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Knowledge, networks and economic activity. Revisiting the network effects in the knowledge economy

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Presentation

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The knowledge-based economy is a network economy. The part that networks play in society is not a new thing, but perhaps their application and study are. The survival of the Roman Empire was undoubtedly due to its network of roads and the ease with which its culture, troops and merchandise could move about through its territories. The industrial revolution of the 19th century, and the fact that it extended to all four corners of the world, was thanks to the railway network which aided the spread of technology at levels never before seen. The second great industrial revolution – that of the electric engine – was also accompanied by the appearance and growth of electricity distribution networks and an improvement in communications and transport.

However, up until now, the network has been a complement or, at most, an instrument, at the service of a greater objective. These days, the role networks play is completely different. First of all because, in the knowledge-based society, networks are intrinsic to its operation and development. Through networks, knowledge is created and distributed, organisations are transformed and a relationship is established with technology which brings about changes in society.

Knowledge management is now a key factor for economic development. The definition of "knowledge management" is extremely loose, because it includes different concepts, such as the use of technological solutions to get organisations to store, share or be able to create new knowledge by themselves; or the interaction between individuals which generates new practices through the collective use of new technologies; or the relationships which arise based strictly on the effective use of a new kind of knowledge and how it is distributed, even after it has been used. In any case, we are referring to a special interrelation which only occurs through new technologies and which, for the first time ever, means that the process of creating and distributing knowledge is now self-powered.

Unlike the individual processes of the earlier technological revolutions, network economies develop through a collective process. On the one hand, their value is exponentially related to their size. As the number of nodes or connections increases, so does the importance that belonging to them has for each of their members. On the other, the networks allow tacit knowledge to be transmitted, facilitate coordination and reduce conflicts, getting groups to collaborate and add to each other. That is to say, interaction between the knowledge facilitated by ICTs is due to the participation of all the individuals collaborating in the process and benefiting from it at the same time.

Of course, the result that networks achieve in the process of production is not unique, either. Network participants reap the benefit of their participation according to their position in the network. As a result, the network displays the dichotomy of collective participation for the common good and one's own benefit based on the agent's influence within the network. This kind of situation is revolutionising areas, such as e-business, financial transactions or organisational management, although their current potential is still far from being fully recognised.

It is in this sense that I would like to highlight Professor Torrent's contribution: he manages to establish the basis of the role that knowledge plays within the network and how it is linked to economic activity. In other words, he clearly establishes the conditions under which knowledge affects the way in which the economy is organised, depending on typology.

This approach, distilled from the more traditional theories of neoclassical growth, allows us to answer questions which are vital for our current economy, such as the role that knowledge plays in it, either as a resource or as a commodity. In the new society, characterised by the transition from an economy of externalities to the network economy, knowledge is a fundamental factor of growth and the production of knowledge has an obvious economic value. However, as the author acknowledges, it is easy to forget the role of human capital in this technological whirlwind.

Talent is not easy to replace, since it has an immediate repercussion on the economy, either through its distribution throughout the network (observable knowledge) or its incorporation as part of the network of the commodity itself (tacit knowledge). In either case, wherever its own rules of behaviour exist, its incorporation into the productive process already represents a change in the productive paradigm, with dynamic effects on production and wellbeing. This result in itself is at the heart of the network economy and, as in this new paradigm, it also means that once again we have an infinite universe for future research.

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article

Knowledge, networks and economic activity. Revisiting the network effects in the knowledge economy

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Abstract

The progressive consolidation of a knowledge-based economy has caused network effects to become a focal point of analysis into the changes in behaviour evinced by economic agents. This article analyses the changes in production and demand for knowledge commodities arising from network externalities. The analysis reveals two distinct patterns of behaviour in knowledge-based economic activity. Observable knowledge commodities are governed by the effect of direct and indirect network externalities. Also, their demand curve and business strategy depend on new-user entry (marginal value) and the relative size of the network. However, tacit knowledge commodities are governed by learning network externalities and their demand curve and business strategies are dependent on the value generated by the addition of the goods themselves to the network (intrinsic value).

Keywords

information and communication technologies (ICTs), network externalities, industrial economy, knowledge-based economy, demand curve, knowledge commodities

Resumen

La progresiva consolidación de una economía basada en el conocimiento ha situado los efectos de red en el centro del análisis sobre los cambios en el comportamiento de los agentes económicos. Este artículo analiza las transformaciones en la producción y la demanda de las mercancías conocimiento derivadas de las externalidades de red. El análisis efectuado nos ha permitido distinguir dos patrones de comportamiento diferenciados en la actividad económica basada en el conocimiento. Las mercancías conocimiento observable se rigen bajo el efecto de externalidades, directas e indirectas, de red, y su curva de demanda y su estrategia de negocio se sustentan en función de la entrada de nuevos usuarios (valor marginal) y del tamaño relativo de la red. Por el contrario, las mercancías conocimiento tácito se rigen bajo el efecto de externalidades de red de aprendizaje, y su curva de demanda y su estrategia de negocio se sustentan a partir del valor generado por la incorporación a la red de la propia mercancía (valor intrínseco).

Palabras clave

tecnologías de la información y la comunicación (TIC), externalidades de red, economía industrial, economía del conocimiento, curva de demanda, mercancías conocimiento

Introduction

These days, economic activity (production, distribution, exchange and consumption) is undergoing a process of profound transformation, which we can summarise as having started with the migration from an industrial economy towards a new structure characterised by the decisive importance of information, communication and knowledge streams.[1] Although there are several reasons for this evolution, there is a certain academic consensus which places responsibility for this change on a triple feedback interaction.[2] First of all, a process of technological revolution led by investment and the massive use of information and communication technologies (ICTs). Secondly, by virtue of the dynamics of the space-time extension of the market for factors and products or process of globalisation, which assume the capacity to situate the economic sphere on a planet-wide scale in real-time. And thirdly, because of a new pattern in the process of demand from economic agents, which can be characterised through the increased importance of intangibles in both the family and corporate expenditure and investment structures.

From the perspective of the interaction between technology, economy and society, we might say that ICTs – which, broadly speaking, include the converging array of items of equipment and digital applications in the areas of microelectronics, information technologies, telecommunications, optoelectronics and the recent advances made in nanotechnology and biotechnology – have become one of the main foundations of the current process of radical change in economic activity and social structure. We can characterise this process of disruptive change induced by ICTs with three basic affirmations. Firstly, ICTs are fast becoming general purpose technologies,[3] that is, technologies which can be used on a massive scale and applied systematically by economic and social agents. Secondly, ICTs are becoming the building-blocks of a new technical and economical paradigm,[4] that is, they are the basis of a new, innovative substrate which radically transforms the structure of basic inputs and relative costs of production. And thirdly, ICTs are the basic infrastructure of a new process of industrial revolution,[5] that is, they are a series of disruptive changes in technique and production, interconnected with social and cultural changes on an enormous scale.

