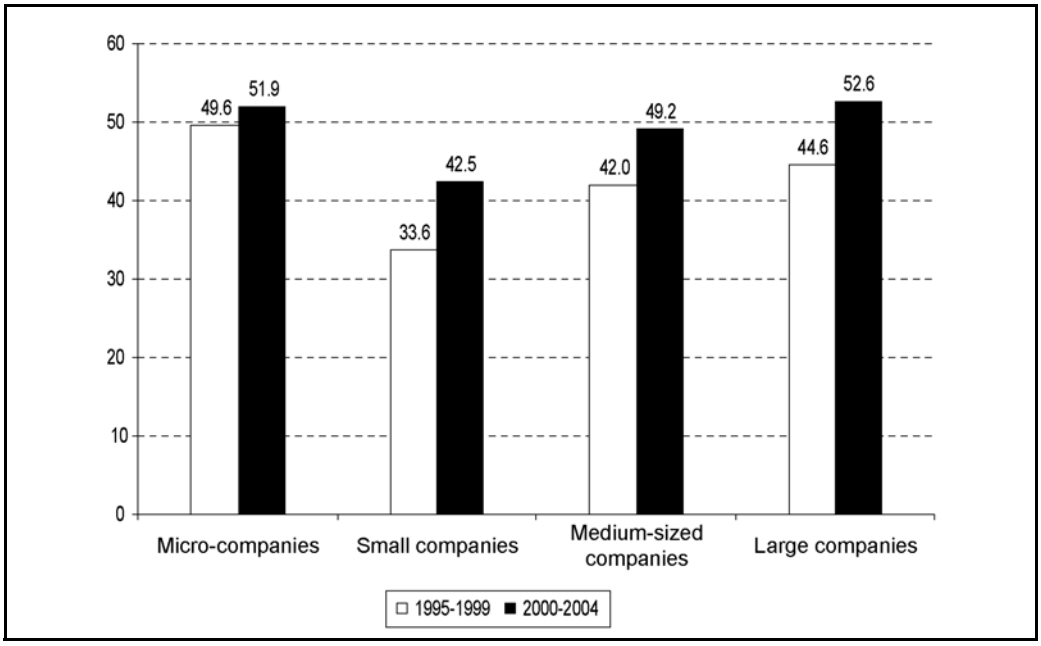



Source: In-house

85. This indicator, very common in the literature on productivity, is used, for want of available information on working hours, for avoiding the over-computation of worker numbers and therefore the underestimation of work-productivity levels. In fact, if we had not taken this into account, two companies with the same GVA, for example, 1000 euros, but with a very different work distributions, with the first (90 full-time and 10 part-time workers) and with the second (10 full-time and 90 part-time workers) would have a work productivity, measured in GVA terms per worker equal to 100 euros in both cases. To avoid this situation, the full-time equivalent worker indicator is used. This indicator is created on the basis of converting part-time workers into full-time equivalent terms. Nevertheless, whether we work with this indicator or with hours worked, we continue to do so under the presumption of homogeneous work, that is, that the aggregate company returns per worker or hour worked is considered to be identical for each worker or hour worked.

86. Following the previous example, the short-term working rate is 10% in the first company but 90% in the second. So, in the first case 1 out of every 10 workers work part time, whereas in the second 9 out of every 10 workers work part-time. The conversion in terms of full-time equivalent workers assumes that, in the first case, the company has 91 workers while in the second case it only has 19 workers.

**Figure 8. Apparent factor productivity (AFP) in Catalonia's companies, by size. 1995-1999 and 2000-2004** (thousands of current euros)




Source: In-house

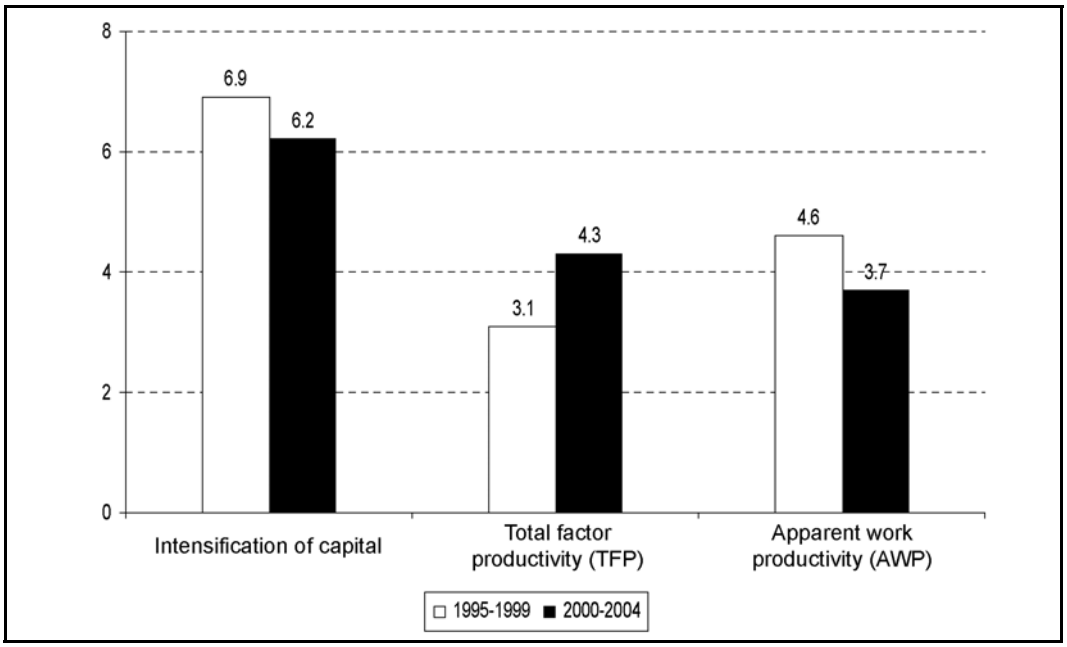
If we examine according to activity sector, we can see a link between technological intensity and knowledge and the larger levels of apparent work productivity. Therefore both information industries and high-technology industries and knowledge-intensive services recorded during the 1995-2004 period a level of apparent work productivity significantly over that attained by the other branches that are less intensive in using technology and knowledge (45,300, 48,300 and 60,200 euros, respectively). These differences moreover have become accentuated since the year 2000.

Finally, the last piece in the productivity puzzle is represented by capital intensification. We have ascertained then the capital endowment per worker based on an indicator which measures the asset volume of companies per equivalent full-time worker. We are now ready to deal with the breakdown exercise of apparent work productivity which depends, as formula 4 denotes, on the intensification of capital per worker and on the efficiency with which these are combined. The descriptive data (figure 9) indicate that: a) the long-term growth potential of Catalonia's companies has declined. In fact the nominal average rate of progress in the apparent work productivity of Catalan companies has gone from a 4.6% growth for the 1995-1999 period to a 3.7% growth in the 2000-2004 period; b) with components, note that the growth potential of Catalan companies is largely sustained in the intensification of capital. Indeed, although the growth of capital endowments per worker declined between the two reference periods, it still continues to grow with force (from a nominal average of 6.9% in the 1995-1999 period to 6.2% in the 2000-2004 period); and c) finally, it should be mentioned

that despite advancing at lower rates, the rate of efficiency advancement of the private production network in Catalonia has been accelerated during the two reference sub-periods (from a 3.1% nominal average in the 1995-1999 period to 4.1% in the 2000-2004 period).

Good and bad news is therefore established for the trajectory of apparent-work productivity in Catalan companies. The bad news has to do with the slowing down of the long-term growth potential of Catalan companies. The good news is connected with the improvements in the growth of its efficiency component. In order to explain this, we shall develop a causal-relation model below that aims at understanding the determining factors in the dynamics of the growth potential in Catalan companies. So we shall estimate the model represented in equation 4 by ordinary least squares. And, more specifically, in order to understand the effects of digital innovation on apparent work productivity we have divided up our company sample into sections according to intensity of use of digital technologies. In this sense, the ICT-use indicator shows the sufficiency of ICT use in five corporate-activity value elements: production, supply and distribution; marketing, basic organisation and human resources (accounting and invoicing, wage payment and internal communications); and complex organisation and human resources (data management and/or information operations, management information systems and integrated management systems). This sufficiency, which is shown through the availability of digital technological systems in each of these five value elements, determines the three levels of the indicator: low ICT uses, where companies have technological systems available for none or one of the five defined value elements; average ICT uses where companies have technological systems available for two or three of the five defined value elements; advanced ICT uses where companies have technological systems available for four or five of the five defined value elements. We therefore expect that a larger intensity of digital-technology use is connected with higher levels and advancements in apparent work productivity, and in particular, in its efficiency component. Tables 1 and 2 show the results of the estimation carried out; the first for the 1995-1999 period and the second for the 2000-2004 period.

**Figure 9. Capital intensification, total factor productivity (PTF) and apparent work productivity (AWP) in Catalan companies. 1995-1999 and 2000-2004** (nominal annual average growth rates)




Source: In-house

**Table 1. Determinants of apparent work productivity (AWP) in Catalan companies. 1995-1999** (method of analysis: estimation by ordinary least squares; dependent variable: apparent work productivity, understood the GVA per equivalent full-time worker)

| | 1995 | 1996 | 1997 | 1998 | 1999 | 1995-1999 |
|---|---|---|---|---|---|---|
| **Low ICT uses** | | | | | | |
| k (K/L) | 88,3*** | 59,2*** | 60,0*** | 66,8*** | 70,0*** | 68,9 |
| TFP | 21,8*** | 46,9*** | 47,5*** | 45,9*** | 31,4*** | 38,7 |
| n (=i) | 118 | 171 | 181 | 210 | 270 | |
| Significance | 0,000 | 0,001 | 0,000 | 0,000 | 0,000 | |
| **Medium ICT uses** | | | | | | |
| k (K/L) | 53,9*** | 53,1*** | 62,2*** | 26,4*** | 30,5 | 45,2 |
| TFP | 51,5*** | 48,8*** | 44,1*** | 71,8*** | 61,6 | 55,6 |
| n (=i) | 118 | 149 | 155 | 182 | 211 | |
| Significance | 0.000 | 0.000 | 0,000 | 0,000 | 0,005 | |
| **Advanced ICT uses** | | | | | | |
| k (K/L) | 62,4*** | 70,8*** | 99,5*** | 68,3*** | 68,7*** | 74,0 |
| TFP | 44,9*** | 33,8*** | n.d. | 35,8*** | 36,4 | 30,2 |
| n (=i) | 82 | 101 | 108 | 125 | 133 | |
| Significance | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | |
| **Catalan companies** | | | | | | |
| k (K/L) | 78,4*** | 52,6*** | 92,3*** | 53,4*** | 55,4*** | 66,4 |
| TFP | 32,9*** | 53,1*** | 3,2*** | 52,3*** | 43,9*** | 37,1 |
| n (=i) | 316 | 419 | 442 | 515 | 612 | |
| Significance | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | |

*** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

Source: In-house

**Table 2. Determinants of apparent work productivity (AWP) in Catalan companies. 2000-2004** (method of analysis: estimation by ordinary least squares; dependent variable: apparent work productivity, understood the GVA per equivalent full-time worker)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2000-2004 |
|---|---|---|---|---|---|---|
| **Low ICT uses** | | | | | | |
| k (K/L) | 44,1*** | 66,9*** | 55,9*** | 59,3*** | 58,7*** | 57,0 |
| TFP | 50,7*** | 40,3*** | 49,0*** | 39,5*** | 35,8*** | 43,1 |
| n (=i) | 229 | 309 | 304 | 346 | 341 | |
| Significance | 0,002 | 0,001 | 0,000 | 0,000 | 0,001 | |
| **Medium ICT uses** | | | | | | |
| k (K/L) | 53,9*** | 53,1*** | 62,2*** | 26,4*** | 30,5 | 45,2 |
| TFP | 51,5*** | 48,8*** | 44,1*** | 71,8*** | 61,6 | 55,6 |
| n (=i) | 118 | 149 | 155 | 182 | 211 | |
| Significance | 0.000 | 0.000 | 0,000 | 0,000 | 0,005 | |
| **Advanced ICT uses** | | | | | | |
| k (K/L) | 62,4*** | 70,8*** | 99,5*** | 68,3*** | 68,7*** | 74,0 |
| TFP | 44,9*** | 33,8*** | n.d. | 35,8*** | 36,4 | 30,2 |
| n (=i) | 82 | 101 | 108 | 125 | 133 | |
| Significance | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | |
| **Catalan companies** | | | | | | |
| k (K/L) | 78,4*** | 52,6*** | 92,3*** | 53,4*** | 55,4*** | 66,4 |
| TFP | 32,9*** | 53,1*** | 3,2*** | 52,3*** | 43,9*** | 37,1 |
| n (=i) | 316 | 419 | 442 | 515 | 612 | |
| Significance | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | |

*** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

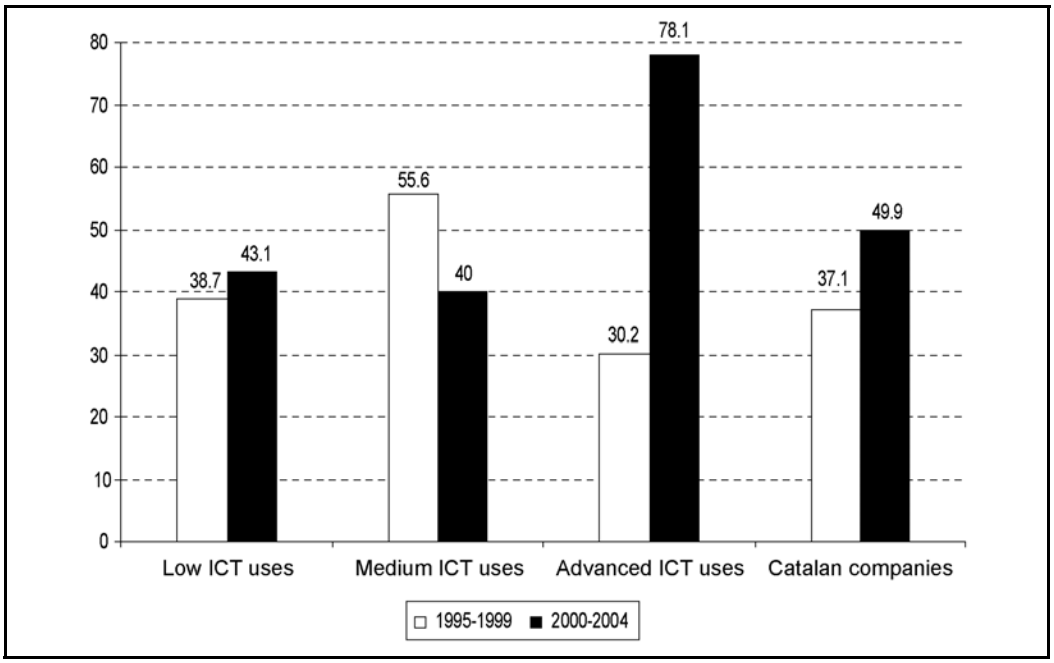
Source: In-house

As to the results of the estimation, we must first mention that all the estimated annual coefficients of capital intensification and of TFP are significant at 99% of confidence, with the exception of TFP for 1997, which does not show significant effects on apparent work productivity. This translates into an overall estimation for the year. With the latter, TFP has a significant effect on PTL at confidence levels of 90%. Second, and from the perspective of the entire production network in Catalonia, it is important to make it clear that the impact of the capital-intensification coefficient on the growth potential of Catalan companies declines as we move forward through the sample years. In fact the standardised coefficient of this variable has developed downwards during the reference period, and if we calculate its average value, we observe that this has gone from a value of 66.4 thousand euros in the 1995-1999 period to another one of 43.4 thousand euros between 2000 and 2004. By contrast, the total factor productivity has shown the opposite trajectory, and has gone from an average value of the estimated annual coefficient of 37.1 thousand euros in the first period to another of 49.9 thousand euros in the second period. It is therefore shown that in determining the long-term growth potential of Catalan companies, the efficiency by which it combines their inputs takes on a growing role, at the expense of capital intensification. This is basically the case with the excellent results attained during the financial years of 2000, 2002 and 2004, which reversed the trends of the second half of the 1990s, during which the

growth potential of Catalonia's private sector was being explained chiefly through capital intensification.