This process of disruptive change is, in fact, characterised by: a) interconnection over a network; b) investment, falling prices and the persistent and innovative use of ICTs; and c) the increasing presence of information, communication and knowledge streams in the area of economics, within a context dominated by the globalisation of economic relations. There has been a consensus to identify this process of transition from an industrial economy towards a knowledge-based economy.[6]

Thus, the knowledge-based economy becomes consolidated through a new technical property: the symbiotic relationship between ICTs and knowledge. Or, in other words, the application of new knowledge and information to knowledge-generation and information and communication-processing devices.[7] At present the economic application of knowledge is being used more than ever. One example to illustrate this: during the second industrial revolution, scientific knowledge developed the internal combustion engine which progressively became a key technology in the scheme of production. In this case, knowledge developed a technology which, once technically applied to production processes, caused a radical change in economic activity. In the case of the digitalisation process, we have technologies which are, as usual, based on the economic application of knowledge to develop factors and products reproducibly. However – and here is the novel aspect of this – the effect that this knowledge has is not limited to the production of technology, since ICTs are also involved in generating knowledge itself. ICTs are technologies which, as such, are knowledge and also expand and prolong the human mind in its knowledge-generation process. In other words, what we have here is a social stock of know-how which uses knowledge as an input and which contributes directly to the generation of knowledge as an output.[8]

In short, and using a wide perspective of technological processes, understood as man's dominion over nature and his social environment,[9] ICTs not only affect the capacity for reproduction and control of the environment but also, more than ever, we have a technological apparatus which acts directly on man's dominion over himself or, more correctly, over the generation of his own knowledge. Contrary to manufacturing-based technologies, which affected manual labour, the application of ICTs to the apparatus of production extends and

1. Torrent (2008).
2. Kranzberg (1985); David (1990); Mokyr (1990; 2002); Castells (1997; 2004); Vilaseca (2005).
3. Bresnahan (1995); Jovanovic (2005); Albers (2006).
4. Dosi (1988); Torrent (2004).
5. De Long (2001); Atkeson (2001); Baily (2001); Baily (2002); Gordon (2004).
6. Pérez (2002); Rodrigues (2002); Foray (2004); Vilaseca (2005); Rooney (2005); Dolfsma (2006).
7. Castells (2000: 62).
8. Torrent (2004: 49).
9. McClellan (1999).

replaces mental labour.[10] So what is the most relevant conclusion we can reach from analysing this intrinsic feature of digital technologies? It seems evident that the productive application of ICTs is associated, to a great extent, with the stock and dynamics of knowledge within an economy.

In this sense, if we want to conduct research into the main features of the process of transition towards a knowledge-based economy, we cannot obviate the important link between its material basis and the production factor and the commodity – knowledge, which has the most weight in this explanation of economic change. And, bearing in mind the symbiotic relationship between ICTs and knowledge, this article is designed to analyse the impact of network externalities on the economic structure from a conceptual perspective and within an analytical context. To do so, and after this brief introduction, we shall follow an analytical process to discuss the most general aspects to the most specific ones. First of all, and in order to contextualise the disruptive change that the transition to a knowledge-based economy signifies, we shall discuss the most aggregate approximations that social sciences have postulated with regard to this phenomenon. Secondly, and once we have explained the general context of the knowledge-based economy, we shall cover the microeconomic foundations, i.e. provide our analysis of the particular transformations that using knowledge as an input and commodity subject to market transactions means. Thirdly, after discussing the microeconomics of knowledge, we shall be in a position to study one of its basic components: network externalities. At this point, we shall ask what impact the network effects have on economic functions and market structure. The article will end with the main conclusions of our analysis and the references used in the text.

1. Technology, innovation, cycles, paradigms and revolutions: the conceptual basis of the knowledge-based macroeconomy

The impact of knowledge and technology on economic activity and society has been a matter of concern for social researchers for some time now. From an economic perspective, technological progress has been one of the concepts used most frequently to analyse the incorporation of knowledge into economic activity. This notwithstanding, an approximation to the classical way of thinking with regard to political economics, which the neoclassical school of thought would later reproduce, shows that only Marx,[11] with his study of the laws which govern the progress of capitalism (*theory of exploitation* and *theory of accumulation*), and Schumpeter,[12] with his study of innovation and innovative entrepreneurship waves, placed technological progress at the centre-stage of capitalist development. Other highly-relevant authors from the classical school, such as Malthus, Smith, Ricardo, Stuart Mill and Marshall, interpreted technological change as a mere instrument for achieving scale economies and to achieve displacement of the production function, or improved productivity. In fact, modern thinking has only contributed two new, although important, ideas to the legacy of classical thought. The first is the notion of technical progress as part of the capital contribution;[13] and the second is the importance of education as a form of human capital incorporated within the workforce.[14]

Based on Marx and Schumpeter's important contributions and breaking with the neoclassical interpretation, modern economic analysis has highlighted the close link between long-term economic growth and technological innovation. The starting point for this association comes from the works of Solow and Swan.[15] Their *exogenous economic growth model*, which postulates that technical change is exogenous to economic activity, whereby the factors which explain growth are reduced to the contribution of factors which already exist within an economy (the production function), reaches the paradoxical conclusion that the rate of growth of income per capita in a long-term balanced economy can be explained only by technological progress. Without adding knowledge and technology to production (innovation), the accumulation of capital will suffer from falling revenue and productivity levels, i.e. the potential for long-term growth that an economy has will fall over the long-term. The empirical exercises which compare the sources of economic growth or *growth accounting* exercises, confirm the importance of this residual element to the detriment of the accumulation of factors to explain the long-term potential for growth that an economy has. This phenomenon, often called the *productivity paradox*, leads to results which are hard to accept in the light of conventional economic theory, since it reveals a clear gap between the connections of the process of savings and investment in productive factors and long-term economic growth.

However, as the proposal regarding the exogenous characteristic of technical change relaxed, a new approximation

10. Autor (2003); Vilaseca (2003).
11. Marx (1867/1883).
12. Schumpeter (1934).
13. Salter (1960).
14. Schultz (1961).
15. Solow (1956; 1957); Swan (1956).

to the sources of economic growth became consolidated: the *endogenous theories of economic growth*. In this approximation, knowledge and technology are no longer the "manna from Heaven" and their use in production is directly linked to production factors. Broadly speaking, we could say that there are two large families of endogenous economic growth models: the *learning by doing models* and the *human capital theories*. In the former, increases in productivity are a by-product of economic activity.[16] In other words, the acquisition of knowledge is the result of normal investment and production which end up generating accumulated experience. In this sense, the main source of economic growth is determined by the increasing revenues associated with the features which make knowledge a public good.[17] The latter group of models, however, considers that increases in productivity are the result of intentional investment in education and research by economic agents, making technological progress a costly process.[18] Based on these two different approaches to the sources of economic growth, in the early 21st century a certain consensus was reached[19] which posited that economic growth is the combined result of the contribution of productive factors and innovation in economic activity. There are two reasons for this. Investment and profitability are the two bases for the accumulation of factors; and investment and the spread of knowledge are the bases for technological progress.

In spite of this consensus, which combines the classical approach with the residual approach to explain long-term economic growth, a series of critical contributions need to be highlighted. These refer to the importance of other forms of non-technological innovation and other methods of observation to explain this phenomenon.[20] The incorporation of knowledge and technology within economic activity ought to be interpreted from a specific, dynamic and relational perspective. Specific because it is impossible to understand the complexities of technological progress without becoming familiar with the technology itself, forcing us to move from a general concept to a more specific one: from technology to technologies. Dynamic because not only do technologies change over time but also several technologies coexist at a particular moment in time. And relational because we cannot analyse the effects of technological change without considering the particular context within which it is born and develops. So the fact that technological change is an extremely-complicated social process which is hard to assimilate in an economic model and the fact that technological change is a phenomenon with dimensions which we cannot force convincingly into the limitations of a particular academic discipline, make research into it a necessary form of observation which goes beyond conventional disciplinary boundaries. In this sense, the interpretation of the economic fact of knowledge and technology should be approached from a multidisciplinary perspective which includes all kinds of innovations, not just the ones which relate to its purer forms, within a context where they are produced endogenously and can be related to the economic and social context within which they are born and develop.

The analysis of the changes in Information and Communication Technologies (ICTs) does not constitute an exception within the conceptual framework of analysis which defines the traditional relationships between knowledge, technology and economic activity. Quite the opposite. The clearly feedback-produced link between ICTs and knowledge, both of which are key inputs and outputs of the current economic context, means that any study will need to be an even more multidisciplinary form of observation. To do this, we shall now introduce two concepts which will be extremely useful to the progress of our analysis. The first, the more general concept of industrial revolution, will help us define the process of transition towards the knowledge-based economy and society. The second, the more specific concept of the technical-economic paradigm, will help us measure the structure and evolution of the incipient knowledge-based economy.

We have already said that one of the main distinctive features of present-day economic activity is the appearance and consolidation of a new kind of technology, based on the process of digitalisation (coded representation of a signal through streams of light which are identified with binary digits) which we group together under the umbrella name of information and communication technologies (ICTs) and which have impregnated economic activity as a whole and social habits and practices to a great extent. In this sense, two basic ideas stand out from the background. First, the idea that ICTs are at the core of economic and social transformation; and second, the idea that ICTs impregnate, or in economic terminology "exercise synergic effects" over economic and social activity as a whole. In other words, ICTs are revealing themselves to be the basic material for a process of industrial revolution, the process of transition towards a knowledge-based economy and society.

Although it is not our intention to conduct an in-depth analysis into the bases and particularities of the concept of industrial revolution in this chapter, it is worth pausing for a moment to consider whether we are currently undergoing

16. Arrow (1962).
17. Romer (1986).
18. Lucas (1988); Romer (1990).
19. Torrent (2004).
20. Rosenberg (1976).

such a process. Historians' analyses of technology suggest that an industrial revolution would be based on two elements in particular: 1) a series of technical changes which are fundamental for the production and distribution of goods, accompanied by – and in some cases caused by and in yet others reflecting –, but in any case relating to; 2) a series of huge social and cultural changes.[21] Within this context, a certain consensus has been reached regarding the fact that at least capitalist dynamics are characterised by the presence of two industrial revolutions, both based on the productive development of new technologies. The first industrial revolution started in the latter half of the 18th century and was based on the steam engine and, more generally, on the process whereby tools were replaced by machines. The second industrial revolution, which began towards the end of the 19th century, was based on electricity, the internal combustion engine and the development of communication technologies (the telegraph and the telephone in particular). However, there was an important difference between these two processes: the different importance of scientific knowledge as an instrument which acted as the driving force behind technological development. Although in the first industrial revolution a degree of knowledge was instrumental in replacing tools with machines, it was not until the latter half of the 19th century that scientific knowledge became directly linked with economic activity.

In this sense, we could say that the last two decades of the 20th century were characterised by the presence of a revolutionary phenomenon, since the conditions of life and society were undergoing a change. And this revolution was an industrial one because the development of technology for production would establish the bases for an inter-related economic and socio-cultural change. In these approaches, the third industrial revolution's process of consolidation was called the "Information Age".[22] However, the new thing about the current process of disruptive change is not to be found in its grounding in information and knowledge, which were also features of the first and second industrial revolutions. The truly new thing which constituted the basis for the third industrial revolution was the application and use of the new knowledge generated. As we have already pointed out, the knowledge used for the productive application of digital technologies can also be used to generate, apply and distribute new knowledge to economic activity. In this way, and through digital infrastructures, knowledge is both a key input and a key output of the economic and social structure within a process of constant feedback between generation and use. This is precisely the phenomenon which allows us to say that the current dynamics of industrial revolution constitute the process of transition towards a knowledge-based economy and society.[23]

After ascertaining that the arrival of the knowledge-based economy and society is a process of industrial revolution, we shall now address the approach towards the change in the technical-economic paradigm which hinges more around the study of its technical and productive dimension. Research into paradigms was introduced into economic analysis by science historians within the context of studying scientific revolutions. We understand the term "paradigm" to refer to the entire series of universally-recognised scientific achievements which, over a period of time, provide models of problems and solutions to a scientific community.[24] Conceiving it in terms of scientific thought can be translated in terms of generalised technological progress. A series of authors who were unhappy with the traditional conception which links technological change to economic activity has used the technical-economic paradigm as the jumping-off point for a different perspective of the foundations of technical innovation. According to this approach, a technical-economic paradigm is a series of linked technical, organisational and management-related innovations, with advantages over and above the production of a new range of products and systems, since they also include the dynamics of cost in relation to all production inputs. In each new paradigm a specific input, or series of inputs, can be described as the key factor for the paradigm, characterised by a fall in relative costs and universal availability.[25] Changes in technical-economic paradigms are far-reaching processes of transformation in the technological system, which are vitally important for the behaviour of the economy as a whole. A change of this kind refers to a combination of innovative interrelations between products, processes, techniques, organisation and management philosophies which lead to a quantitative leap in the potential for productivity and competitiveness of the entire economy and which opens up new opportunities for investment and profit. In other words, the consolidation of a new technical-economic paradigm means much more than the implementation of incremental or radical innovations; it is even much more than the appearance of a new technological system which consolidates the appearance of a new production sector. The change in paradigm means a large-scale capacity for penetration over economic activities as a whole, leading to a radical transformation of the sources of productivity and competitiveness.

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21. Kranzberg (1985: 37).
22. Kranzberg (1985); Mokyr (1990).
23. Torrent (2008).
24. Khun (1971: 13).
25. Dosi (1988: 10).

Under this perspective, the contemporary change in the technical-economic paradigm (or the fifth long-term economic cycle of capitalism)[26] can be considered to be a changeover from a technology fundamentally based on cheap energy inputs to another based on cheap inputs of information and knowledge as a result of the spectacular progress made in microelectronics and communications. More specifically, the technical-economic paradigm of information and communication technologies, upon which the long-term cycle of the knowledge economy is based, has three basic components as a necessary condition for it to occur.