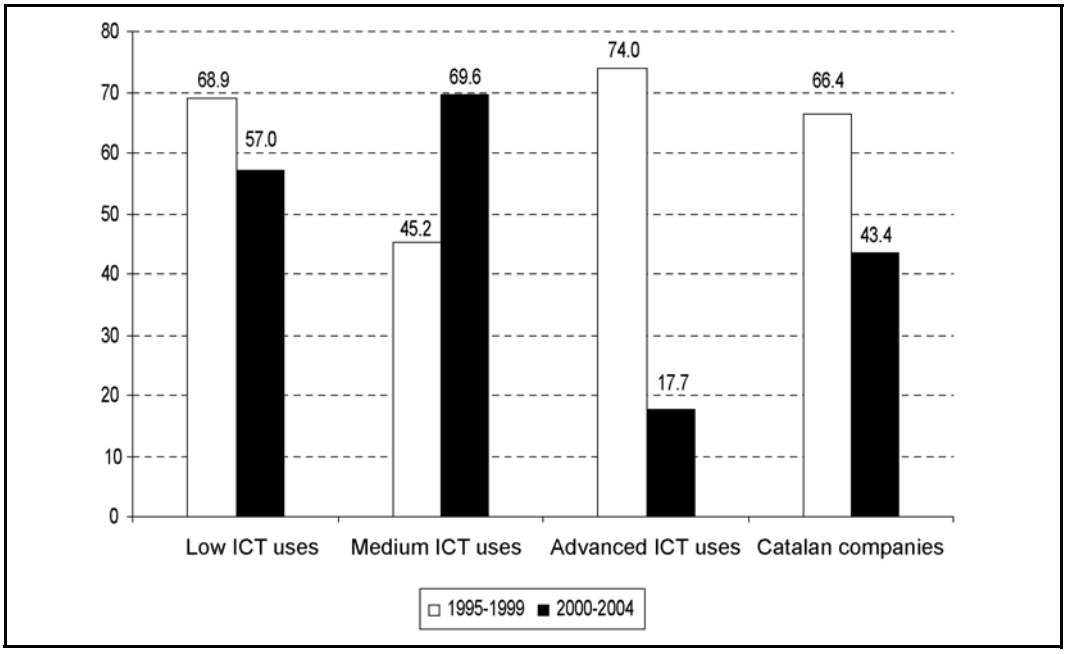
This specific analysis of Catalonia's corporate network, by dividing it up into sections according to the intensity of ICT use, also brings startling conclusions. In fact, the level of estimated annual TFP coefficients for all companies making intensive use of ICTs has developed very substantially during the reference period. So calculating the average of the estimated values through the two reference sub-periods demonstrates: the average efficiency-coefficient value in this set of companies went from 30.2 thousand euros in the 1995-1999 period to more than double that during the 2000-2004 period, with an average of 78.7 thousand euros. This trajectory clearly contrasts with the development shown by the sub-sample of companies with low and medium ICT use. In the set of companies with low ICT-use, even though the impact of the average TFP coefficient on apparent work productivity accelerated (from 38.7 thousand euros in the 1995-1999 period to 43.1 thousand euros for the 2000-2004 period), these values still fall below those registered for capital intensification. With the medium ICT-use companies, the average annual efficiency-coefficient share in apparent work productivity dropped (from 55.6 thousand euros in the 1995-1999 period to 31.0 thousand euros in the 2000-2004 period. They show that the intensity of digital changes in Catalan companies relates to a greater impact of efficiency levels on the long-term growth potential of the private production network and that this has emerged as the principal explanatory element in the efficiency improvements of Catalonia's economy (figure 10). In contrast, companies with a lesser intensity of ICT uses show a greater capital-intensification impact in explaining apparent work productivity (figure 11). In fact, with this analysis exercise on the long-term, potential-growth determinants of Catalan companies, the explanation demonstrates the existence of both positive and negative aspects. The negative aspects have to do with the slowing down of apparent work productivity. This seems to relate to the significant contribution of capital intensification in our production network and to an efficiency impact on the relatively-modest work productivity in those companies that use digital technologies with less intensity. The positive aspects have to do with the acceleration in efficiency with which the productive network combines its factor endowment. This is directly related to the very favourable impact that TFPs have on apparent work productivity in companies making intensive use of ICTs.

**Figure 10. The (TFP) efficiency component in explaining apparent work productivity (AWP) in Catalan companies, according to intensity of ICT use. 1995-1999 and 2000-2004** (thousands of current euros)




Source: In-house

**Figure 11. The (k) capital intensification component in explaining apparent work productivity (AWP) in Catalan companies, according to intensity of ICT use. 1995-1999 and 2000-2004** (thousands of current euros)




Source: In-house

## 2.3. Work-productivity sources in Catalan companies[87]

We find numerous approaches to the relationship between work organisation, ICTs, human capital and work productivity in the current literature. In fact, various investigations suggest that the productivity differences between companies can be explained by three factors: first, by investment in ICTs, and in particular by that done in productive processes based on microelectronic technologies; second, by the way that organisations structure and organise their work; and third, by the effectiveness of the companies' innovation strategies and, as a result, by the success in the introduction of new products, services and processes.[88]

From the analytical perspective of the impact of ICTs on corporate efficiency, the literature shows that: a) rates of return from digital investment are relatively higher than those in other physical components; and b) this is so because often digital investments are accompanied by other forces, in general, for improving human capital and changing organisational structures. It is precisely in this co-innovation process that the transformational impact of digital investment, along with its effects on company performance, is made clearer.[89] On the basis of these investigations, it can be demonstrated that a good part of the explanation for corporate efficiency depends on productive factor endowment, on improvements in the quality of human resources and on the relationship between technology and the organisation of work.[90] In fact the consolidation of ICTs as general utility technologies,[91] that is, as a source of long-term economic growth (or corporate efficiency), arising from both a direct contribution to advances in productivity and an indirect contribution through the creation of supplementary innovations (such as organisational ones), forms one of the main distinctive traits of economic (and corporate) activities at present.

As for the relationship between new organisational practices and corporate efficiency, a growing set of investigations has shown that there is a direct link between new formulas for work organisation and competitive company performance. The following five facts have been identified in this sense:[92] 1) there are considerable differences in the performance of more-or-less efficient companies or production plants; 2) it has been shown that a significant part of these differences is due to the variations in managing contractual relations; 3) there is a widespread consensus on what the organisational practices of high-performance work

87. This section is an extract from professor Pilar Ficapal's doctoral thesis.
88. Leoni et al. (2001).
89. Brynjolfsson and Hitt (2003).
90. Pilat (2006).
91. Albers (2006).
92. Pfeffer (2000).

mean; 4) better organisational practices can be linked to company strategy and interact to create positive effects; and 5) high-commitment organisational practices must interact with other elements to maintain a long-term positive effect. It is precisely in this line that various investigations show how new forms of work organisation establish productive improvements and increases in corporate-activity efficiency.[93]

Even so, although the international empirical literature has shown a significant correlation between new organisational work forms and the productive performance of companies, the indicators developed have not always explicitly incorporated the impact of ICT investment and use and their employment as a tool for organisational improvement in explaining corporate performance. To solve this problem, a set of work has emerged which incorporates the digital component in analysing the effect of high-performance organisational practices on company performance, especially on work productivity. Following this line, and already since the beginning of the second half of the 1990s, certain investigations have been confirming the problems arising from the lack of complementarity relations between technological and organisational innovation and arguing that one of the chief reasons to explain the weak progress of work productivity in various countries, in European ones in particular, is the feeble investment of companies in new forms of work organisation.[94] In fact, various authors have verified with UK companies[95] on the one hand and with a panel of UK and French companies[96] on the other, that the link between innovation at the work place and work productivity, has been become increasingly clear as the system of employment relations has developed towards establishing joint practices in decision taking and in resolving problems between business people and workers.

As for the study on causal relations, and from an investigation on the impact that ICT use in relations between work organisation and productivity by a broad range of US companies, the following conclusions were reached.[97] First, where non-management work uses computers, this is highly correlated with work productivity. Second, it has been confirmed that workplace reengineering leads to greater productivity, although other practices, such as payment by profits and/or stock options do not affect output per hour worked. As for the use of self-managing work teams, these seem to be linked to lower productivity levels, although during

93. The positive effects of new organisation systems on company returns have been demonstrated in a wide set of investigations. Among these, mention may be made of the corporate-level transversal and inter-industrial studies (Becker and Gerhart, 1996); of the establishment-level longitudinal and inter-industrial studies (Becker and Huselid, 1996; Black and Lynch, 1997), and of the intra-industrial investigations: Dunlop and Weil (1997) for textiles, MacDuffie (1995) for automobiles, Ichniowski, Shaw and Prennushi (1997) for steel, or Batt (1995) for telecommunications.
94. Andreasen et al. (1995).
95. Nickell and Van Reenen (2000).
96. Caroli and Van Reenen (2001).
97. Black and Lynch (2000; 2004).

the initial implementation of this practice, with the investigation's data referring to the end of the second half of the 1990s, seems to explain this paradoxical result. The proportion of workers who are regularly found in groups for exchanging information over work place issues, also have a positive impact on work productivity. Third, and in an accounting exercise on the growth realised by US industrial manufacturer companies during the 1993-1996 period, the decisive significance of work-place innovation systems is confirmed, above all that which arises in establishments that have unions protecting work safety, in explaining corporate efficiency.

In this line, a series of work attempts to verify causal relations between innovation at the work place and investment in and use of digital technologies for various countries and companies, and has found evidence to demonstrate this positive link between digital and organisational innovation and work productivity. In an analysis of a sample of US manufacturing-industry companies, the effectiveness of technological and organisational changes was examined.[98] To that end, innovative practices at the work place were defined on the basis of a series of indicators relating to human capital (current training level and training practices), decentralisation of decision making (work teams: presence/absence of stocks, activities, promotion and mainstreaming) and authority to take decisions. It was shown that companies making intensive use of ICTs, and having a high degree of process innovation established at the work place, show a work-productivity level which is 7% above that of companies which are innovative in this way. Moreover, the impact on labour productivity is practically non-existent where there is hardly any digital or organised innovation in corporate activities. Evidence confirming a positive link between digital and organisational innovation and work productivity has also been found in Denmark.[99] It shows in particular how companies that had invested in physical digital equipment and new ways to organise work, were recording annual labour-productivity growths of over 1 point compared to companies that had only invested in physical digital equipment, and in excess of 2 points compared to companies that had invested in neither of the two components. Other studies in Italy show that ICT investment would enable changes to be implemented in production processes, strategies, structures and organisational company practices and external relations, but, by the same token, digital investment and use would require organisational changes for their effective implementation.[100]

The establishment of positive effects among some of the new organisational practices and work productivity (for example, work teams, competency delegation for autonomous produc-

98. Bresnahan, Brynjolfsson and Hitt (2002).
99. Danish Ministry of Business and Industry (1996).
100. Leoni et al. (2001).

tion-problem solving and contacts with clients) has also been conclusively shown in Switzerland as has the fact that organisational innovation sets unexpected negative effects (for example, job rotation and comprehensive manager-competence delegation to workers). In addition, creating an indicator for the innovation practices at the work place establishes a positive effect on work productivity, though clearly less than the effect of the joint ICT-uses and human-capital indicators. Finally, and on the matter of complementarities, there is strong evidence for explaining work productivity among ICTs and human capital, but no complementarity relationship has been identified between these two last elements and work organisation.[101] In Germany a series of work, based on various time samples in companies from the industry, has shown there to be dependency relations between work productivity and investment in digital technologies and new work-organisation formulas, although evidence of complementarity relations can only be assessed for explaining labour efficiency in the area of ICT and human-capital links.[102]

We have basically seen how the literature highlights the positive effects of these complementarity relations between work organisation and technology on company performance, in particular on work productivity, but there is growing evidence too of the interaction capacities of digital-technological and organisational changes in developing the requirements expected of the work force and the tasks carried out at the work place. There is empirical evidence which shows how ICT investment and use do not become more widespread in productivity enhancements until workers and companies achieve the necessary training, technical and organisational competencies.[103] In fact, in a characterisation exercise of companies making intensive use of ICTs, it has been shown that digital investment is larger in organisations where there is more delegation to employees, there is more investment in training and drilling and less vertical organisational structures are adopted.[104]

Indeed, the literature has also started gathering evidence that complementarities between technological and organisational changes end up reinforcing changes to the skills and competencies required in work forces. In general, the literature calls these two effects Skill-Biased Technological Change (SBTC) and Skill-Biased Organisational Change (SBOC). Although at the start, the investigations carried out pointed to technological changes at the epicentre of corporate changes, granting a subsidiary role[105] to organisational changes, there is a growing, significant body of evidence which shows that, in the debate on the determining

101. Arvanitis (2003; 2005).
102. Bertschek and Kaiser (2001); Wolf and Zwick (2002); Hempell (2003); Bauer (2003).
103. Kato and Morishima (2002); Gibson (2002).
104. Brynjolfsson and Hitt (2000).
105. Aghion, Caroli and Garcia-Peñalosa (1999).

factors of changes in skills, competencies and occupational structures, technological-digital and organisational changes strongly interact and establish clear complementarity relations in the reasons for these requirements being in demand and in the changes to work places. From the biased perspective created by technological and organisational changes on worker capacities, an investigation carried out in Italy has demonstrated the additive effect among technological-organisational changes while also explaining changes to the make-up of skills and the structure of jobs[106]. Another investigation in that country, on a sample of group of companies in the private sector, has concluded[107] that: 1) possibilities of adopting new work-organisation practices and of using ICTs do not depend on the specific dynamics of companies: 2) ICTs and organisational changes do not determine value added increments where these are independently adopted. On the contrary, where certain specific practices are developed, such as changes in the hours-worked system, in work techniques and in training extensions, these make individual contributions to marginal work productivity increases; 3) ICTs establish a significant increase in work productivity and a net gain in added value if and only if they are combined with the adoption of practices that favour delegation of responsibility and a larger degree of autonomy to workers and, more generally, practices that change work techniques; 4) a very significant complementary effect on the productivity of companies has been appraised where extended training, drilling and introduction of ICTs interact. More specifically, in companies which adopt the practices of information sharing, increased worker autonomy or favoured relational aspects for achieving objectives and 5) product or service innovations become more profitable where ICTs and training programmes are developed in conjunction.

From the digital-change perspective, ICTs change the way in which decisions are taken in companies, making hierarchies redundant, since they are ousted by the interaction between work teams, facilitating lateral communications and increasing the involvement of workers in intensive, information-processing tasks.[108] In this regard, a notable correlation has been shown to exist between such technologies and improvements in delegating authority to workers.[109] It is precisely in Spain too that the links between ICTs and work-force skill improvements have been verified and a bias in skills resulting from digital technological changes has been conclusively demonstrated.[110] Other investigations show that a low level of human capital and a lack of (or slowness in) work reorganisation in companies act as barriers to ICT investment.[111]

106. Piva, Santarelli and Vivarelli (2003).
107. Cristini, Gaj and Leoni (2003).
108. Caroli (2001).
109. Siegel, Waldman and Younghdahl (1997).
110. Aguirregabiria and Alonso-Borrego (2001).
111. Bugamelli and Pagano (2001).

We shall specifically deal below with analysing the links between technology, organisation and work productivity, for the purpose of verifying a labour-efficiency determinant model for Catalan companies to demonstrate the effect of complementarities among these components. We shall take the line of the authors who consider that the set of work-place innovation practices measured through an indicator establishes a positive effect on productivity, though less than that of the joint ICT-use and human-capital indicator.[112] In this respect, the investigation leads us to consider a series of work hypotheses which we shall explain in detail below. From a review of the literature, significant inter-dependencies are shown to exist between technology, work organisation and human resources in companies with corporate performance. We should point out that many of the investigations, based on establishing relationships between variables, present serious problems when identifying causal relations and their management. Nevertheless, the investigations analysed confirmed that a good part of the explanation for corporate efficiency depends on productive factor endowment, on improvements in the quality of human resources and on the relationship between technology and the organisation of work.[113] This premise leads us to consider the first work hypothesis: ICT uses, new organisational practices and work qualifications are determining factors for work productivity in companies.

If we go a step further, and as we saw above, empirical evidence has been found on complementarities between technology, organisational changes and work-force competencies in explaining the long-term growth potential of companies.[114] In this regard, the available empirical evidence concludes that investing in digital technologies creates sustained productivity increases where such investment is combined with organisational changes and increased work-force capacitation. We shall therefore consider that combining technological, organisational and work-qualification factors produces synergies that affect corporate efficiency. In this line, we shall attempt to verify that combining technological, organisation and work-qualification factors produces synergic effects that explain work-productivity differences in Catalan companies.