First of all, a new philosophy of production, i.e. the incorporation of a new (or several new) productive resources, which results in a) a variation of relative costs; b) an increase in production efficiency; c) a change in entrepreneurial organisation; d) the appearance and consolidation of new economic activities; and e) the use of these new goods and services by the other economic activities and agents. In this particular case, the necessary condition for the change in paradigm to become consolidated is the massive incorporation of knowledge to the act of production. In this sense, we need a new production sector to appear (the ICT sector) and the production philosophy of the old industrial paradigm to be revised, with new sources of long-term growth in productivity and competitiveness over the entire economy. Secondly, a new philosophy for the production of knowledge is also required. In our case, a series of new trends in the social basis of all kinds of knowledge, applied to economic activity, in order to generate incremental and radical innovations, which make better use of the new productive factor of relative low cost. Apart from this, and in order to optimise the competitive advantage of the new input, there must be a change in direction in the investment in knowledge. This change means, among other things, a wave of investment in ICT goods and services, but also taking advantage of knowledge-based networks (investment and innovation in intangibles) and the international spread of technology. Thirdly, new patterns of expenditure and investment are needed, which in our case is a demand-based boost (consumer activity, investment and foreign relations) in production based on the input of knowledge.

So the methodological approach adopted by analysing changes in the technical-economic paradigms has demonstrated that the main condition for finding that there has been a change in the economic substrate is the massive incorporation of the new resource and commodity, which determines productivity, across the entire economic panorama. Within this context, we might say that the term "knowledge-based economy" means analysing the behaviour and the events relating to the economical application of the know-how.[27] Several notes regarding this:

Firstly, in spite of the fact that this is self-evident, a knowledge-based economy is part of the economic analysis and, therefore, uses the methodological approach of economy as a science. This does not mean, however, that a knowledge-based economy never uses other disciplinary approaches. Quite the contrary, given the very characteristics of knowledge, we cannot take an overall approach to behaviour and the economic events deriving from it without visiting methodological, technological, sociological, psychological and philosophical aspects – to mention just a few of the ones most frequently used in the intrinsically multidisciplinary analysis of the knowledge-based economy.

Secondly, and as we shall analyse in detail below, we understand the term "economic application of know-how" to be the incorporation of a wide range of either observable or hard-to-measure knowledge to economic activities. Therefore, the knowledge-based economy is not only limited to the analysis of the economic application of scientific and technological developments. Neither can it be compared, for example, to the economy of education because these are just some of the developments of know-how, which are incorporated into economic activities.

Thirdly, although it is part of economic analysis, the knowledge-based economy does not deal with analysing specific sectors or economic resources; it is much more than that. One might think that the knowledge-based economy is equivalent, for example, to the information-based economy, but we must place emphasis on the fact that this is a deep, transversal concept.[28] Through the knowledge-based economy, we can analyse how the economic application of this resource and commodity changes both production activities, with new goods and services and changes in the existing ones, and demand activities, either consumer, investment or foreign-sector related. The fact is that the massive manifestation of know-how in economic activity from the 1990's onwards, encouraged basically by the hatching of ICTs, has changed the behaviour of the economic agents, generated new activities and caused some of the existing ones to vary significantly. It is precisely in this wider sense that we need to interpret the knowledge-based society, since knowledge has become one of the key elements of progress in productivity and competitiveness and, therefore, of the growth of the economy and material wellbeing of society.

26. Pérez (2002).
27. Torrent (2004: 119).
28. Vilaseca (2001).

2. The knowledge-based microeconomy: from scale economies to network economies

Following on from the above analysis, which allowed us to establish the conceptual bases of the process of transition towards a new technical-economic paradigm, characterised by the importance of streams of knowledge, we shall now conduct a more detailed economic analysis of this resource of such vital importance for a competitive future and material wellbeing. To do so, we need to ask ourselves the following questions: Is it possible to identify any characteristics which show how knowledge is being incorporated into economic activity? And if so, which are they? And finally, how do they transform the structure of the economy and the markets? Or, in other words, what role do they play in building a new economic substrate which is different from the industrial economy? The answers to these questions lead us inevitably towards economic characterisation as a resource and a commodity, of knowledge and the distinction between the structure of the economy and the markets in either an industrial economy or a knowledge-based economy.

We understand the term "knowledge" as given in epistemology, the theory of knowledge: the human and dynamic process which consists of justifying a personal belief to the point of certainty.[29] This vision of knowledge as a true, adequately-justified belief places the central problem of its theory on the issue of how we justify beliefs, i.e. on the explanation of the difference between knowledge and simple, true belief. Leaving these matters aside, the very epistemological definition of knowledge refers to two, very important elements which need to be highlighted from an economic point of view. First, the fact that knowledge is related to human action and second, the fact that the generation of knowledge is a dynamic process, since it is created on the basis of interactions between individuals, groups, organisations and societies. These two characteristics allow us to place knowledge within our own domain. That is to say, the dynamic, human action of knowledge creation can be interpreted, among other things, as an economic activity.

More specifically, can we approach a production of knowledge? To respond to this question we need to refine even further the interpretation we make of knowledge from the perspective of economic analysis. In this context, the first thing we need to make clear is the distinction between knowledge and information, or the stream of messages from which knowledge is generated.[30] Although both concepts are closely related, the economic approach focuses on the fact that information is one, if not the only, input in the process whereby knowledge is generated. The information provides a new perspective for interpreting events or objects and, as such, is a means or material necessary for obtaining and building knowledge. Information affects knowledge and adds something or restructures it. In fact, we might even say that in the act of knowing, an accumulative flow between three elements is established: data, information and knowledge. This stream of generating know-how consolidates knowledge as a resource used daily by economic agents to take decisions within the economic structure. And not only that: the knowledge generated can be represented economically through its production-based function. We could say, then, that knowledge, as a tool for production, distribution, exchange and use, is economically relevant.[31]

These days, economic activity basically covers four types of knowledge:[32] *know-what*, *know-why*, *know-how* and *know-who*. As regards know-what, it is easy to see how this kind of knowledge is identified with information, since it can easily be segmented and represented through bit-streams. Know-what, then, refers to knowledge about facts. Know-why is an extremely important kind of knowledge for technological development in some areas of production. The production and reproduction of this kind of knowledge occurs within the context of specialised organisations, such as universities, for example. In short, know-why refers to scientific knowledge of the laws on how nature, the human mind and society develop. Know-how refers to the development of a person's capabilities and attitudes. It refers, then, to the capacity that individuals interacting in the economic activity have to do things (*skills*). This includes a wide range of characteristics that people have and which can go from abilities and capacities to skill and talent. Finally, know-who refers to a kind of knowledge that is becoming more and more important and which is based on a combination of skills, including the possibility of social action. Currently, this kind of knowledge is very important because in the knowledge-based economy people are considering the need to access a very varied range of knowledge (who knows what and who knows how to do what), knowledge which is also extremely scattered. In short, know-who refers to the concept of knowledge networks and how to use them. As a result, this is what relates and causes the other three to interact.

We can acquire these four types of knowledge through different channels. Whereas know-what and know-why can be gleaned from books and access to data, the other two are mainly gained through practical experience. Know-how comes

29. Terricabres (2001: 277).
30. Neef (1998).
31. Neef *et al.* (1998); Thurow (2000); Stehr (2002); Mokyr (2002); Torrent (2004).
32. Lundvall (1994); Foray (1996).

mainly from the educational learning relationships and also from professional development. Know-who is acquired through the social exercise of one's profession and sometimes from specialised educational environments.

One additional characteristic of these four kinds of knowledge is that whereas know-what and know-why are easily reproducible, know-how and know-who are more difficult to turn into information. This feature – facility of reproduction – leads us to a grouping of knowledge production which is very interesting for our own purposes.[33] It refers to the distinction between the production of explicit, observable or codifiable knowledge and that of tacit or implicit knowledge. The production of explicit, observable or codifiable knowledge is that which can be expressed in a formal and systematic language, so that it can easily be processed, transmitted and stored. The production of tacit or implicit knowledge is associated with the work factor and includes technical and cognitive elements, such as practical experience, skill and qualifications which are difficult to list.

Once we have defined the main characteristics of the production of knowledge, that is, the different, relevant forms of knowledge as an economic resource and how it is grouped together on the basis of ease of reproduction, we will be in a position to discuss how to incorporate it into economic activity as a whole. At this point, we need to highlight two elements. First of all, knowledge will be economically relevant providing it manifests itself in economic activity. For example, the knowledge incorporated by people who are economically non-active, scientific knowledge not applied to production or observable knowledge which is not used for economic activity are of no interest to us from the perspective of incorporating knowledge into the economy. However, from the point of view of production of knowledge itself, all aspects of knowledge which are not economically-manifest actually do interest us – a lot. Secondly, economic activity has always incorporated knowledge as a resource: the innovative entrepreneur and human capital are two of the most illustrative examples of this. The vision of the innovative entrepreneur, who accumulates knowledge about production and the market for his new product, or the efforts to capitalise work, linked to education and training for people, are two important examples of how knowledge is incorporated into production structures.

However, it is important to point out that, over the last few decades, digital technologies have allowed us to encourage, extend and modify the economic supply of knowledge. This substantial increase in the presence of knowledge in economic activities can be seen basically from two things: the first has been the significant increase in observable knowledge used in economic activity. It is evident that the spectacular improvement in the access to, and management of, streams of information and knowledge have caused the barriers to distribution and the productive use of observable knowledge to come down to a great extent. The second is the transformation of tacit knowledge into observable knowledge and the change in the training requirements and skills and in experience that the knowledge-based economy demands of the workforce. In short, we can conclude this vision of knowledge as a resource of economic activity by saying that the intensive use of ICTs has resulted in: a) an increase in the supply of observable knowledge; b) the transformation of tacit knowledge into observable knowledge; and c) the development of new abilities within the workforce, which has ended up generating a virtuous circle between the production of knowledge and its economic and social uses.[34]

We have just seen how, when knowledge interacts with ICTs, it becomes consolidated as a resource of capital importance for economic activity. However, if we were to limit our description to this single aspect, we would only be able to reach partial conclusions because these days knowledge is not only an implicit resource for the production of all goods and services, but has also become a commodity which can be traded, an item or a service which is exchanged on the markets. In this sense, it is important to point out that knowledge goods and services or commodities have certain special characteristics that we must be able to analyse. To do so, just as with knowledge as a resource, we must make a distinction between: a) the economic properties of easily-reproducible or observable knowledge commodities deriving from the economic application of know-what and know-why; and b) the economic properties of knowledge commodities which are difficult to reproduce or tacit in nature, deriving from the economic application of know-how and know-who.

An initial approach to the characteristics of easily-reproducible knowledge commodities is the one that, on the basis of the process of digitalisation, can list the economic properties of what are known as information goods.[35] The terms "information goods" or "observable knowledge commodities" (i.e. the manifestation of observable knowledge as an output) refer to any good or service which can be digitalised, i.e. coded as a series of bits. For our purposes, these can be football results, books, databases, magazines, films, music, stock market listings and web pages, among many others.

Their first, fundamental characteristic relates to the cost structure and comes from the fact that observable knowledge goods and services are expensive to produce and very cheap to

33. Polanyi (1978); Nonaka (1995).
34. Antonelli (2000).
35. Shapiro (1999); Shy (2001).

reproduce. In economic terminology, they have high fixed costs and very low marginal costs (with a trend towards zero). This, then, leaves us in the world of increasing returns to scale. That is, with increases in output which are higher than the increases in the productive supply of inputs. This cost structure has important consequences when it comes to setting prices, because it cannot be based solely on cost (which is very low for reproduction) but must inevitably include how much the consumer values the good or service. In fact, the presence of increasing returns leads us inexorably to product differentiation strategies as an opportunity to increase the extent to which the end consumer values observable knowledge commodities.

A second characteristic of observable knowledge as a commodity is the fact that it is considered to be an experience good. A good or service is an "experience" good or service if consumers need to try it to see whether or not it is useful. In spite of the fact that any new good or service is an experience good, observable knowledge commodities are experience commodities because the end user cannot determine whether they are useful until he/she consumes them. Also, this occurs each time the need to consume them is considered. The goods and services of the industry creating, editing and disclosing content are a clear example of this. The person who reads a book, the user of an education service or the viewer of a film cannot determine how useful the merchandise that they have purchased is until they use them. From the company's perspective, this situation occurs when, as experience in production increases, the cost per unit produced falls. Experience economies exist when the average cost of production falls as the company acquires more experience. In short, companies which produce observable knowledge commodities reduce the unit cost of production as their experience in the consumer's final perception of its goods increases. As a result, there is a circular flow of perceptions of observable knowledge commodities between entrepreneurs and consumers as the two economic agencies' experience grows.

A third characteristic of easily-reproducible knowledge commodities is the decreasing marginal usefulness that access causes. This idea of saturation generates a sensation of accessible and observable knowledge overload. So the problem we are currently facing is not one of access to the information, but of information overload. Therefore, this kind of knowledge commodity is characterised by a degree of consumer satisfaction which decreases as the sensation of saturation increases due to the overload of outputs to which the consumer has access. This, together with the cost structure, is one of the reasons why many companies producing this kind of commodity apply differentiation strategies designed to increase customer loyalty.

A fourth characteristic, related to the convergent evolution of digital technologies and also to companies' product differentiation strategies, are the tremendous barriers to the release of observable knowledge commodities. In other words, the technological dependency of users of this kind of knowledge means that the costs of changing (*lock-in*) are very high. They may be very wide-ranging, from the expense of changing technology to the cost of learning how to obtain the new knowledge required to use it (*wetware*). A typical example of this situation are the problems arising when IT software is changed. These range from incompatibilities with other programmes to the need for new training.

Finally, easily-reproducible knowledge commodities have a fifth attribution, deriving from the progressive usefulness of a growing number of users for consumers. This characteristic – which, in economic terms, is related to the network externalities deriving from its use – is based on the fact that usefulness for consumers grows exponentially as their numbers increase (Metcalfe's Law).