A primary source of information provides us with a set of 1,283 companies taken from an initial database, arrived at through the elimination of strange cases and cases for which there is no available information for any of the variables included in the analysis. To mitigate the effect of such a loss of information we have weighed up the database obtained, according to a factor which corrects this situation on the basis of company size. One of the aims of the study, reflected in the hypotheses under consideration, consists in analysing the de-

112. Arvanitis (2003; 2005).
113. Pilat (2006).
114. Bresnahan, Brynjolfsson and Hitt (2002).

gree of incidence for the proposed explanatory variables on work productivity. It therefore concerns a type of explanatory analysis for which analysing multiple regressions by ordinary least squares proves to be appropriate. Our proposal is to incorporate a basic model into the analysis which includes explanatory factors for work productivity, and subsequently, a compact model where the independent variables referred to in organisation, technology and training are grouped together into systems (organisational, technological and training systems), which, again, are incorporated as explanatory factors for the model. Furthermore, this specification has to incorporate the combined effects of technology, organisation and human capital. By this we wish to verify the effects of the various constitutive factors of the models according to whether they are incorporated into the analysis in isolation or as part of a group, and to analyse the explanatory value of the complementarities between the technological, organisational and human-capital components in work productivity. Finally, we shall reproduce the estimations for large activity sectors, in particular according to whether the company is industry or service related. Following the specifications we have already put forward in this chapter, we shall attempt to explain work productivity through a model establishing its level that is based on the combination of some of its physical, technological, human and organisational capital as well as employment relations and the innovation culture.

Having reviewed the literature and statistical analysis conducted for verifying the link between work productivity and various technological, human and organisational components, we shall consider different types of variables in this investigation. We shall understand by the dependent variable, that is to say, work productivity, the sales turnover of companies per full-time worker. As for the independent variables: a) first, we shall include an intermediate-expenses indicator, necessary for the conversion in added value of the sales indicator used for understanding the productivity numerator; b) second, we shall appraise the influence of physical capital in work productivity through the company total-asset indicator; c) third, a set of variables relating to organisational planning; d) another set of variables shall measure the educational level, of technological competencies, and of extending training for management and non-management workers; e) a set of indicators referred to in managing the company's human resources; and f) an organisational-culture indicator for innovation. Table 3 shows the indicators used in the analysis.

**Table 3. Description of the variables used for establishing the explanatory factors for work productivity in Catalan companies. 2003**

| Name | Description | Scale |
|---|---|---|
| | Materials per full-time worker | |
| DESPINT | Total assets | Continuous (Log thousands of euros) |
| ACTIU | | |
| | Blue-collar workers take decisions in the operational sphere | Continuous (Log thousands of euros) |
| PREDECIS | | |
| PROCES | Companies are organised through processes or projects | |
| EQUIFLEX | Flexible and adaptable teams | Dichotomic (0, 1) |
| SUPEROBJ | Predominant form of supervising work by objective | Dichotomic (0, 1) |
| INTERINF | Workers can share and exchange information | Dichotomic (0, 1) |
| INPTIC | Innovations in the process based on ICTs | Dichotomic (0, 1) |
| INORG | Organisational innovations in the last two years | Dichotomic (0, 1) |
| | | Dichotomic (0, 1) |
| FREGDIR | Regulated training and/or extended regulated training of managers | Dichotomic (0, 1) |
| FREGNDIR | | |
| FTECDIR | Regulated training of and/or extended studies for non-managers | Categoric (1 to 6) |
| FTECNDIR | | Categoric (1 to 6) |
| COMPTEC | Extended technical training of managers | Dichotomic (0, 1) |
| | Extended technical training of non-managers | Dichotomic (0, 1) |
| EQUIPINT | Effect of ICTs on company changes | Categoric (1, 3, 5) |
| SISTPROD | | |
| SISTAPROV | Internet equipment | Categoric (1 to 4) |
| SISTDIST | Computerised production-planning systems | Dichotomic (0, 1) |
| VENDINT | Computerised planning systems with suppliers/purchases | Dichotomic (0, 1) |
| COMPRINT | Computerised planning systems with distributors | Dichotomic (0, 1) |
| | Percentage of sales via Internet out of the total (log) | Dichotomic (0, 1) |
| SEGURET | Percentage of purchases via Internet out of the total (log) | Dichotomic (0, 1) |
| REMUN | | |
| FLEXJORN | Work stability | Dichotomic (0, 1) |
| | Form of remuneration | Categoric (0 to 2) |
| CULTORG | Working-hour flexibility | Dichotomic (0, 1) |
| | Organisational innovation with the aim of developing new organisational structures | Dichotomic (0, 1) |

Source: In-house

As we have noted above, a growing body of investigations demonstrate direct links between the new work-organisation formulas and the competitive performances of companies and confirm that the new forms of work organisation establish improvements in production and increases in corporate-activity efficiency. In this respect, we have represented organisational capital through different variables which measure the intensity by which new organisational work practices are established. Although these elements do not include all the practices proposed by the various investigations to involve workers more closely and improve their efficiency (there is a large diversity in number and typology and this makes it difficult for a specific model to be adopted), their representation must be stated in relation to organisationally-improved forces.

So, as an indicator of the work units' specialisation and grouping parameters, the flexible and adaptable work-team-presence variable has been considered (EQUIFLEX). The use of

this work-team typology is gauged through the responses of the companies, each of which has indicated whether or not it has such work teams present. Their presence is indicated by the value 1 and their absence by the value 0. The variable which records the capacity enjoyed by workers for sharing and exchanging information from all or almost all work points measures exchanges of information and communication between work units within companies (INTERINF). It takes the value 1 where this is affirmative and the value 0 where there is no such possibility. The PREDECIS variable measures the autonomy of workers to take decisions and is therefore configured as an indicator of decentralisation of work organisation, through the question: who takes decisions in the operational sphere? In this context, business people or managers had to reply where the decisions were being taken by managers, lower and middle management and/or blue-collar workers. In our approximation, the variable takes the value 1 where blue-collar workers take decisions in the operational sphere and the value 0 where it is managers or middle and lower management who take the decisions in the operational sphere. As the organisational literature,[115] points out, the availability of a performance-assessment system setting objectives and linking pay to these objectives is a substantial component in new corporate designs. In this context, business people or managers had to reply by explaining prevailing work-monitoring/supervision form used in their respective companies. In our approximation, the variable SUPEROBJ takes the value 1 where the prevailing monitoring/supervision form is based on setting objectives/results, and takes the value 0 where it is based on hierarchies. With regard to organisational reconfigurations, companies were asked about the organisational forms adopted by them: projects or processes, products or services; geographical and/or functional area. In our investigation, the variable PROCES takes the value 1 where the organisation takes the process form, and the value 0 for all other cases. As for innovation, the questionnaire first asked for Catalan managers to answer whether there had been any innovations carried out in the company in processes using ICTs over the last two years (INPTIC). In our approximation, positive answers take the value 1 and negative ones take the value 0; and second, Catalan business people had to answer whether any organisational innovations had been introduced into their companies over the last two years. In our approximation, positive responses take the value 1 and negative ones the value 0.

We shall go on to apply a principal-component factor analysis after the Correlation Matrix has confirmed the presence of a significant correlation between the components, and this will demonstrate the appropriateness of the test. Prior to extracting the factors, and so as to verify the suitability of this analysis, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy has been calculated (KMO: 0.570) and Bartlett's test of sphericity (value: 257.228; signifi-

115. Huselid and Becker (1996; 1998).

cance: 0,000). 4 factors have been retained by which 64.7% of the variance can be explained. An interpretation of the four factors obtained from the Rotated Component Matrix has led us to link the first factor with innovation, shaped by the innovation in process based on ICTs and by organisational innovations over the last two years (INNOV). The second factor, formed by the decision making of blue-collar workers in the operational sphere and by objective/result management as the prevailing form for monitoring or supervising work, has been called autonomy (AUTON). The third factor, which has been called interconnection is linked to the presence of flexible and adaptable work teams for various business lines and with which workers can share and exchange information (INTERC). Finally, factor 4, which we call process-orientated organisation (ORGPRC), refers to project or process organisation form.

On the other hand, and as we have already seen, what the debate on new organisational corporate designs has in common is the consideration of changes in human and organisational capital as essential references for competitive advantage development. We have attempted to gather information on human capital in Catalan companies through three approaches: first, recognised training plus extended regulated studies, second, ongoing and/or made-to-measure training plus extension of this type of training; and finally technological competencies. The first dimension we attempt to measure has to do with the educational level available to management and non-management workers with regard to the regulated training and extended regulated studies borne by companies. We understand regulated training as the course that progresses from compulsory basic education to university studies, that is to say, that body of essential knowledge and skills provided by educational systems that qualifies people to accomplish the goals of their respective jobs.

In order to create a regulated training indicator for each collective, a classification has to be made for managers (FREGDIR) and non-managers (FREGNDIR) according to the level of recognised training and the extended regulated training. In this respect, values have been granted *a priori* through two dimensions: completed studies are scored according to an arithmetic progression so that primary studies or lack of studies take the value 1; secondary studies take the value 3; and university studies take the value 5; extended training takes the value 1 or 0 depending on whether or not management or non-management workers are trained at the company's expense. The combined sum of the two dimensions results in the following scoring: for primary studies or lack of studies and non-extended training, the value 1, if extended training, value 2; for secondary studies and non-extended training, the value 3 and if there is extended training, the value 4; finally, for university studies, the values given are 5, where there is no extended training, and 6, where there are extended regulated studies.

Second, we wish to measure the extension of ongoing and made-to-measure training of management and non-management workers at the heart of companies. In fact, and based on a research of the literature, investment in training and capacitation, in other words, where all the members of the work teams regularly receive training at the work place, has been identified as one of the components in high-performance work systems which leads to greater efficiency.[116] To this end we have created a technical manager-training indicator (FTECDIR) deriving from the sum of ongoing and made-to-measure manager training borne by companies. Companies where managers have undergone certain types of training (made to measure and/or ongoing) take the value 1; and where they do not, such companies take the value 0. The same criterion is followed for created a technical non-management worker training indicator (FTECNDIR). Finally, as for the technological competency level of workers, we have introduced a variable that measures the effect which ICTs have had on changing corporate activities (CTEC). We have assumed that positive perceptions regarding activity changes in companies according to digital innovation indicate a need for higher technological capacitation. This variable, which originally takes values from 0 to 10 (0=having no effect at all; 10=having full effect), has been categorised into 3 stages depending on its response: low level (values from 0 to 4), medium level (5 to 7) and high level (values from 8 to 10). The new variable's recodification is as follows: low level, value 1; medium level, value 3; and high level, value 5.

We shall now apply a principal-component factor analysis whose suitability has been confirmed using the correlation matrix (statistics: Kaiser-Meyer-Olkin Sampling Adequacy Test (KMO: 0.561) and Bartlett's Test of Sphericity (value: 804.941; significance: 0,000). 3 factors arise which explain the 78.3% variance. A first factor which we call technique and ranges from extended technical training by managers and non managers at the expense of the company (FTEC); a second factor which we call educational level is made up by regulated training levels and in the extended regulated training of managers and non-manager workers (NEDUC); and a third factor, competencies in using technologies (COMPTEC).

Incorporating a group of variables relating to technological resources is for the purpose of corroborating the transformational impact of digital investment and its effect on company performance. We consider technological-equipment endowments, as well as intensive use of digital technologies in both internal and external planning, being capable of consolidating themselves as a tool for centring and managing the contribution of employees towards organisational objectives and therefore towards corporate efficiency. In this respect we shall detail below the variables that measure technological capital. As for general equipment

116. European Commission (2002).

(EQUIPINT), the Internet equipment indicator measures the degree to which this digital technology is established and is a clear indicator of the use of this technological network. It takes four values: 1) very low equipment level, where companies are not connected to the Internet; 2) low equipment level, where companies have narrow-band connections to the Internet; 3) normal equipment level, where companies have narrow Internet connections and their own webpage; and 4) advanced equipment level, where companies have broad-band Internet connections and WebPages.

With regard to the uses of digital technologies, measurements are made on the one hand where companies have a computerised planning system for production. This variable (SISTPROD) takes the value 1, where it has this available, and the value 0 where it does not. On the other hand, two variables referred to in external ICT use are included: their measures interest us where companies rely on external-agent planning systems. We make measurements specifically where companies have a computerised supplier/purchase planning system available (SISTAPROV) and where they have a computerised distributor planning system (SISTDIST). Both variables are dichotomic and each takes the value 1 where positive; and the value 0 where they lack this system. Finally, through the information with which the questionnaire provides us, we have considered whether companies sell through the Internet; and whether they buy through the internet. The measurement is taken through a logarithm of sales percentages (VENTINT) and purchase percentages (COMPRINT) through the Internet. We have applied the factor analysis through the principal-component method. The correlation matrix shows us the suitability of the analysis and we have beforehand calculated the Kaiser-Meyer-Olkin Sampling Adequacy Tests (KMO: 0.643) and Bartlett's test of sphericity (value 89.423; significance: 0,000). The resulting factors explain 68.7% of the variance; and we have identified as follows: 1) the first factor we identify as an operations network, includes the availability of technological systems in supply activities, production and distribution (XOP); 2) another factor, such as e-commerce, consisting of sales and purchases over the Internet (CELECT); and 3) the last factor, consisting of Internet equipment. (EQUINT).

We shall introduce a set of variables, based on the investigations linking various human-resource and company-performance management practices, which relate to recruitment methods, forms of payment and types of work days. We shall assume that safety at work, meaning the establishment of stable employment relations through an indefinite contract, enables workers to identify more with their company. This has an impact on efficiency.[117] Based on the variable for contract types used in companies, we shall produce a new varia-

117. Womack, Jones and Roos (1990); Ichniowski, Shaw and Prennushi (1993).

ble, SEGURET. This will take the value 1 where the indefinite contractual method is above the Catalan average; but it will take the value 0 in all other cases. As to the achievement and performance of workers, our analysis will include the new payment systems that are consolidated as wage-flexibility mechanisms intended explicitly for the allocation of financial rewards where specific results are obtained. In our opinion, designing incentive systems allows alignment of the objectives behind the various collectives involved in performance activities and enables provision of the forces that have positive effects on company performance. The variables which constitute the various forms of payment are fixed payment, variable payment, profit sharing, stock options and deferred payments. We aim to create a form-of-payment indicator (REMUN) using the information that is available for managers and for non-managers. To do this, information will first be processed from the two collectives separately. All non-fixed payment variants are added up for each collective, so that we may find out which of the records are the ones where the forms of payment are variable for both managers and non-manager workers. Having analysed the link between the two created variables according to whether or not managers receive variable payment (value 1 where managers do, and 0 where they do not), and whether non-manager workers do as well (value 1 where they do and value 0 where they do not), we have decided to leave out company groups whose managers do not receive variable payment but whose non-manager workers do, for a low proportion of individuals. To this end, we shall create the indicator REMUN as well as 3 groups which will represent the other links. The values taken by the variable are 0 where neither managers nor workers receive any form of variable payment; 1 where only the managers receive variable payment; and 2 where managers and non-manager workers receive some form of variable payment.

The last component to be incorporated on employment relations within the company has to do with work day flexibility. Establishing more flexible organisational forms opens the way for allocating more varied work day hours, where they are configured as an opportunity, provided that the application made of them by companies benefits not just the organisation but its workers too; or they may become instrumental in work precariousness. In this respect, the practice will provide different company-performance explanations depending on how it is applied. The part-time work day variable will be expressed as a percentage of workers; for this reason, we have created a variable, FLEXJORN, which has the value 0 where the usual work day at the company is full-time, and the value 1 where it is part-time. Finally, we have included a variable which relates to innovative organisational culture. The supposition on which the inclusion of this variable is based is that companies would be induced to implement changes in organisational structures where there would be, among other things, improved processes, returns for investing in intangibles, responses to new supply and client demands, or more effective use of digital technologies; components which would further improved efficiency. We have used the variable CULTORG, which takes the value 1 where companies have mentioned having performed any innovation in organisational structures

over the last two years; and takes the value 0 where they state that no such organisational innovation has taken place.