On the other hand, as we said above, knowledge commodities also incorporate a less easily-reproducible kind of knowledge. In fact, this is basically how to market the know-how and the know-who. Some examples of knowledge commodities which are hard to reproduce are the capabilities, abilities, talent or skill which the workforce brings to the economic activity, the knowledge that economic agents have about production, the market or a specific sector and the capacity for social interaction in order to glean in-depth knowledge of the features of an economic activity. In spite of the fact that there are some markets for this kind of knowledge – *head-hunters* would be one of the more paradigmatic –, many of these exchanges of knowledge occur within the company (internal job markets). However, what are the economic properties of this kind of commodity?

First of all, we must point out, as we have above, the difficulty of processing, storing and transmitting tacit knowledge commodities. This leads us to a relevant economic consideration: the difficulty of reproducing them. For example, it is easier to reproduce a book, a CD or a film digitally than it is to reproduce the skills workers use to carry out their jobs. The marginal costs of this kind of knowledge commodity are higher than those of observable knowledge merchandise and, therefore, the condition for increasing returns is less intense. However, under no circumstances does this mean that tacit knowledge goods and services break away from the concept of non-rivalry, one of the characteristics of knowledge commodities, or rather one of the characteristics of public goods. The idea of a non-rival good highlights the fact that once a good is produced it can be consumed by more than one person at a time. The difference between a banana (rival good) and a mathematical formula (non-rival good) is, precisely, that the former can only be consumed once, while the latter – once generated – can be applied to economic activity as many times as necessary. At present, the fact is that – with the use of ICTs – not only can we access huge amounts of information and training which affect tacit knowledge, but new markets for tacit knowledge commodities

Table 1: The economic characteristics of observable knowledge and tacit knowledge commodities

Type of knowledge	Ease of reproduction	Type of good	Economic properties	Examples
Know-what	Observable knowledge	No rival Experience good Capacity for exclusion	High increasing returns Decreasing marginal usefulness High barriers to release Use network externalities	Digital content Media Hardware, telecommunications and machinery Software and services
Know-why	Observable knowledge	No rival Experience good Average exclusion	High increasing returns Decreasing marginal usefulness High barriers to release Use network externalities	Scientific knowledge Research and development Patents Innovation systems
Know-how	Tacit knowledge	No rival Experience good Low exclusion	Average increasing returns Decreasing marginal usefulness Few barriers to release Use network externalities	Internal labour markets Internet job sites Wetware Digital competition
Know-who	Tacit knowledge	No rival Experience good Low exclusion Intrinsic network externalities	Average increasing returns Increasing marginal usefulness Few barriers to release Use network externalities	Capital and social networks Relational wetware Professional networks

Source: bespoke creation.

have developed: for example, internet companies which act as intermediaries between the supply and demand for jobs.

The second characteristic of tacit knowledge goods and services that needs to be analysed is the fact that they are considered experience goods. Here they coincide with observable knowledge commodities, insofar as their usefulness for the consumer is determined once they are consumed. However, as in the previous case, ICTs affect the usefulness of the producer and the consumer, in the sense that they facilitate and improve the exchange of information or displays of content.

With regard to the decreasing marginal usefulness of access to tacit knowledge commodities, everything seems to point to consumer saturation being lower than in the case of observable knowledge. There are two basic reasons for this. First, because – as we have already said – the difficulty of reproduction means that these commodities are not present on digital markets in the same way as commodities which can easily be turned into information. And second, because tacit knowledge commodities become a priority for developing economic activity, which boosts the demand for them. In this sense, we might even say that, whereas in the case of some observable knowledge commodities consumers may feel that there is an excess of supply, with tacit knowledge commodities there is more a sensation of an excess of demand.

On the other hand, the difficulty of transferring tacit knowledge to an activity which can be economically-traded also minimises the effect of barriers to release or to the change from one tacit knowledge commodity to another. Finally, there is one more, highly-relevant characteristic. This is the important network externalities and the use of tacit knowledge goods and services. These externalities come from two areas. Firstly, as with observable knowledge, given the increase in usefulness which comes from a larger number of users (use network externalities). Secondly, given the characteristics of knowledge in this type of commodity (intrinsic network externalities), which involve a high level of relational knowledge (know-who).

Taking the four types of knowledge included in economic activity and the ease of reproduction of knowledge commodities into account, table 1 reproduces the economic characteristics of observable and tacit knowledge commodities.

3. Network externalities in the knowledge-based economy

After analysing the macroeconomic bases and the microeconomic properties of knowledge we can now cover in greater detail one of the properties which most often develop in digitally-based economic activity: network externalities. The concept of externality is very important in economics because it looks at the impact that individual decision-making has on the other agents. It is a concept of comparison, which refers to how decision-making involves others without there being any kind of consideration or exchange.[36] Externalities can be positive or negative, depending on the direction of the impact (positive or negative) of individual economic decision-making on the other agents. For example, and to cite different directions – externalities – that the same action can generate: the decision by public governments to implement an infrastructure – a road, for example – can generate a series of positive externalities in the sense that it boosts activity and synergies in economic activity, but at the same time it can also generate negative externalities in the sense of increasing traffic jams and environmental problems.

The term "network externalities" refers to the increased usefulness that a user of a technology/product/service gets as the number of users of the same technology/product/service increases.[37] This property, also known as "demand-side economies of scale" or "network economies" introduces a dynamic on the market which assumes that the price that users are ready to pay is partly determined by the size of the network to which the technology/product/service belongs. And not only that: the decision to use or purchase the technology/product/service is determined by the expectations for success of the different competing networks.[38] However, the appearance of network economies assumes that there is a certain degree of complementariness and/or interaction between the various individual agents/nodes which configure them. As in the more aggregate case, network externalities may be either positive or negative, depending on the interactions involved.

Broadly speaking, network economies fall into three large groups: 1) direct network externalities; 2) indirect network externalities; and 3) learning network externalities.[39] Direct network externalities refer to the increased usefulness of the network for the user as the number of nodes grows. This is the typical positive effect of Metcalfe's Law and which can be seen on communications networks, software users or internet portals. In the same way, negative effects can also be generated, linked to congestion or the problem of a saturation of information. Indirect network externalities refer to the improvement in market conditions directly linked to standardisation. Increases in the number of nodes in a network can cause prices to fall (scale economies), variety to increase (complementary products) and conditions of access and use to improve. This is the typical positive effect linked to the standardisation of a hardware and complementary software as a result of massive use.[40] As in the previous case, this can also cause negative effects, linked to the existence of dominating position on the market and competition-restricting practices. Finally, the externalities of the learning network refer to the consolidation of a specific, expert knowledge as the network nodes increase. The cumulative contribution of specific knowledge to other network users and the dilution of learning costs are the main reasons for this kind of network economy. This is the typical external effect on which the consolidation of the use of the current computer keyboard, the spread of the PC and even the success Linux and Open Office-type operating systems and software is based.[41] As above, we can also find negative learning network externalities relating to entrance barriers to expert knowledge, changeover costs or the costs of the opportunity to learn.