Once the extraction process has been described in detail for factors making up the basic work-productivity explanation model, we shall then describe the creation process for variables forming the compact model. We wish, by all this, to verify the effects of the various constituent variables of the models according to whether they are included in the analysis individually or in groups. We shall create, in particular, work-organisation, technology and human-capital indexes based on the indicators obtained by analysing the main components mentioned above. To obtain such indexes we shall calculate the factors' arithmetic mean. On the one hand, the four factors, innovation, autonomy, interconnection and organisation by process to create the organisational capital index (ORG); the three factors, technical training, educational level and technical competencies for human capital (HUMA); and finally, the three factors, operations network, e-commerce and Internet equipment for technological capital (TECN). In conjunction with these indicators, this second model also contains variables linked to human-resource management, safety at work, forms of payment and working-hour flexibility; the variable for organisational culture vis-à-vis innovation. In addition, the model will also include the intercepts ORG*HUMA, HUMA*TECN and ORG* TECN. By making such an inclusion in the analysis we hope to verify one of the hypotheses of the investigation, according to which the complementarities of technological, organisational and human capital *produce synergic effects that explain work-productivity differences in Catalan companies.* So, by following the empirical evidence in use, we shall estimate, by ordinary least squares, a function of apparent work productivity for the sample group of companies which has the following functional form, i where $\varepsilon_i$ represents the error term (basic model):

$$PTL = \sum_{i=1}^{n} \beta_0 + \beta_1 DESPINT_i + \beta_2 ACTIU_i + \beta_3 ORG_i + \beta_4 HUMA_i + \beta_5 TECN_i + \beta_6 SEGURET_i + \beta_7 REMUN_i + \beta_8 FLEXJORN_i + \beta_9 CULTORG_i + \beta_{10} ORG*TECN_i + \beta_{12} EQUINT_i + \beta_{13} SEGURET_i + \beta_{14} REMUN_i + \beta_{15} FLEXJORN_i + \beta_{16} CULTORG_i + \varepsilon_i$$

In the same way, the functional form of the compact model is as follows:

$$PTL = \sum_{i=1}^{n} \beta_0 + \beta_1 DESPINT_i + \beta_2 ACTIU_i + \beta_3 ORG_i + \beta_4 HUMA_i + \beta_5 TECN_i + \beta_6 SEGURET_i + \beta_7 REMUN_i + \beta_8 FLEXJORN_i + \beta_9 CULTORG_i + \beta_{10} ORG*TECN_i + \beta_{11} TECN*FORM_i + \beta_{12} ORG*FORM + \varepsilon_i$$

Prior to applying the analysis, the correlation coefficients were examined, and no multi-collinearity problems were detected that could prevent the method's application. From the basic model's estimate (table 4) it can be inferred that the set of variables introduced have a very significant explanatory power in explaining the level of work productivity in Catalan companies (p=0.000). In addition, the model offers a good fit ($R^2 = 0.745$).

**Table 4. Determinants of work productivity in Catalan companies, the Basic Model.[1] 2003** (linear multiple regression analysis: ordinary least squares; dependent variable; sales per full-time worker (log))

| | Coefficient Estimation | T-value |
|---|---|---|
| Constant | | 28,181*** |
| Materials per full-time worker (log) | 0,676*** | 36,935 |
| **Physical capital** | | |
| Asset per full-time worker (log) | 0,224*** | 12,152 |
| **Organisation** | | |
| INNOV | -0,066*** | -3,558 |
| AUTON | 0,020 | 1,369 |
| INTERC | 0,035** | 2,398 |
| ORGPRC | 0,029** | 2,001 |
| **Training** | | |
| NEDUC | 0,101*** | 6,513 |
| FTEC | -0,013 | -0,882 |
| COMPTEC | 0,050*** | 3,174 |
| **Technology** | | |
| XOP | -0,037** | -2,390 |
| CELECT | -0,049*** | -3,332 |
| EQUINT | -0,068*** | -4,139 |
| **Employment relations** | | |
| SEGURET | 0,038** | 2,526 |
| REMUN | -0,003 | -0,173 |
| FLEXJORN | 0,031** | 2,094 |
| **Culture** | | |
| CULTORG | 0,103*** | 6,010 |
| n (=i) | 1.283 | |
| Corrected $R^2$ | 0,745 | |
| F | 235,361 | |
| Sign. | 0,000 | |

1: Catalan productive network group

*** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

Source: In-house

As for the standardised coefficients obtained, the following considerations are to be noted: a) productive capital offers a significant and highly notable contribution in explaining the level of apparent work productivity in Catalan companies; b) the coefficients of three out of the four organisational factors contemplated are statistically significant in the explanation of growth potential in Catalan companies. Work-interconnection and process-organisation factors exercise positive effects in explaining labour efficiency, while the innovation factor, highly significant, acts negatively. Autonomy in decision making is not statistically relevant; c) on the matter of work qualification, coefficients are obtained that are both significant and positive in explaining apparent work productivity by regulated training factors (standardised educational level and regulated, extended training) and for digital technological competencies, whereas technical training (ongoing and made-to-measure extended training) is not signifi-

cant and therefore not relevant; d) all the coefficients of the digital technological factors contemplated are significant, even if they have a negative impact on corporate work productivity; e) with regard to employment relations, we observe a significant, positive impact on labour efficiency from security in work (indefinite recruitment) and from working-hour flexibility (part-time work days). Forms of variable payment do not have any significant effect on labour efficiency; and f) innovative organisational culture, taken on the basis of innovations which change the organisational architecture of companies, has a significant, positive impact on the labour efficiency of the private production network in Catalonia.

We can therefore assert that productive physical capital, work interconnections, process organisation, regulated training, digital technological competencies and contractual security as well as working-hour flexibility and innovative organisational culture are determinants in explaining the level of apparent work productivity in Catalan companies. By contrast, the components of process and organisational innovation and the indicators which relate to ICT endowment and use had a negative impact on labour efficiency in Catalan companies in 2003. For their part, autonomy in decision making, technical training and forms of payment do not have any effect on the determination of labour productivity. In fact, these results highlight: a) mixed evidence on the impact of organisational reconfigurations and work-force qualifications on work productivity; b) a negative impact of ICT use on the long-term growth potential of Catalan companies. To confirm whether the labour efficiency of Catalan companies do not depend to a large extent on their organisational components, on qualifications and digital technology, which would presuppose a sharp contrast between the international evidence and could pose serious problems in the sustainability of its long-term growth model, we shall consider a compact model below which shows the joint impact on the apparent work productivity of the systems' organisation, qualification and digital-technology practices along with their corresponding complementarities.

As for the contribution of the indexes, we have estimated, by ordinary least squares, the compact model in two stages. The first does not consider that impact of complementarity relations (model 1), while the second considers the impact of the inter-related set of digital technological and organisational changes and of work qualifications in determining corporate labour efficiency (model 2). The latter model has been reproduced for the case of sectorial company positions (industry and services). The four models, represented in table 5, offer a notable explanatory capacity (p=0.000) while the goodness of fit (corrected $R^2$) is never below 70%. As for the coefficients obtained in the estimates, the following considerations ought to be mentioned. For the compact model without complementarities (model 1): a) just as in the basic model, investment in productive physical capital continues to produce maximum contributions in explaining the level of apparent work productivity in Catalan companies; b) creating indicators for new joint organisation practices, qualifications and digital

technology turns out to be appropriate, seeing that the three offer a significant contribution in explaining labour efficiency, although each with a very different one: the organisation and qualification work indicators have a positive impact on productivity, while the digital technological indicator has a negative on; c) again, as in the basic model, the contributions above are complemented by a significant, positive impact on employment relations based on security in work (indefinite recruitment) and flexibility in work day hours; and with a favourable effect of a certain innovative organisational culture which promotes organisational architectural changes in companies.

For the compact model with complementarities (model 2) it is remarkable that: a) again, the coefficient of the productive physical capital is the most notable in explaining the labour efficiency of Catalan companies, b) the introduction of indicators that capture complementarities among the new systems of organisation practices, of work-force qualifications and investment and the uses of digital technologies proves to be appropriate, seeing that the three combinations of indicators are significant in explaining the level of apparent work productivity. Despite that, we should point out the double direction of these contributions: while the interaction between organisation and technology and between organisation and qualification have a positive effect on labour efficiency, the interaction between technology and qualifications establishes a negative impact on the level of labour productivity; c) the introduction of the complementarity indicators changes the contribution of their individually-treated indexes. So while in the organisational case, the introduction of their complementarities with work and digital technology qualifications makes their individual contributions significant, in the case of qualifications just the opposite occurs, since the introduction of the interaction with organisation and technology proves to be insignificant in this variable; d) as was already the case before, the given contributions combine with a significant, positive employment-relations contribution, based on security in work and flexibility in the types of worki day, together with an innovative organisational culture that is committed to changing company organisational designs.

We can therefore conclude this approximation to the determinants of apparent work productivity of Catalan companies in 2003 to assert that there is a confirmed establishment of significant, positive relations between new joint organisation practices and work qualifications and between the new organisational systems and ICT investment and use. In contrast, the interaction between the new work-qualification schemes and investment and digital technology uses has a negative effect on determining labour efficiency. In this way we can identify a long-term economic growth model for Catalan companies that is characterised by a significant contribution of productive physical capital and new forms of work organisation. In addition, the latter increase their long-term synergic effects on the growth potential of

companies where they are combined with an improvement of human capital and with ICT investment and use. Similarly, it should be pointed out that the contributions above are complemented with a positive impact of certain labour relations, based on contractual stability and work day flexibility, and within a setting where a prevailing innovative-organisational culture ends up transforming the organisational structure of companies. However, this efficiency model is not characterised by the importance of joint work-qualification schemes (insignificant) where the digital component, as well as its interaction with improvements in human capital, has a negative impact on the determination of labour efficiency of Catalan companies in 2003.

In addition, we have repeated, while looking for differentiated forms of behaviour, the causal-relationship analysis as specified in the compact model with complementarities (model 2) for the two large activity sectors in Catalonia's private production network, industry and services. Apart from the importance of the impact of productive physical capital, it confirms that there are differentiated behaviour models in explaining labour efficiency in the industry and service sectors. We observe in the industry sector that neither the new systems for work-organisation practices nor the capacitation of human capital have any significant impact on apparent work productivity. Digital technologies, on their own, have a negative impact on the long-term growth potential of industrial companies. As for complementarities, note it is solely the interaction between digital technology and work qualifications that has a significant and favourable impact on labour efficiency. This forms a clearly distinctive element regarding the results obtained for the entire private productive network. On the matter of industry-sector employment relations, note the significant, positive impact of wage flexibility, in a system where, again, security in work and an innovative organisational culture also turn out to be important in explaining the growth potential of Catalan industrial companies.

Services, for their part, offer a behaviour model for explaining their efficiency, an efficiency that differs considerably from that of industry companies. In this large activity sector, the organisation component proves to be very significant and positive, to the point where it exceeds the contribution of productive physical capital in explaining the level of apparent work productivity. On the other hand, even though the digital technological component and its interaction with work qualifications yet again have a negative impact, it should be pointed out that positive complementarity relations are established between the new systems for work organisation practices and qualifications and ICT investment and uses. All these impacts are made within a framework defined by certain labour relations where it is solely the flexibility of work days that affects productivity, and by the relative importance of an innovative organisational culture that promotes organisational changes in company organisation.

**Table 5. Determinants of work productivity in Catalan companies, the Basic by activity sectors. 2003** (linear multiple regression analysis: ordinary least squares; dependent variable; sales per full-time worker (log); compact model)

| | Model (1) | Model (2) | Industry (3) | Servies (4) |
|---|---|---|---|---|
| Constant | (29,122)*** | (29,360)*** | (21,993)*** | (24,943)*** |
| Materials per full-time worker (log) | 0,683***<br>(37,704) | 0,681***<br>(37,875) | 0,814***<br>(9,819) | 0,664***<br>(29,355) |
| **Physical capital** | | | | |
| Asset per full-time worker (log) | 0,229***<br>(12,544) | 0,232***<br>(12,767) | 0,201***<br>(9,165) | 0,216***<br>(9,480) |
| **Organisation** | | | | |
| ORG | 0,095***<br>(6,544) | 0,148***<br>(12,767)) | 0,018<br>(0,805) | 0,221***<br>(9,045) |
| **Training** | | | | |
| HUMA | 0,058***<br>(3,667) | 0,023<br>(1,335) | 0,013<br>(0,715) | 0,031<br>(1,363) |
| **Technology** | | | | |
| TECN | -0,102***<br>(-6,468) | -0,116***<br>(-7,306) | -0,038**<br>(-2,214) | -0,122***<br>(-5,861) |
| **Employment relations** | | | | |
| SEGURET | 0,028*<br>(1,875) | 0,029**<br>(1,958) | 0,031**<br>(2,021) | 0,021<br>(1,026) |
| REMUN | -0,001<br>(-0,043) | 0,001<br>(0.043) | 0,036***<br>(2,592) | -0,031<br>(-1,582) |
| FLEXJORN | 0,039**<br>(2,611) | 0,045***<br>(3,055) | -0,011<br>(-0,775) | 0,063***<br>(3,147) |
| **Culture** | | | | |
| CULTORG | 0,103***<br>(6,010) | 0,051***<br>(3,441) | 0,027*<br>(1,914) | 0,040*<br>(1,935) |
| ORG*TECN | | 0,035**<br>(2,304) | -0,027<br>(-1,308) | 0,050**<br>(2,542) |
| TECN*FORM | | -0,078***<br>(-4,615) | 0,061**<br>(2,918) | -0,105***<br>(-4,680) |
| ORG*FORM | | 0,070***<br>(3,949) | 0,023<br>(1,310) | 0,130***<br>(5,164) |
| n (=i) | 1.283 | 1.283 | 310 | 889 |
| Corrected $R^2$ | 0,745 | 0,748 | 0,948 | 0,712 |
| F | 410,258 | 318,925 | 474,179 | 184,257 |
| Sign. | 0,000 | 0,000 | 0,000 | 0,000 |

Model (1): entire Catalan productive network without intercepts; Model (2): entire Catalan productive network with intercepts. Industry (3): Services (4)

Value t between brackets. *** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

Source: In-house

## 2.4. Conclusions

Throughout this chapter, which focuses on the study of the long-term growth potential of Catalan companies, we have attempted two analytical exercises. In the first one, which is recorded in the literature on the facts of productivity, we have examined the contribution of capital intensification (ratio of capital per worker) and the contribution of the efficiency by which the inputs (or total factor productivity, TFP) combine in explaining the growth potential of corporate activities (or work productivity). We expect that the greater the impact of digital change, the more the TFP contribution will increase in explaining work productivity. The descriptive data show that: a) the long-term growth potential of Catalonia's companies has declined. In fact the nominal average rate of progress in the apparent work productivity of Catalan companies has gone from a 4.6% growth for the 1995-1999 period to a 3.7% growth in the 2000-2004 period; b) with components, note that the growth potential of Catalan companies is largely sustained in the intensification of capital. Indeed, although the growth of capital endowments per worker declined between the two reference periods, it still continues to grow with force (from a nominal average of 6.9% in the 1995-1999 period to 6.2% in the 2000-2004 period); and c) finally, it should be mentioned that despite advancing at lower rates, the rate of efficiency advancement of the private production network in Catalonia has been accelerated during the two reference sub-periods (from a 3.1% nominal average in the 1995-1999 period to 4.1% in the 2000-2004 period). Good and bad news is therefore established for the trajectory of apparent-work productivity in Catalan companies. The bad news has to do with the slowing down of the long-term growth potential of Catalan companies (PTL). The good news concerns the improved growth of its efficiency component. In order to explain this, we developed a causal-relation model with the aim of finding out the determining factors in the growth potential dynamics of Catalan companies.

From the perspective of the entire production network in Catalonia, it is important to make it clear that the impact of the capital-intensification coefficient on the growth potential of Catalan companies declines as we progress through the sample years (1995-2004). In fact the standardised coefficient of this variable has developed downwards during the reference period, and if we calculate its average value, we observe that this has gone from a value of 66.4 thousand euros in the 1995-1999 period to another one of 43.4 thousand euros between 2000 and 2004. By contrast, the total factor productivity has shown the opposite trajectory, and has gone from an average value of the estimated annual coefficient of 37.1 thousand euros in the first period to another of 49.9 thousand euros in the second period. It is therefore shown that in determining the long-term growth potential of Catalan companies, the efficiency by which it combines their inputs takes on a growing role, at the expense of capital intensification. This is basically the case with the excellent results attained during the financial years of 2000, 2002 and 2004, which reversed the trends of the second half of

the 1990s, during which the growth potential of Catalonia's private sector was being explained chiefly through capital intensification.

This specific analysis of Catalonia's corporate network, by dividing it up into sections according to the intensity of ICT use, also brings startling conclusions. In fact, the level of estimated annual TFP coefficients for all companies making intensive use of ICTs has developed very substantially during the reference period. So calculating the average of the estimated values through the two reference sub-periods demonstrates: the average efficiency-coefficient value in this set of companies went from 30.2 thousand euros in the 1995-1999 period to more than double that during the 2000-2004 period, with an average of 78.7 thousand euros. This trajectory clearly contrasts with the development shown by the subsample of companies with low and medium ICT use. In the set of companies with low ICT-use, even though the impact of the average TFP coefficient on apparent work productivity accelerated (from 38.7 thousand euros in the 1995-1999 period to 43.1 thousand euros for the 2000-2004 period), these values still fall below those registered for capital intensification. In the set of companies with medium ICT use, there was a fall in the average share of the annual efficiency coefficient on apparent work productivity (from 55.6 thousand euros in the 1995-1999 period to 31.0 thousand euros in the 2000-2004 period).

These therefore confirm then that the intensity of digital changes in Catalan companies is linked to a greater impact of efficiency levels on the long-term growth potential of the private productive network and that this has been established as the main explanatory element for efficiency improvements in the Catalan economy. In contrast, companies with a lesser intensity of ICT uses show a greater capital-intensification impact in explaining apparent work productivity. In fact, with this analysis exercise on the long-term, potential-growth determinants of Catalan companies, we are given confirmation that there are both positive and negative aspects. The negative aspects have to do with the slowing down of apparent work productivity. This seems to relate to the significant contribution of capital intensification in our production network and to an efficiency impact on the relatively-modest work productivity in those companies that use digital technologies with less intensity. The positive aspects have to do with the acceleration in efficiency with which the productive network combines its factor endowment. This is directly related to the very favourable impact that TFPs have on apparent work productivity in companies making intensive use of ICTs.

On the other hand, and from the perspective of work-productivity sources, we wished to ascertain the impact that the processes of technological, organisational and human-capital co-innovation have. To summarise, we can confirm that the new organisational forms, in conjunction with digital technology investment and use and with work qualification processes, under an employment-relations framework which is defined by security and flexibility, and

by the presence of an innovative, organisational culture, are determinants in explaining work productivity levels in Catalan companies.

All the same, two considerations must be made. First, it should be noted, as inferred from the results of the analysis of the basic model's determinants, that the evidence on the impact of organisational reconfiguration, ICT uses and work qualifications on the labour efficiency of all of Catalonia's companies is mixed. In a situation that is notable for the significance of productive physical capital, only the factors that are linked to the interconnection of work, process organisation, regulated training, digital technological competencies and innovative cultural organisation are positive and significant in explaining the long-term growth potential of Catalan companies. By contrast, other factors such as innovation, autonomy, technical training, operation networks, e-commerce and Internet equipment have either a significant and negative impact or not impact at all in explaining the work productivity of Catalan companies. Second, it should be noted that, as can be inferred from the results of the analysis of the compact model's determinants with complementarity relations, the establishment of joint practices, for new networked-work and ICT-use organisation schemes and for new networked-work and work-qualification organisation schemes, have a significant and positive impact, though clearly below that of productive physical capital, on the labour-efficiency levels of Catalan companies. By contrast, the establishment of complementarity relations between joint ICT-use and work-qualification practices reduces the work productivity of Catalonia's entire private productive network.

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# Chapter 3

# ICTs and the international competitiveness of Catalan companies

**Joan Torrent and Ángel Díaz**

We have analysed, in the previous chapters, the impact which digital technologies and their co-innovation elements have in determining the long-term growth potential and the wages borne by Catalan companies. In fact, we could have concluded that the interaction between digital-technology investment and use, productive re-orientation and organisation and training of human capital establish better materials both for companies (work productivity) and for workers (wages). However, we must point out that these positive effects have not become widespread within Catalonia's productive network. We have had to divide up the productive network into sections while looking for organisations where technological and organisational co-innovation processes have a higher presence and where knowledge-use intensity is a more common resource, so we could discover any impacts on efficiency and wages. This is probably so because these days Catalonia's economy shows a two-fold productive structure. On the one hand, here we have the larger part of the productive network, making no intensive use of ICTs, having a clearly improvable level of training for its work force, presenting productive and organisational structures that have little flexibility and low decision-making autonomy and capacity among its workers and where innovative processes are still of rare occurrence. This set of companies, and we cannot pin it down to an activity sector or specific dimension, shows an extensive growth pattern, that is, bases its long-term expansion dynamics on an increase in its factor endowment, and in work factors in particular. It is precisely for this reason that Catalonia's work-productivity growth has been developing along disturbingly low rates. On the other hand, another, smaller set of companies establishes its growth potential on the interaction between human capital, production and organisation re-orientation and ongoing innovation dynamics, in particular those that are digital based. This set of companies, clearly smaller than the first group but with a much higher long-term growth potential, is the one that determines increases, even if modest, in the efficiency of our productive network.

On the basis of the above-mentioned situation, we shall embark below on an analysis of the international competitiveness of Catalan companies. In fact, we wish to verify whether the determinants for improving efficiency, that is, educational stock, ongoing extended training and technological and organisational co-innovation processes, which have turned out to be so successful for improving the productivity of companies that introduce them intensively, are also a reason for the advance of the international market share, in an environment shaped by globalisation of economic flows. We shall therefore examine the international-competitiveness situation for Catalan companies and their determinants.

## 3.1. ICT, intangibles and international competitiveness: theoretical framework and empirical evidence

The academic preoccupation with competitiveness has grown considerably over the last years. We can broadly ascribe this interest to three phenomena that are bringing about considerable changes to the structure of the world economy: a) the consolidation of the globalisation process, which presupposes an economic capacity in real time and on a planetary scale; b) the wide-spread growth of economic regionalisation processes. The creation of regional economic areas, by which convergence problems grow, adds to the already-traditional literature on the disparities in income and welfare of the world's various economies; and c) the empirical verification of increased differences in growth of product per capita in the planet's two main economic areas, the USA and the European Union.

In fact, economics literature has dealt with the problems of competitiveness, and its divergences, along four main lines of analysis.[118] The first two are aggregated while the second two are disaggregated. The first approximation is the one represented by the growth-accountability models we have already seen in detail in the previous chapter. According to this approximation, work-productivity improvements are explained by capital intensification (ratio of capital per worker). In this context, competitive differences between wealthy and poor countries can be reduced where smaller levels of capital, whether physical or human, raise the marginal productivity of capital and, in this process, accumulation is encouraged. In this way growth would be accelerated in the more under-developed economies and would favour the challenge of convergence with the wealthier economies.[119] In the second family of models, based on the theory of endogenous economic growth,[120] competitiveness and its convergence can be determined by the technological differences between economies. In fact, the presence of endogenous factors promoting technical progress in advanced economies could ensure that differences between countries continue. Such a technological catch-up could explain the maintenance of efficiency differences between economies. The third family of models, based on the structural-change approximation,[121] underscores the economic-growth process and the convergence in competitiveness being tightly bound to the structural changes that are associated with them. So over the periods during which economies carry out broad resource shifts among sectors, their efficiency growth potential ostensibly improves, achieving significant convergence with other economies. To this end, it is worth stating that wide-spread innovation stages such as the current one, characterised by

118. Caselli and Tenreyro (2004). Pérez et al. (2006).
119. Barro, Mankiw and Sala-i-Martin (1995).
120. Romer (1990); Grossman and Helpman (1991); Aghion and Howitt (1998).
121. Passinetti (1989); Caselli and Coleman (2001).

the consolidation of ICTs as general utility technologies, are associated with significant changes in the structure of companies and sectors, and this allows movements both within and between economies. Finally, the fourth family of models, developed along the new theory of international commerce,[122] argues for the importance of international openness in explaining economic growth and competitiveness. In fact, benefiting from competitive advantages and efficiency incentives arising from external competition are two factors which may contribute to the explanation of both the level of material well-being per capita and the convergence in competitiveness of an economy.

In this analytical context, it is important to point out that the recent meanings approach the concept of competitiveness from a broad perspective, which goes further from the traditional capacity that economies have for entering external markets. According to this approximation, the sustained approach in the material well-being of an economy would be determined by productivity levels, as these are the determinants for creating work and for capital-accumulation incentives. In fact, this competitiveness approximation as the capacity which an economy has for long-term growth, inevitably brings our attention over to the sources of economic growth. In this way, we again find ourselves with perspectives relating to the capacity an economy has for intensifying its per-capita capital endowment and improving its rate of technological progress. This does nothing more than highlight the provisional nature of competitive advantages which, moreover, are clearly seen to be strengthened in the current globalisation context.

From the company point of view, competitiveness, which is understood as the capacity held by a company to extend its market share, has also been altered by the changing nature of economic-growth sources and market structure. So, in this framework, we shall embark below on an analysis of the determinants for international competitiveness in Catalan companies. To do this, and in line with the current literature, we shall examine the significance of various investment typologies, and in particular, on intangible investment, which is the best way to discover the significance of information and knowledge flows and that the intangible nature of accumulation established in the determining element of corporate capacity for gaining international market shares.

In fact, we already have a large body of evidence available today which confirms how a significant part of the value creation in corporate organisations is to be explained by investment in intangible products and services or intangible assets.[123] The economic characterisation of these

122. Krugman (1995); Ventura (1997).

123. Lev and Sougiannis (1996); Bueno (1998); Lev and Zarowin (1999); Edvinson and Malone (1999).

assets[124] underscores the fact that they are any non-physical element having properties or establishing the possibility of creating incremental profits for companies. Among the most common intangibles in corporate activities we find franchises, patents, trademarks, copyright, goodwill, R&D investment and the skills and tacit forms of knowledge of workers and organisations.

It is therefore established that a growing part of the strategic core of every corporate activity is to be found in the intangible assets owned or controlled by a company which are used for corporate differentiation or for reducing competition. For this reason we must point out that the renewed interest of corporate literature in the productive contribution of intangible assets is to be largely explained by the growing differences detected in the application of two of the main valuation instruments of a company: market value and asset value or purchase value.

The significance of such intangible elements in explaining corporate growth suggests that there is a need to deal with, albeit briefly, their features and economic nature.[125] A first feature of intangible assets is their cost structure. Such commodities are generally expensive to produce, but very cheap to reproduce or, in other words, establish very high fixed costs and very low marginal costs. This cost structure has important consequences on pricing, as it is not solely determined on the basis of cost but must necessarily include consumer valuation. The singularity of cost structures, together with their non-rivalry conditions (consumption simultaneous with various alternative uses without utility reduction), determines the ownership of the growing returns on a scale linked to investment in intangibles.[126] It is precisely this scalability (potentiality for creating value), in connection with non-rivalry and the increasing returns of intangible assets, which largely explains the valuation which the market makes of the entire corporate system.

A second basic feature is that network economies are frequently created on the basis of intangible assets. This establishes them at the core of network markets, which are characterised by the triplet idea-product-control. However, intangible assets also shape the periphery of networks, that is, they are also essential in developing alliances and collaborations that contribute to the creation of network economies both within and without the structure of economic agents.

A third important element of intangible assets to be highlighted consists of the partial exclusion and positive externalities deriving from their private investment. In other words, where intangibles are invested in general, it is inevitable that non-owners will benefit from their in-

124. Hand and Lev (2003).
125. Shapiro and Varian (1999).
126. Lozano, Miguel and Pintado (2001).

direct use, given that there are diffuse property rights and high possibilities of imitation in their productive application. A constant tension therefore arises between the value-creation potential inherent in these assets (scalability) and the difficulties of appropriating the benefits of their productive application. In addition, intangibles also introduce imperfections into markets which end up creating significant barriers to entry to competition. In sum, investments in intangible assets, where it is possible to overcome the restrictions that these impose, are a clear source of competitive advantage.[127]

The last and fourth attribute that we wish to underscore relates to the virtual non-existence, save in a handful of exceptions such as patents and managerial skills, of organised markets for the purchase and sale of numerous intangible factors. This has to do with the difficult exchange of resources as a result of the asymmetry of information between buyers and sellers. A lack of defined property rights, an uncertainty over prices, joint application with other productive activity resources and high specificity levels all help explain this reduced transfer capacity. The transferability value of intangible assets is consequently low and this explains the appearance of intermediary organisations and the running of operations through internal work markets.

In short, intangible assets are essentially commodities with public-property features, significant externalities, network economies and increasing returns. In spite of that, they are hard to market, having diffuse property rights, serious problems in creating contingent contracts and a cost structure that neither favours nor sets stable pricing or competitive conditions.

Investments in and productive applications of intangible-asset elements are realised through the intensive and direct use of productive determining factors, such as workers' skills and competencies or developments of innovation processes. Nevertheless, productive consolidation of digitisation processes has brought a vitally-important element to the traditional chapters of intangible investments. This relates to investments in and productive applications of intangibles that are directly linked to ICTs, such as generic information factors or IT applications. It can be observed then that this typology of intangible factors offers broad and diverse casuistics, and ends up by creating, among other things, new productive processes, new business projects, new human-factor adaptations or new management skills.[128]

In this context, and despite their high dispersal, some investigations[129] have suggested cataloguing four infrastructural corporate-activity elements which, together with physical infrastruc-

127. Salas Fumàs (1989).
128. Brynjolfsson, Hitt and Yang (2000).
129. Bueno (1998); Edvinsson and Malone (1999).

tures, would determine competitive advantages. First, human capital. This integrates all the capacities and skills of the company's workers and all the investments intended for guaranteeing that people's attributes suit the needs of corporate activities such as, for example, selection-process activities or staff training. Second, structural capital. This element includes all the investments made for improving experience and organisation quality, whether through processes or through management. Third, relational capital. This includes efforts made for improving the efficiency of managing communications and transactions with clients and the company's suppliers. And fourth, technological capital. This includes investments directed towards optimising innovations processes and digital-technological infrastructures.

Directly or indirectly, all these investments, which enable intangible factors to be internally configured, end up as various manifestations of corporate innovation processes. It is precisely this interpretation of intangible investments as an instrument for corporate innovation which leads us towards the phenomenon of competitiveness and, more specifically, towards the links between innovation in intangibles and international competitiveness. There is no doubt that innovation is one of the main driving forces behind company changes. In a globalised and globally-competitive setting, digital technologies, knowledge and intangible-asset development become highly-valuable competitiveness factors.[130] Notwithstanding that, corporate innovation is a complex concept with numerous meanings. On the one hand, the current relationship between innovation processes and the presence of intangible assets such as R&D&I investment or human capital. On the other hand, the significant and heterogeneous links between the various economic agents that affect innovation processes. Intangibles play an essential role in both these dimensions. By innovation, that learning process which has a basic productive resource, we therefore mean: knowledge, which is also its main result. So corporate innovation is a dynamic and complex process which is fed both by explicit knowledge and tacit knowledge, which is influenced by a variety of internal and external factors, which is used by highly-formalised processes and by other, much more informal ones, which ends up creating radical changes or small incremental improvements, and which, all said, presupposes changes to the efficiency and competitiveness of companies.

Although the concept of innovation has traditionally been directly linked to technological changes, recent developments in the literature of international competitiveness have identified certain intangible assets, in corporate innovation processes, in particular human capital and several infrastructures and digital uses.[131] It is important here to point out that Catalan companies are no strangers to the internationalisation of factor and product mar-

130. Huerta (2002).
131. Dosi (2000); Molero (2000); Baumol (2002).

kets, nor either to the significance of the innovation based on investments in intangibles. Various investigations[132] show the significance of the economic-activity globalisation process as a driving force in corporate activities, while at the same time there is growing evidence of the positive relationship between technological innovation and international competitiveness.[133] Nevertheless, and in the specific case of Catalan companies, we have little evidence available to analyse the impact of intangible investments on the international competitiveness of Catalonia's productive network. But this analysis is exactly what we aim to do below. We therefore wish to verify the effect of intangible investments on the exporting capacities of Catalan companies. Before doing this, however, we shall pause in order to analyse how some of the dimensions to company value are linked to the internationalisation process of Catalonia's productive network.

In 2003, 31.5% of Catalan companies sold all or part of their production to international markets (the European Union and the rest of the world). The activity-sector approach, on the basis of knowledge-intensity, shall enable us to verify the presence of the expected *a priori* link between larger exporting capacity and companies making intensive uses of technologies and knowledge. This premise is confirmed in industry, given that wherever companies are more intensive in technology and knowledge, they export more. In fact, if we group the productive industrial network on the basis of technological intensity, that is, if we separate low- and medium-technology industries from high-technology industries we can confirm how this branch of activities showed a percentage of exporting companies (compared to the entire sector) of 51.8%. As the technological intensity diminishes so too does the exporting capacity (41.5% of medium-technology industry companies and 25.4% of low-technology companies). In addition, companies at the digital core of the new economy also showed a significant exporting capacity exceeding that of Catalan average (35.6%).