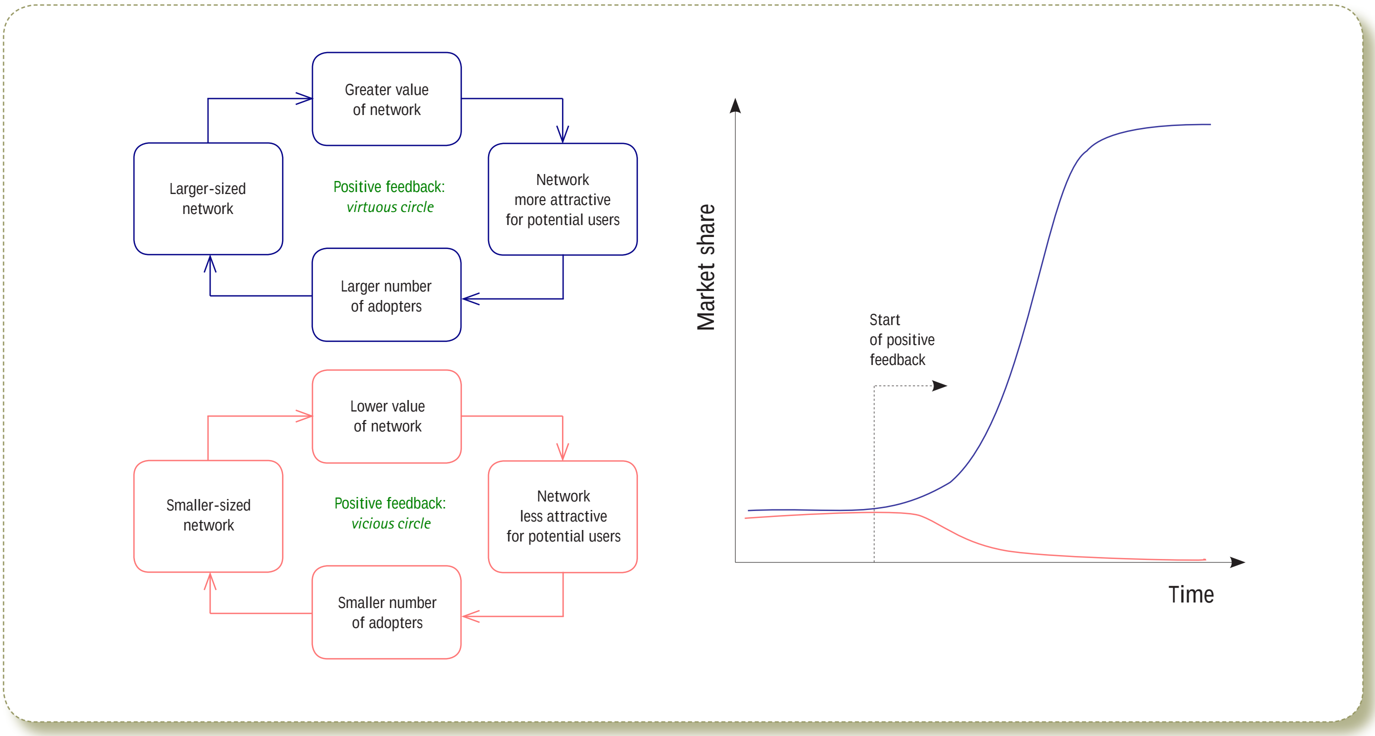
Although network externalities are not a new phenomenon in economic activity, since they have been found to exist, for example, in transport and analogue communications networks, the massive application of ICTs and the internet and the digitalisation of economic activity means that they are of paramount importance for the development of the knowledge-based economy. Doubtless the implementation of business strategies, the analysis of consumer patterns and even the development of public policies need to take the growing presence of network economies into account.

In spite of their increasing importance in explaining economic activity, the large amount of academic and inter-disciplinary research into network externalities has mostly been based more on their theoretical aspects than on the empirical corroboration of their effects and implications. To solve this problem, a large number of studies have appeared over the last ten years which have begun to corroborate the impact of network effects on company strategy, market structure, consumer standards and the development of public policies.[42]

The concept of *positive feedback* establishes the starting point for research into network economies. This approach, linked to the process of adoption and use of technology, says that when in the

36. Katz (1985); Shapiro (1999: 175).
37. Arroyo (2007: 21)
38. Brynjolfsson (1996).
39. Amit (2001); Zodrow (2003).
40. Basu (2003).
41. David (1985); Goolsbee (2002).
42. One which deserves a special mention is the research conducted in the Networks, Electronic Commerce and Telecommunications Institute (www.netinst.org) which belongs to New York University's Stern School of Business. Its principal, Nicholas Economides (Economides, 1996a; 1996b; 2007) is a worldwide authority on analysing the economic impact of networks. Also deserving of mention are the recent works by Bobzin (2006), Goyal (2007) and Jackson (2008). In Spain, we refer in particular to the excellent work done by Arroyo (2007).

Figure 1: Network externalities, feedback process and spread of the technology/product/service



Source: reproduced from Arroyo (2005).

presence of network economies, strong technologies/products/services become even stronger (virtuous circle) whereas weak technologies/products/services become even weaker (vicious circle). Within this context, the process of adopting a technology/product/service in the presence of network externalities will follow a *winner takes all* pattern, in the sense that a single technology/product/service will dominate and the rest will be eliminated.[43] Figure 1 shows how the presence of network economies and the result of the feedback process (virtuous/vicious circle) end up explaining the technology/product/service adoption process.

At this point, it is important to establish certain considerations. First of all, we would point out that the law/rule that value generation fulfils in digital markets in which network effects are present is Metcalfe's Law. This approach states that if a network is made up of n people, the value for each node in the network (user *n*-th) is proportional to the number of the other members of the network, n-1. In this way, the total value of the network is proportional to the number of nodes multiplied by the value of the network for each of them. That is to say, n x (n-1). Although this rule provides us with a simple interpretation of value creation in network-based economies, whether it is fulfilled or not depends on two basic nuances which will provide us with the specific form of the function for adopting a technology/product/service: 1) the combination of marginal, positive and decreasing returns and decreasing marginal returns from the point at which negative congestion externalities are achieved; and 2) the consideration that the interconnection between networks of different sizes adds more value to the smaller network than to the larger one.