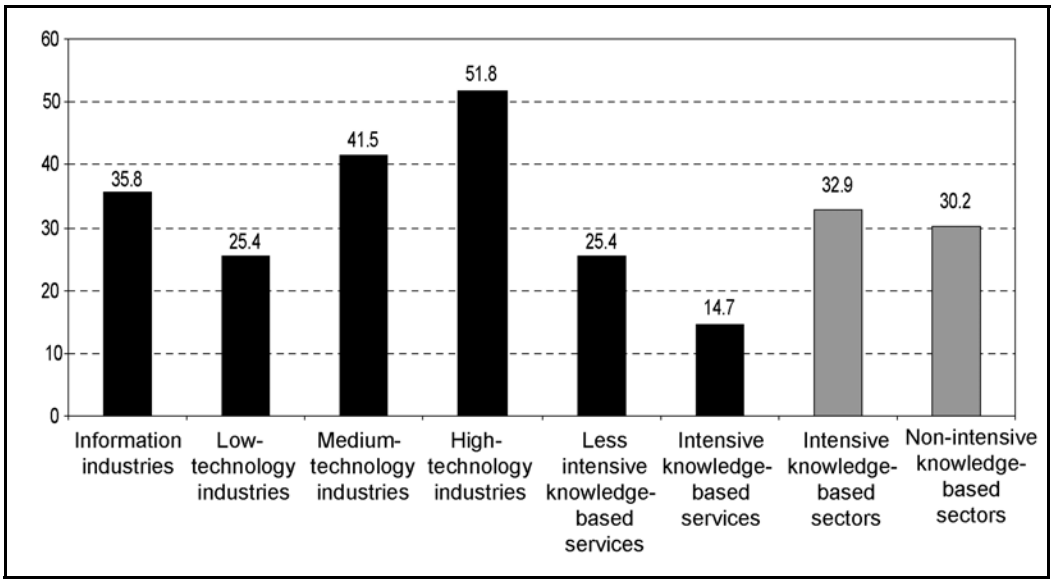
By contrast, the data obtained for service companies are less favourable, seeing that only 14.7% of knowledge-intensive service companies and 25.4% of less knowledge-intensive service companies exported all or part of their production. Despite that, the general grouping by intensity in technology and knowledge (information industries, high-technology industries and knowledge-intensive services, compared to the other branches) of Catalonia's productive network confirm the link between knowledge and exporting activities: In 2003, 32.9% of companies making intensive use of technology and knowledge exported, compared to 30.2% of less-intensive company sectors (figure 1).

132. Ramírez and Delgado (2000); Giráldez (2002); Moreno (2002); Flor (2003).

133. Barcenilla and Lozano (2001); Melle i Raymond (2001); Huerga (2002): Navas and Nieto (2003).

**Figure 1. The exporting capacity of Catalan companies, by activity sector. 2003**

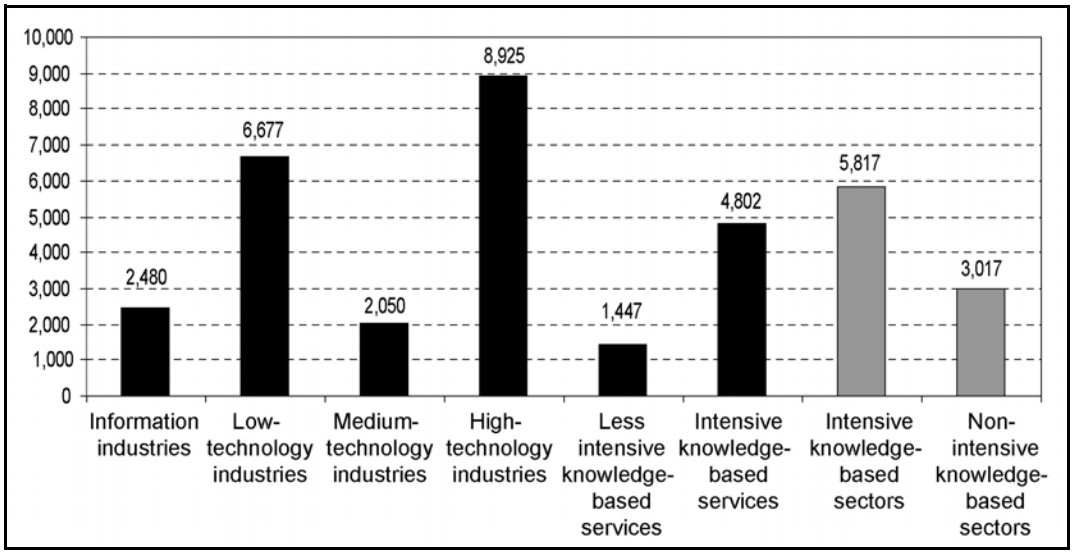
(percentages of exporting companies over the total number of companies for each sector)




Source: In-house

If, in addition, we take account of each company's average exported value when measuring exporting capacity, the differences between sectors making intensive and non-intensive use of technology and knowledge become pronounced (figure 2). So the former exported on average 5.8 million euros while the less intensive branches exported 3 million euros. The main explanation for this difference is to be sought in the high volume of exports by high-technology industrial companies (8.9 million euros in average terms), more than double that for the Catalan average (4.3 million euros).

**Figure 2. Catalan company exports, by activity sector. 2003** (average volume of exports per company in thousands of current euros)

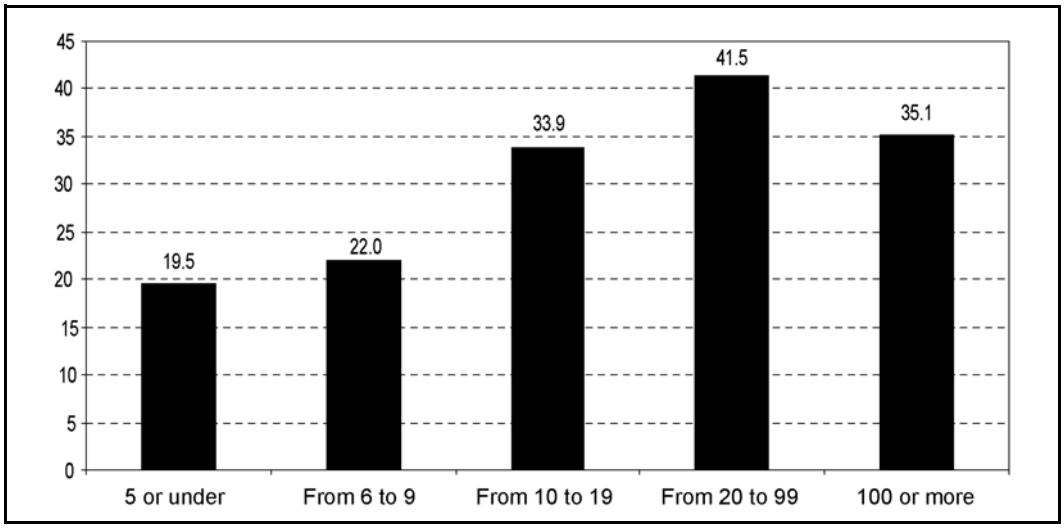



Source: In-house

From the corporate-dimension point of view, exporting capacity is linked to company size. In fact, larger companies export more. So all size dimensions over than 10 workers present an exporting capacity above that of the Catalan average. By contrast, micro-companies (5 or fewer workers) and the sector below that of small companies (from 6 to 9 workers) present an exporting capacity, measured by the percentage of companies that export, is clearly below that of the Catalan average (22% in the case of micro-companies and 19.5% in the case of companies with 6 to 9 workers).

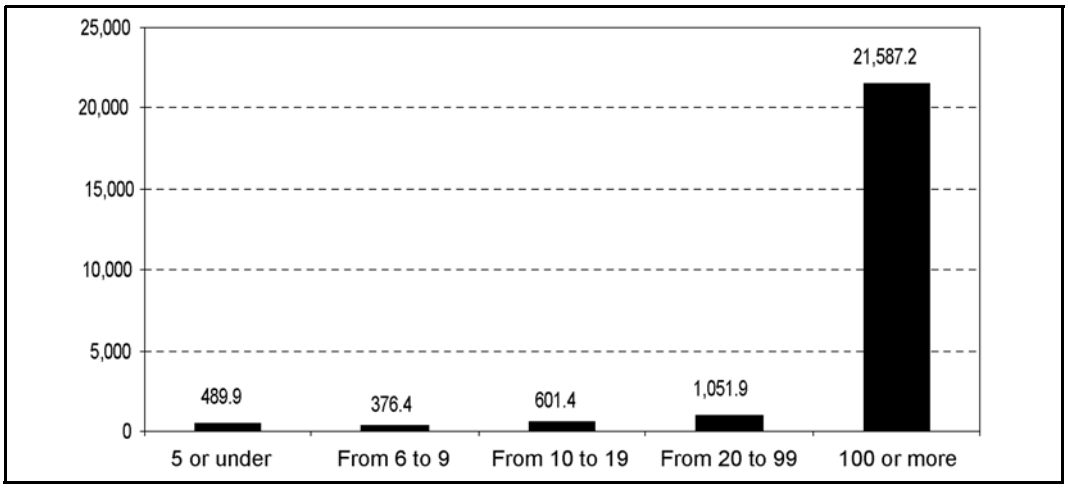
As for the larger sizes, note that there is a larger relative number of exporting companies in the medium size, (from 20 to 99 workers) than in the large (100 or more workers). However, the last phenomenon differs where we take account of the average volume of exports of companies for each size. Indeed, as was to be expected, large companies produce the bulk of exports in the Catalan productive network (21.5 million euros per company), compared to the much smaller, little over a million euros of companies whose sizes range from 20 to 99 workers (figure 4).

**Figure 3. The exporting capacity of Catalan companies, by size. 2003** (percentages of exporting companies over the total number of companies for each sector)




Source: In-house

**Figure 4. Catalan company exports, by size. 2003** (average volume of exports per company in thousands of current euros)




Source: In-house

## 3.2. Determining factors in the international competitiveness of Catalan companies

Having reviewed the conceptual framework, which demonstrates the significance of co-innovation processes based on ICT investment and use and the increasing application in corporate activities of intangible asset and which confirms that exporting capacities in Catalonia are linked to intensity in technology and knowledge on a large scale, we shall analyse the determinants for international, competitive capacities in Catalan companies.

A company's competitiveness factors are diverse and complex. In the classical arguments of competition through cost and technology differences, economics literature has been steadily incorporating into its analyses of the determinants of competitiveness the effects of product- and service-differentiation strategies which companies have been offering markets, whether carried out through their innovative capacities or based on specific differentiation factors developed in their own markets.[134]

It is precisely in the setting shaped by internal competitive-advantage achievements deriving from investments in digital technology and intangible commodities that we propose to verify whether the capacity that Catalan companies have for penetrating international markets is based on their intangible capitalisation processes. Notwithstanding that, this causal relationship has to be understood in the light of other considerations.[135] First, investments in intangible assets require a certain accumulation period and implementation. By extension, they also need a certain amount of time to produce valuable economic returns and this can likewise be extended in the case of international competitiveness. Moreover, and in the second place, the literature also underscores the presence of effects to scale on the returns of companies as their intangible endowment capital increases. Third, investments in intangibles are not just linked to their accountable records of accumulated intangible assets. Work-force training and capacitation improve human-capital endowments and must therefore be regarded as additional intangible asset. In this respect the literature has settled the problem by incorporating wages, strongly correlated with training stocks and worker-competency levels, as an indicator of intangible human capital in explaining the fundamentals of competitiveness. Fourth, in analysing the determinants of competitiveness, empirical evidence also includes the links between efficiency and capacity to penetrate international markets. It is expected that companies which are more efficient at the internal level (higher level or rate of productivity enhancement) will be more capable of gaining market shares (competitive-

134. Lundvall (1992).
135. Hall (1989).

ness). Finally the literature also confirms that where investments in intangibles are combined with intensive digital-technology uses, they have a greater effect on international competitiveness.

So we should like to verify, in analysing the determinants of Catalan-company exporting capacities, whether all intangible assets, as detected using intangible-investment, human-capital and digital-technological-capital indicators, have a determined effect in explaining the volume of exports in the Catalan productive network. Having reached this point, we have created an indicator, so as to understand the effect of digital technologies, where ICT uses feature within the main value-chain elements of corporate activities. This indicator, which measures the degree of digital-technology use in companies, is a composite one and shows the sufficiency of ICT use in five corporate-activity, value-chain elements: production, supply and distribution; marketing, basic organisation and human resources (accounting and invoicing, wage payment and internal communications); and complex organisation and human resources (data management and/or information operations, management information systems and integrated management systems). This sufficiency, which is shown through the availability of digital technological systems in each of these five value elements, determines the three levels of the indicator: low ICT uses, where companies have technological systems available for none or one of the five defined value elements; average ICT uses where companies have technological systems available for two or three of the five defined value elements; advanced ICT uses where companies have technological systems available for four or five of the five defined value elements. For the purposes of our analysis, we have joined low and average ICT uses together and kept them separate from advanced ICT uses.

So, we have observed a statistical link, on the matter of ICT uses, between this intangible indicator and the international competitiveness of Catalan companies. It is furthermore corroborated that the more intensively companies use ICTs, the greater their exporting capacities increase. In fact, in 2003 companies that made an advanced use of ICTs exported close to a million euros on average (985 thousand euros to be precise). In contrast, companies that made less use of ICTs (low and average stages) produced a much lower average international sales volume (335 thousand euros). In fact, our model incorporates the ICT-use variable as a segmentation element for the available sample of companies. In this way, and with the knowledge that companies making more intensive uses of ICTs also export more, we shall analyse whether, in addition, they have different structural behaviours when explaining the exporting capacities of Catalan companies.

Table 1 shows the determinant variables for the exporting capacities of Catalan companies according to empirical-evidence contributions. We have already pointed out that the aim of

our study, the dependent variable, is the volume of exports to international markets, collected using the sales percentage in the markets over the total turnover (EXP). We shall consider investments in intangible assets on the basis of two variables. The first is the volume of the company's intangible assets (ACTIMM). With this we wish to understand whether intangible capital endowment, collected in the form of investments, and therefore, subject to economic transactions, has an effect in explaining the exporting capacities of companies. The second is the average level of the company's wages (SAL). With this variable, we wish to understand the impact of the more tacit components of intangible investment, such as human capital. In addition, we also consider the volume of investment in physical capital, collected through tangible assets (ACTM). By incorporating this variable we may compare the total effect of investing in both physical and intangible capital in explaining degrees of internationalisation. Finally, and as shown in the literature, we have incorporated two additional explanatory variables. The first is the degree of international establishment (ESTIN). With this variable, which takes the value 1 where the company has international establishments and the value 0 where it does not, we wish to show the effect of having establishments abroad has on international sales volumes. The second is the company's experience (EXPEMP), measured through the company's age, a continuous variable, established using the rest between 2003, the year of the database's creation, and the year of the company's incorporation. We aim to find out whether a greater level of experience in activities has an effect in exporting capacitations. Finally, we have created a variable which detects presence in the Spanish market (VENESP): On the basis of this variable, which measures the volume of sales in the Spanish market outside of Catalonia, we shall repeat the causal-relationship analysis to see up to what point the specific determinants for international competitiveness have the same validity for explaining the presence of Catalan products and services in the Spanish market.

**Table 1. International competitiveness and its indicators in Catalan companies. 2003**

| Indicator | Description | Category and value |
|---|---|---|
| EXP | Percentages of exports (European Union and the rest of the world) over total turnover | Metrics (percentages) |
| ACTIMM | Intangible assets | Metrics (current euros) |
| SAL | Average gross annual salaries borne by the company | Metrics (current euros) |
| ACTM | Tangible assets | Metrics (current euros) |
| ESINT | International establishment (European Union and rest of the world) | Dichotomics (1, has it; 0, does not have it) |
| EXEMP | Company age | Metrics (2003 less year of company's incorporation) |

Source: In-house

Table 2 shows the correlation matrix between the variables incorporated into the model. No correlations over 0.4 are observed among the dependent variables, so we can exclude any multi-collinearity problems. The larger correlations observed necessarily occur with the model's dependent variable. This must be read as a good fit in the specifications given.

**Table 2. Correlation matrix between international competitiveness and its indicators in Catalan companies. 2003**

| | EXP | VENESP | ESINT | ACTIM | ACTM | SAL | EXEMP |
|---|---|---|---|---|---|---|---|
| EXP | 1,00 | 0,48 | 0,20 | 0,24 | 0,46 | 0,14 | 0,12 |
| VENESP | 0,48 | 1,00 | 0,17 | 0,34 | 0,87 | 0,09 | 0,20 |
| ESINT | 0,20 | 0,17 | 1,00 | 0,07 | 0,15 | 0,21 | 0,14 |
| ACTIM | 0,24 | 0,34 | 0,07 | 1,00 | 0,37 | 0,07 | 0,10 |
| ACTM | 0,46 | 0,87 | 0,15 | 0,37 | 1,00 | 0,14 | 0,22 |
| SAL | 0,14 | 0,09 | 0,21 | 0,07 | 0,14 | 1,00 | 0,09 |
| EXEMP | 0,12 | 0,20 | 0,14 | 0,10 | 0,22 | 0,09 | 1,00 |

Source: In-house

So, by following the empirical evidence in use, we shall estimate, by ordinary least squares, a function of the determinants of international competitiveness,[136] for the sample group of companies (i), which has the following functional form, i where $\varepsilon_i$ represents the error term:

$$EXP = \sum_{i=1}^{n} \beta_0 + \beta_1 ACTIMM_i + \beta_2 SAL_i + \beta_3 ACTM_i + \beta_4 ESINT_i + \beta_5 EXEMP_i + \varepsilon_i$$

The results obtained, represented in table 3, show first that for the entire Catalan productive network, only investment in physical capital and the presence of establishments abroad are significant in explaining the international competitiveness of our companies. None of the two intangible assets specified, intangible investments and training stocks, perceived through salaries, have any effects. This is probably due to the specialisation pattern of international commerce in Catalonia, which is considerably biased towards low-medium technology products with two-fold technology-training co-innovators. Secondly, in spite of that, from the perspective of productive-network dissection on the basis of ICT uses, the data demonstrate two clearly-differentiated international specialisation patterns.

136 . Vilaseca, Torrent and Lladós (2003).

Indeed, it should first be pointed out that investments in both tangibles and intangibles are significant at 99% of confidence for the sample of companies with high and low ICT uses. Nevertheless, the structure of these investments differs according to the intensity of the digital use. In companies with advanced ICT uses, both investment typologies have positive effects on company exporting capacities, although increasing endowments of transactional intangible assets (and taken into intangible assets) explains, in relative terms, a larger presence of Catalan products in international markets. In contrast, companies that do not use ICTs have a different form of behaviour. The effect of larger intangible assets on international competitiveness in this sector is negative, while a higher physical-asset endowment establishes better international competitiveness. We therefore detect a complementarity relationship, in the explanation of international competitiveness, between physical and intangible capital, in companies that make intensive use of ICTs.

In addition, the international specialisation pattern in digitally-intensive companies is complemented by a significant explanation on the international competitiveness of wages, the experience of companies (age) and presence of establishments abroad. All three are a positive and significant sign, although at various levels of confidence. In short, this explains 76.6% of the exporting capacity of Catalan companies with advanced ICT use. We can therefore assert that companies which are characterised by a digital-innovation intensity, complementarity relations between physical-capital and intangible capital endowments (observable and human), productive experience and presence of establishments abroad, determine their level of competitiveness. In contrast, for companies with a weaker digital-innovation pattern, their international competitiveness is more directly explained by a pattern of physical-capital investment and international presence. In this regard, it is important to underscore that increases in the international competitiveness of Catalan companies would relate more to the international specialisation model based on complementarity relations between digital technologies and various physical-capital and intangible endowments, experience in production and physical presence in external markets.

**Table 3. Determinants of the international competitiveness of Catalan companies, by ICT-use intensity. 2003** (linear multiple regression analysis: ordinary least squares; dependent variable; exports measured using percentage of international sales over total turnover; standardised coefficients)

| | Catalan companies | High ICT uses | Medium and low ICT uses |
|---|---|---|---|
| Constant | (-0,610) | (3,31)*** | (0,20) |
| ACTIMM | 0,069<br>(1,52) | 0,237***<br>(4,25) | -0,182***<br>(-3,11) |
| SAL | 0,047<br>(1,09) | 0,199***<br>(3,66) | 0,000<br>(0,001) |
| ACTM | 0,394***<br>(8,40) | 0,617***<br>(10,01) | 0,516***<br>(8,92) |
| ESINT | 0,122***<br>(2,77) | 0,096*<br>(1,73) | 0,134***<br>(2,73) |
| EXEMP | -0,002<br>(-0,05) | 0,142**<br>(2,39) | -0,012<br>(-0,26) |
| Corrected $R^2$<br>n (=i)<br>Significance | 21,9<br>441<br>0,000 | 76,7<br>90<br>0,000 | 21,6<br>351<br>0,000 |

Value t between brackets. *** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

Source: In-house

Repetition of the same determinant model, now applied however to the capacity of Catalan products to penetrate Spanish markets (table 4) shows us, once more, significant differences according to whether or not the company sector chosen makes intensive use of ICTs. In the intensive case, and in contrast to what occurs for international markets, it is only the variables referring to investment which are significant (99%), and just as in external markets, the capacity to sell to Spanish markets relates more to degree of investment in intangible capital than in physical capital. It should also be pointed out that even though the remaining variables are not significant, the good fit of the model is quite remarkable (83,9%). By contrast, companies with a lower ICT use present a sales specialisation pattern that is the same within and without Spain and which is characterised by a more favourable effect on these markets according to investment in physical capital and dispersal of establishments. Investment in observable intangible capital has a negative effect there.

**Table 4. Determinants of Spanish-market penetration by Catalan companies, according to ICT-use intensity. 2003** (linear multiple regression analysis: ordinary least squares; dependent variable; exports measured using percentage of international sales over total turnover; standardised coefficients)

| | Catalan companies | High ICT uses | Medium and low ICT uses |
|---|---|---|---|
| Constant | (-0,65) | (3,47) | (-0,38) |
| ACTIMM | 0,271*** (11,86) | 0,294*** (6,11) | -0,102*** (2,44) |
| SAL | -0,001 (-0,06) | -0,016*** (-0,43) | 0,038 (1,15) |
| ACTM | 0,687*** (29,76) | 0,701*** (13,56) | 0,624*** (14,97) |
| ESINT | 0,007 (0,41) | 0,002 (0,02) | 0,127*** (3,71) |
| EXEMP | -0,007 (-0,40) | 0,017 (0,42) | 0,000 (0,00) |
| Corrected $R^2$ | 77,8 | 83,9 | 36,2 |
| n (=i) | 722 | 128 | 594 |
| Significance | 0,000 | 0,000 | 0,000 |

Value t between brackets. *** significant at 99% of confidence; ** significant at 95% of confidence; * significant at 90% of confidence.

Source: In-house

We therefore conclude with a slightly different sales specialisation pattern, depending on whether the sales are intended for international or Spanish markets in the case of companies making intensive use of ICTs. The first is based on the establishment of complementarity relations between investment in physical and intangible capital (both valuable and human), experience and physical presence in international markets. And the second is only based on complementarity relations between physical and intangible capital. It would therefore appear that digital-innovative companies which are characterised by a pattern of competition combining physical-capital and intangible endowments (tangible and intangible assets) where international markets have to be penetrated, strengthen this strategy, with larger human-capital endowments and a larger physical presence in the intended markets, and all within the context of experience in production. Non-intensive digital sectors make no distinction in their strategies between Spanish- and international-market penetration, which are based on larger physical-capital endowments and geographical dispersal of establishments. Investments in non-human intangible capital has a negative impact in the expansion of sales to Spain and the work in this company sector.

## 3.3. Conclusions

In this chapter, we have developed a model of determinants for the international competitiveness of Catalonia's private productive network, based on the relations that have been shown to exist between the intensity of technology and knowledge in Catalan companies and the degree by which their products and services penetrate markets. The principal conclusions of the investigation are: a) first, for the entire Catalan productive network, only investment in physical capital and the presence of establishments abroad are significant in explaining the international competitiveness of our companies. None of the two intangible assets specified, intangible investments and training stocks, perceived through salaries, have any effects. This is probably due to the specialisation pattern of international commerce in Catalonia, which is considerably biased towards low-medium technology products with two-fold technology-training co-innovators; b) secondly, in spite of that, from the perspective of productive-network dissection on the basis of ICT uses, the data demonstrate two clearly-differentiated international specialisation patterns.

In fact, investments in both tangible and intangible assets are significant in explaining the international competitiveness of the sample of companies making high and medium and low uses of ICTs. Nevertheless, the structure of these investments differs according to the intensity of the digital use. In companies with advanced ICT uses, both investment typologies have positive effects on company exporting capacities, although increasing endowments of transactional intangible assets (and taken into intangible assets) explains, in relative terms, a larger presence of Catalan products in international markets. In contrast, companies that do not use ICTs have a different form of behaviour. The effect of larger intangible assets on international competitiveness in this sector is negative, while a higher physical-asset endowment establishes better international competitiveness. We therefore detect a complementarity relationship, in the explanation of international competitiveness, between physical and intangible capital, in companies that make intensive use of ICTs. In addition, the international specialisation pattern in digitally-intensive companies is complemented by a significant explanation on the international competitiveness of wages, the experience of companies (age) and presence of establishments abroad. All three are a positive and significant sign, although at various levels of confidence. In short, this explains 76.6% of the exporting capacity of Catalan companies with advanced ICT use.

We can therefore assert that companies which are characterised by a digital-innovation intensity, complementarity relations between physical-capital and intangible capital endowments (observable and human), productive experience and presence of establishments abroad, determine their level of competitiveness. In contrast, for companies with a weaker digital-innovation pattern, their international competitiveness is more directly explained by a

pattern of physical-capital investment and international presence. In this regard, it is important to underscore that increases in the international competitiveness of Catalan companies would relate more to the international specialisation model based on complementarity relations between digital technologies and various physical-capital and intangible endowments, experience in production and physical presence in external markets.

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# Summary

## ICTs and corporate performance in Catalonia

**Joan Torrent and Jordi Vilaseca**

Economic activity is currently going through a process of profound change. While there may be numerous reasons for this dynamic, there is a broad, academic consensus which ascribes the process to a three-fold interaction: a) a process of technological revolution, led by investment in and massive use of information and communication technologies (ICT); b) a temporally- and spatially-expansive dynamic within factor and product markets, or process of globalisation; and c) a new pattern in the norms of consumer demands and family and company investments.

In this regard, it may be asserted that ICTs are consolidated as general-purpose technologies and form the material basis of a new techno-economic paradigm from which a process of industrial revolution emerges. In fact, it has been agreed that this process of change, which is characterised by networking, investing, price decline and persistent use of ICTs, and by a growing presence of information and knowledge flows in the economic sphere, should be called the transition process, from an industrial economy to a knowledge economy.

The transition to the knowledge economy occurs in companies with the appearance and consolidation of a new strategic, organisational and productive model: the network company. This model is based on the networked decentralisation of companies' entire business units and presupposes a change in corporate running towards a variant configuration system whereby work is networked and the integrated value chain is diluted. Notwithstanding that, this requires a potent technological tool, that is ICTs. Furthermore, this process of change cannot be seen in isolation either from the more significant processes with which it is involved or from the structure and configuration of the economic agent to be studied. The strategic, organisational and productive changes in Catalan companies, linked to ICT uses, cannot be construed to their full extent without an analysis of the principal driving force behind this transformation: economic globalisation, which sets new requirements for competition, based on innovation and flexibility, in order to attain improvements in productivity and competitiveness. We must not lose sight either of the fact that Catalan companies having other very pronounced, defining features also determines the transition process towards the knowledge economy.

This is precisely the methodological course that has been followed for the investigation, which we now conclude: describing and characterising the current situation for Catalan companies, with regard, above all, to the consolidation of transformation processes linked to ICT use and globalisation of economic activities. In addition, for the purpose of answering, in the case of Catalonia, the questions raised in the national and international investigation, conclusive evidence has been gathered on the impact ICT uses have on activity reconfigurations for the main value elements in companies and, more particularly, in performance changes. To this end, we have worked with a database on strategic, organisational, produc-

tive and performance outlines of Catalonia's private productive network, based on a survey of a representative sample of 2,038 Catalan companies, whose field work was carried out during the winter and spring of 2003. This sample of companies, moreover, is stratified into six large activity sectors, according to their technological intensity and use of knowledge (information industry, high-, medium- and low-technology industry and more and less knowledge-intensive services), and into 5 sizes: micro-companies (up to 5 workers), small companies (from 6 to 19 workers), medium-sized companies (from 20 to 99 workers) and large companies (over 100 workers). Finally, we shall present the principal conclusions of this investigative work.

*First. At the start of the 20th century, Catalan companies were small, family-based and flexible, having clearly improvable levels of training, with dual employment relations and a low level of international competitiveness.*

At the dawn of the 21st century, Catalan companies find themselves in a period of transition, half way between the consolidation of a new activity scheme, based on variant and networked interconnections of their value elements, and the maintenance of the traditionally organisational and productive structures of industrial and service economies. In this regard, it is corporate structures in Catalonia that determine the speed and direction of this transition process. Some points for consideration on this matter. First, it should be noted that Catalan corporate sectors are characterised by their small size. Over 88% of Catalan companies have under 5 workers (i.e. are micro-companies), 8.8% are small companies, 2.7% are medium-sized companies and only 0.5% are large companies. Furthermore, Catalan companies with under 5 workers form the bulk of private gross value added in Catalonia. Approximately 60% of the private GVA in Catalonia derives from micro-companies, while companies place their value contributions at around 21% of the total. Second, it should be pointed out that most of Catalonia's productive network consists of family companies, although there are powerful corporate groups, with large companies and headquarters outside the Principality. 64% of Catalan companies are family-based and over 90% of Catalan-company share capital originates from Catalonia. 28.1% of the capital of large companies is of international provenance, compared to the much lower percentage of 8.5% for the rest of Spain. Third, it should be made clear that the Catalan-company environment is dynamic and complex. The Catalan-company competitiveness model largely follows a strategy of product/service differentiation (86.5% of cases). This differentiation is based, above all, on quality (40.7%) and on offering specific products or services for every type of client (25.8%). In spite of that, around 10% of companies still apply a cost-leadership strategy. In this regard, although 69.4% of Catalan companies have reopened their strategies for better adaptations to market changes, only 27.9% have obtained quality certificates for their activities. Fourth, we assert that Catalonia has been relying on certain companies with a significant level of flexibility, at the same time when the signs of change have been observed in their activities'

organisation schemes. This confirms that Catalan companies have a certain degree of productive-activity orientation towards the process. So 28.9% of companies are organised by process, 32.2% have introduced organisational aspects to their innovations and 48.9% use flexible and adaptable work teams for business lines. The proportion of managers (41.9%), the involvement of women in management tasks (17.4%) and the average age of company officials (close to 45 years) also demonstrate certain transformation processes in the organisation of corporate activities. Moreover, we can also highlight the majority presence of women in the more value-added sectors of Catalonia's economy, such the knowledge-intensive services (66.3% of work in the operational work). 4.7% of companies rely on workers coming originally from Latin-America, 2.8% from Africa and 2.6% from the European Union. Fifth, it should be pointed out that the average training level of Catalan workers is improvable. Managerial work presents a largely-university level of studies: 53%, compared to 38% with secondary studies and 8% with primary studies. By contrast, the average training level of Catalans consists of secondary studies, with 53.7% of cases being virtually the same for university-training and primary-education levels (21.5% and 22.4% respectively). Only 20% of Catalan companies follow continuous training or made-to-measure programmes, following essentially an on-site methodology. Sixth, it is clear that Catalan companies have dual employment relations. Private work in Catalonia basically offers a majority-type indefinite contractual option. There is also another reality: close to 30% of work has temporary contractual dimension. Furthermore, 90.6% of Catalan workers have full-time work days while 9-5% work part-time. Seventh, and final, account should be taken of the fact that few Catalan companies are opened abroad, despite there being a high interaction with competitors, suppliers and clients from outside Spain. Under 10% (7.9%) of Catalan companies sell more than a third of their products outside Spain. That said, Catalan companies compete both locally and globally. 92% of the companies acknowledge being in competition with Catalan competitors, 44.4% with the rest of Spain, 28.3% with the rest of the European Union and a not inconsiderable 20.9% with the rest of the world. Catalan companies are local and global suppliers. 94.7% of the companies acknowledge having suppliers from Catalonia, 65.2% from the rest of Spain and 37.9% from the rest of the European Union while twenty per cent (19.6%) of Catalan companies are supplied by the rest of the world. Finally, Catalan companies have geographically dispersed clients. 94.9% of these companies acknowledge having clients in Catalonia, 43.7% in the rest of Spain, 18.5% in the rest of the European Union and 11% in the rest of the world.

*Second. Capacitation challenges in Catalan companies: extended training accentuates the differences between trained and untrained workers*

As to the challenges of training within Catalan companies, we have considered the determinant elements which explain the probability, in the corporate-activity framework, of resources being directed towards the extension of current training levels, whether the costs for such

are borne by companies or by their workers. It can be broadly stated that workers have a greater probability of extended training where they have already been trained, have employment stability, are younger and work in large companies using ICTs. In fact, extended training in Catalan companies is characterised by a high presence of self-training schemes (42.8% of companies confirm that their managers undergo self-training programmes, with the percentage for non-managers going down to 30.2%) and by the fact that around a fifth of companies have their workers (managers and non-managers) follow extended training programmes paid for by the company, above all with on-site methodologies. Only 2% of companies have their workers undergoing virtual training programmes. As to the determinants of extended training of managers carried out under the corporate-activity framework, note that level of completed studies, size of company and recruitment stability are the most likely elements in explaining extended training of management work. In addition, it is confirmed that the older the company, the less extended the training. Introducing corporate-structure variables such as the presence of foreign capital or competitive pressure does not explain the probability of adopting extended training, although where companies have more advanced Internet equipment, the probability of improving human capital is higher. As for the determinants of extended training of non-manager workers in Catalan companies, note again that initial training stages for both managers and non-managers, size of company, contractual stability, decision making at tactical levels, younger age and Internet equipment explain the probability of extended training for non-managers.

*Third. Although Catalan companies are well equipped digitally, they make insufficient use of ICTs*

Digital equipment in Catalan companies are considerably widespread, so ICTs are already a regular technology for productive activities. Nevertheless, Catalan companies are at an initial stage in using the full potential offered by digital technologies. In fact, Catalan companies are well equipped digitally. 91% of Catalan companies are connected to the Internet, 87.4% have email, while 46.1% have Web pages, 21.7% buy over the Internet and 11% sell over the Internet. However, corporate uses of ICTs are clearly improvable. A very significant part of Catalan companies (over two thirds) make insufficient use of ICTs in the fields of operations, marketing, organising and human resources. 73.4% do not plan production (or service offers) using ICTs. 75.7% have no external technological planning system with suppliers or distributors. 77.6% of companies have no integrated systems for obtaining and managing information that is created with clients, so they make insufficient use of ICTs in the sphere of marketing. 84.6% do not use basic ICT equipment in organising and human resources, that is, they do not make use of systems for accounting and invoicing, wage payments or even internal communications. Regarding ICT uses, note that these basically apply in companies for management, administration and accounting tasks. 44.4% of Catalan companies use ICTs for management, administration and accounting tasks, 29.3% for obtaining

information, 27.4% for connections with suppliers and clients and 23.4% for general communications. There is nothing strange in this context about the fact that 72.1% of Catalan companies consider ICTs to improve and speed up their management and that 89.2% of companies believe ICT uses to involve, with more or less intensity, increases in productivity, competitiveness, profits and individualisation of employment relations, whereas over 20% consider the principal inconveniences of ICTs uses to be technical problems and IT dependency. Around two thirds of companies that do not use ICTs consider them to be unnecessary. Nevertheless, this reality co-exists alongside close to 15% of companies that see ICTs as their basic business tool. Finally, it should be pointed out that the international position of Catalan companies with regard to digital equipment is favourable, although ICT uses are more intensive in other countries. In fact, computers, Internet access, email use and web pages in Catalonia occur above the average recorded for the five great EU countries. However, in other territories (the United Kingdom and Baden-Württemberg, for example) e-commerce is used much more intensively.

*Fourth. ICTs and productivity facts in Catalan companies: deceleration of long-term growth potential, majority presence of an intensive competition pattern in work and weak impact on efficiency of digital technological changes.*

In line with the analyses on productivity facts, we have considered the contribution of productive factors (or intensification of capital, construed as the capital/work ratio) and the efficiency by which they combine (or total factor productivity, TFP) in explaining the long-term growth potential of corporate activities (or work productivity, PTL). We expect that, through the greater impact of digital technological changes, the contribution of efficiency in explaining work productivity will rise, and so confirm the substantial and differentiating impact on the private productive-activity growth model in Catalonia. The descriptive data obtained for the 1995-2004 period answer three distinctive issues. First, that the long-term growth potential of corporate activities in Catalonia has diminished. The nominal growth rate of work productivity has moved from advancing at an annual average rate of 4.6% in the 1995-1999 period to one of 3.7% in the 2000-2004 period. Second, note that this deceleration is explained by a decline in the growth rate of productive factor endowment (capital/worker ratio), which as moved from growing at an annual average nominal rate of 6.9% for the 1995-1999 period to 6.2% in the 2000-2004 period. By contrast, and third, the development of the efficiency by which inputs combine has improved, from an average nominal increase of 3.1% in the 1995-1999 period to one of 4.1% in the 2000-2004 period. The causal relationship analysis that measures the impact of capital intensification and TFP on the development of the corporate-activity growth potential in Catalonia shows us: a) that the component which measure the ratio of capital per worker has developed downwards from an average value of 66.4 thousand euros during the 1995-1999 period to 43.4 thousand euros in the 2000-2004 period; and b) that the efficiency component has shown the opposite trajectory, and has moved from

an average nominal value estimated at 37.1 thousand euros in the 1995-1999 period to one of 49.9 thousand euros in the 2000-2004 period. A section of these results based on intensity digital technological changes in Catalan companies shows us a very positive development of the coefficient estimated for the efficiency indicator (TFP) for that group of companies (5% of the total) which make intensive use of ICTs. So in companies that make intensive ICT use, as interpreted through the presence of digital planning systems for production, operations, marketing and human resources, the total factor productivity coefficient has moved from an average value of 30.2 thousand euros during the 1995-1999 period to one of 78.7 thousand euros in the 2000-2004 period. This improvement in efficiency in companies making intensive use of ICTs contrasts, and considerably, with the records of the companies that show low- and medium-ICT use: the TFP coefficient for the group of companies with low ICT uses (65% of the total) has moved from 38.7 thousand euros in the 1995-1999 period to 43.1 thousand euros in the 2000-2004 period; while the coefficient for the group of companies with medium ICT uses (30% of the total) has moved from 55.6 thousand euros in the 1995-1999 period to one of 31 thousand euros in the 2000-2004 period). So then, as for the analysis of the determinants of the long-term growth potential of corporate activities in Catalonia, we find both bad news and a positive element. The negative aspects have to do with the deceleration of work productivity, resulting from a decline in the contribution of capital intensification, understood as a majority intensive economic growth pattern in work, and from the very modest impact of efficiency in those companies, the most numerous, where little digital technological change has been established. Nevertheless, in a reduced group of companies, those making intensive use of ICTs, a significant acceleration can be observed in the efficiency by which inputs combine, and this has raised joint developments of total factor productivity in Catalan companies. In this respect, no substantial or majority changes are detected in the long-term growth potential of Catalan companies as a result of digital technological changes.

*Fifth. ICTs and work-productivity sources in Catalan companies: complementarity relations between organisations changes and ICTs, as well as organisational changes and work qualifications, in the context of employment stability, work day flexibility and innovative organisational culture, in explaining the growth potential of Catalan companies.*

Regarding work–productivity sources, we wanted to understand the impact of digital-technological–co-innovation, organisational and work-qualification processes, as well as employment-relation and innovative-culture processes, in explaining the long-term growth potential of Catalan companies. In fact, the work productivity of Catalan companies is mainly explained by investments in physical capital, supplemented with certain organisational and work-qualification practices (such as information exchange, process organisation, educational level of workers and technological competencies), by stable employment relations flexible work days and by a certain innovative culture. Notwithstanding that, technological

(digital operations networks, e-commerce and Internet equipment) and other organisational components (organisational and process innovation, autonomy in decision making) are not significant, or where they are they are so negatively, in explaining the work productivity of Catalan companies. The parameterisation of an explanatory model for work productivity levels in Catalan companies, which examines the effects of complementarity relations between digital-technological, organisational and work-qualification changes, brings certain remarkable conclusions to light. First, once again investment in physical capital continues to be the most significant component in explaining the long-term growth potential of Catalan companies. Second, the incorporation of synthetic indicators which examine a set of practices in digital-technological uses (operations networks, e-commerce and Internet equipment), of organisation changes (process and organisation innovation, information exchange, autonomy in decision making and process organisation), and of work qualifications (regulated training, technical training and technological capacitation), proves to be appropriate given that the three are significant in explaining work productivity. Nevertheless, it should be noted that there is a two-fold direction in these contribution: whereas the interaction between the technology and organisation indicators, and the organisation and human capital has a positive effect on work productivity, the interaction between technology and qualifications has a negative effect on company efficiency. Third, the aforementioned contributions are combined with a positive contribution on the productivity level of Catalan companies regarding security in work, flexible working hours and the presence of an innovative organisational culture. For the large activity sectors, and aside from the notable importance of physical capital, marked differences are seen in the determinants for work productivity in industrial and service companies. We observe in the industry sector that neither the new systems for work-organisation practices nor the capacitation of human capital have any significant impact on apparent work productivity. Digital technologies, on their own, have a negative impact on the long-term growth potential of industrial companies. As for complementarities, note it is solely the interaction between digital technology and work qualifications that has a significant and favourable impact on labour efficiency. This forms a clearly distinctive element regarding the results obtained for the entire private productive network. On the matter of industry-sector employment relations, note the significant, positive impact of wage flexibility, in a system where, again, security in work and an innovative organisational culture also turn out to be important in explaining the growth potential of Catalan industrial companies. Services, for their part, offer a behaviour model for explaining their efficiency, an efficiency that differs considerably from that of industry companies. In this large activity sector, the organisation component proves to be very significant and positive, to the point where it exceeds the contribution of productive physical capital in explaining the level of apparent work productivity. On the other hand, even though the digital technological component and its interaction with work qualifications yet again have a negative impact, it should be pointed out that positive complementarity relations are established between the new systems for work organisation practices and qualifications and ICT investment and uses. All these impacts are made within

a framework defined by certain employment relations where it is solely the flexibility of work days that affects productivity, and by the relative importance of an innovative organisational culture that promotes organisational changes in company organisation.

*Sixth. ICTs and the competitiveness of Catalan companies: in spite of the preponderance of a very primary competitive model, based on investments in physical capital and establishments in markets, a more effective and advanced, albeit minority, competitive pattern is observed, which is that of companies making intensive use of ICTs, based on a combination of investments in physical and intangible capital (intangible and human), the productive experience of the company and a presence in international markets.*

Just as we did with productivity and wages, we have analysed the determinants of competitiveness in Catalan companies. We expect a larger volume of investment in physical and intangible elements, a larger training stock, measured by wages, a physical presence abroad and company experience establish a larger penetration of products and services from Catalan companies into international external markets. We also wanted to confirm whether these are also the determinants for the capacity for penetrating Spanish markets. To understand the impact of digital innovation we have to divide up our sample of available companies into sectors according to intensity of ICT use (low and medium uses compared to advanced ICT uses). The descriptive data confirm that in 2003, only 31.5% of Catalan companies sold all or part of their production to international markets (the European Union and the rest of the world). A segmentation of Catalonia's productive network shows a larger capacity for penetrating international markets by companies in sectors making an intensive use of technology and knowledge (with an average export volume of 5.8 million euros, compared to little over three million euros in non-intensive sectors). However, we note a higher capacity for penetrating international markets in high- and medium-technology industries (51.8% and 41.5% respectively) and in information industries too (35.8%). Nevertheless, services, especially the knowledge-intensive ones, show a share of exports that is clearly below the average (14.7%). As for size, we observe that the larger exporters are medium-sized companies (41.5% of exporting companies), compared to 35.1% of large companies and 19.5% of micro-companies. Analysing the determinants of the share of exports (exports over total turnover made) in Catalan companies shows us that only investments in physical capital and establishments abroad explain the international competitiveness of Catalan productive networks. None of the intangible elements specified, intangible investments and training stocks, explains the capacity of Catalan products and services to penetrate international markets. These results probably show a specialisation pattern for international commerce in Catalonia that is highly biased towards low- and medium-technology products and services and where the co-innovator triplet, technology, organisation and qualification, has little representation. A segmentation of Catalonia's private productive network according to ICT uses confirms the presence of two clearly differentiated patterns of penetration into in-

ternational markets. In companies making more intensive use of ICTs, the level by which Catalan products and services penetrate international markets depends on the investment complementarity in physical and intangible capital (intangible and training), productive experience and establishments abroad. In companies that make less intensive use of ICTs, International competitiveness is explained by a pattern of investment in physical capital and by establishments in international markets, in a context where investments in intangible assets have a negative impact. So, taking into account that the export levels of companies making intensive use of ICTs is triple that of the Catalan average, improvements to the international competitiveness of Catalan companies would be determined by the establishment of complementarity relations between ICT uses, combining physical with intangible investments, experience in production and a physical presence in external markets. Analysing determinants for the penetration of Catalan products into Spanish markets shows us that Catalan companies which make more intensive use of ICTs gain a market share in Spanish markets according to combined investments in physical and intangible capital, whereas companies that do not use ICTs intensively gain a market share in Spain through investments in physical capital and the presence of establishments in these markets. Investing in intangible assets has a negative effect on having presence in Spanish markets. In sum, the analysis of the determinants for Catalan product and service penetration into Spanish and international markets confirms that there are differentiated strategies for gaining competitiveness depending on whether or not companies make intensive use of digital technologies. In companies where digital technological changes are clearly established, strategies for the external market penetration (in Spain and abroad) of this sector of companies is explained by the combined investments in physical and intangible capital which, in the case of international competitiveness, is complemented with larger human-capital endowments, a physical presence in target markets and experience in production. Companies making less intensive use of ICTs do not distinguish the strategies for Spanish- and international-market penetration, such strategies being based in both cases on investments in physical elements and in a physical presence in markets, whereas investments in intangible elements have a negative impact on competitiveness.

*And, sixth. The weak presence of co-innovation processes based on the intensive use of ICTs and knowledge and information flows; on internationalisation and flexible adaptation to activity demands; on new ways to organise production and work; on investments in intangible assets; on financing, formal structures and cooperation networks in innovation; and on the continually extended capacitation of workers and enrichment of work places, reduces the competitive potential of Catalan companies very significantly.*

In sum, the analysis carried out for the entire private productive network of Catalonia fails to show any direct relationship between digital-based innovation processes and activity performance in Catalan companies. In fact, we have had to examine other, non-technological

dimensions to the co-innovation processes in order to understand the material improvements both for companies (productivity, competitiveness and returns) and for workers (wages). For this purpose, we have had to divide up the productive network into sections looking for organisations where digital technological and organisational co-innovation processes have a higher presence and where knowledge-use intensity is a more common resource, so we could discover any significant impacts on the principal corporate performances. This is probably so because these days Catalonia's economy shows a two-fold productive structure. On the one hand, here we have the larger part of the productive network (more than four fifths) making no intensive use of ICTs, having a clearly improvable level of training for its work force, presenting productive and organisational structures that have little flexibility and low decision-making autonomy and capacity among its workers and where innovative processes are still of rare occurrence. This set of companies, and we cannot pin it down to an activity sector or specific dimension, shows an extensive growth pattern, that is, bases its long-term expansion dynamics on an increase in its factor endowment, and in work factors in particular. It is precisely for this reason that Catalonia's work-productivity growth has been developing along disturbingly low rates and that, in a competitive setting dominated by globalisation, the problems of competitiveness are significant. By contrast, another, much smaller group of companies (less than a fifth) base their growth potential on the interaction between physical and intangible capital, human capital, strategic reorientation of work production and organisation, and a continuous innovative dynamic, of a digital technological nature in particular, but also in managing human resources and employment relations. It is precisely in this group of companies, clearly smaller than the one described before, yet possessing a much greater, long-term growth potential, where a favourable development in efficiency, competitiveness, wages and returns is established for our productive network. We therefore hope workers, business people, civil society, universities and public politics in particular will not stint on furthering the activities of this second group of companies. The future of the economy is at stake.


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