Metcalfe's Law postulates that the marginal value provided to the network by one user to all the other users is constant, k. This being so, user *n*-th contributes a value to the rest of the network users which is the result of his/her contribution minus the contribution of the other users, i.e. k x (n-1) - k x (n-2) = k. If we now calculate the relative contribution of user *m*-th, where m>n, we find that k x (m-1) - k x (m-2) = k. In fact, the assumption that all connections contribute an equal value to the network is highly debatable for at least two reasons.[44] Firstly, because the profile of the users who connect up to the network and their value contribution does not necessarily always have to be the same. And secondly, because in large networks, the possibility of additional user interconnection does not have to be total. In mathematical terms, the growth of a network

43. McGee (2002).
44. Zodrow (2003); Odlyzko (2006).

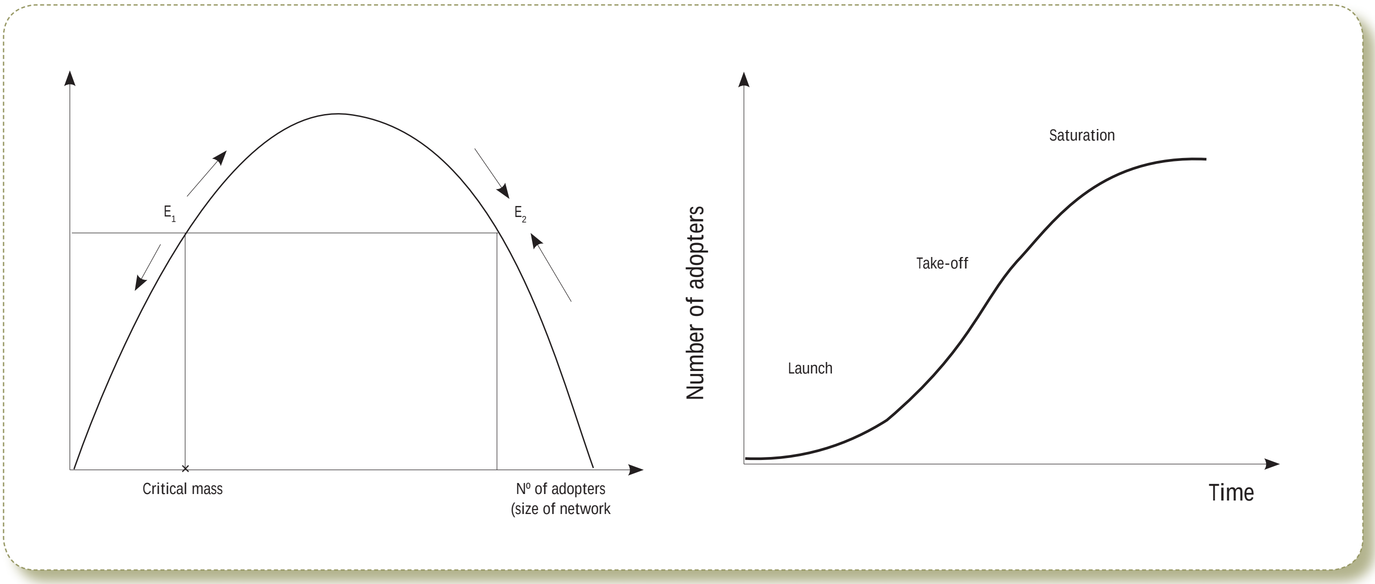
from n to n+1 users means an increase in the total number of possible connections of 2n, the result of deducting the possible connections by n+1, i.e. n x (n+1), from the possible connections at the initial point n, i.e. n x (n-1). However, for an individual user, the increase in the number of possible connections in the move from a network with a size of n to a network with a size of n+1 is 1. Within this context – the increase of one connection to the network – the size of n is tremendously important, because an additional connection to a small network is not the same for a new user as to a large network. As a result, the value added to the network depends on the point of time at which the additional user joins and the size of the network. In this sense, after a certain number of users, congestion externalities may appear because the value that an additional user adds to a large network may be negative since it sets limits to existing connections.

On the other hand, Metcalfe's Law supposes that, when two networks merge, the value of both of them increases by the same amount, regardless of their initial size. Suppose we have two networks, A with n users and B with m users, where n>m. With the merging of the two networks, each user of A finds that his value increases proportionally to the number of new connections, m. Therefore, the total increase in value for network A is established in proportion to n x m. Following the same line of reasoning, the total increase in value of network B is established in proportion to m x n. In this way, and regardless of their sizes, A and B would increase their value in the same proportion. This result, which lies at the heart of the second rider to Metcalfe's Law, would not explain why smaller-sized networks are prepared to pay to join a larger network, thanks to the relative increase in value that the merger brings.

Secondly, it should be pointed out that the form of the adoption/purchase of technology/products/services curve in the presence of network externalities depends on how far a critical mass of users has been achieved. That is to say, the minimum size of the network which encourages potential users to join it (establishes the starting-point for positive feedback). The image on the left of figure 2 outlines the point at which critical mass is achieved for a technology/product/service based on its price and the number of people adopting it (size of the network). Given a demand function for a technology/product/service with network effects, whose functional form (concave) we will analyse in depth later, the figure shows us that there are two possible amounts of balance for a given price, E_1 and E_2. E_1 is an unstable balance and represents the point of achievement of critical mass, whereas E_2 is a stable balance. In fact, for networks smaller than point E_1, the demand curve for the technology/product/service is lower than its price, that is, the price of the networked commodity is fairly unattractive given the small size of the network. In such a situation, new users are not interested in the network and even existing ones may feel an incentive to leave it. In the same way, in networks larger than point E_1, with networked commodity prices higher than demand, the incentives are for the size of the network to continue to grow until it achieves its size for balance E_2.

In this sense, it should be noted that the concave shape of demand and reaching the point of critical mass determine the sigmoidal shape (S-shape) of a technology/product/service adoption curve under network effects (the image on the right

Figure 2: Critical mass of users and the technology/product/service adoption curve under external network effects



Source: Rohlfs (1974). Reproduced from López (2006).

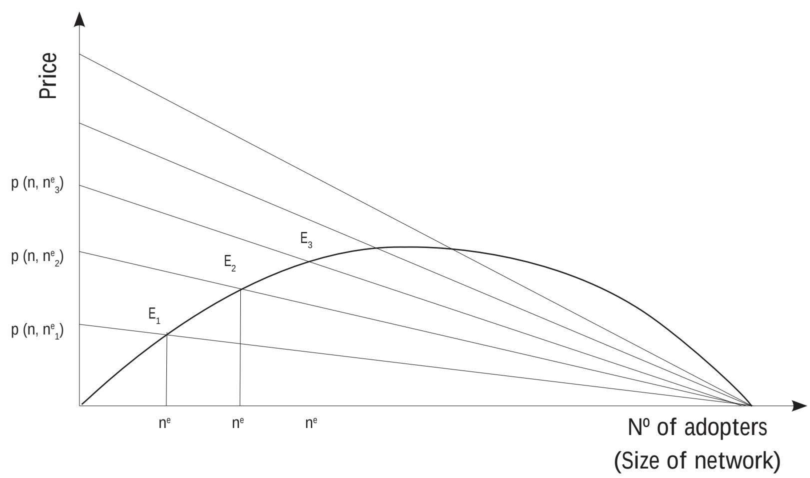
of figure 2). This shape, which is also present in many other technology/product/service adoption curves without network effects, is substantially different from those of other, non-digital technologies/products/services, particularly as regards the duration of their three stages: launch, take-off and saturation. In the first, or launch, stage adoption growth is very slow and the curve is almost flat. This is due to the problems of achieving the necessary critical mass and this period is often called the *penguin effect*. In the second, or take-off, stage there is sharp growth, much greater than where there is no positive feedback, once the network has achieved critical size. In the third, or saturation, stage growth slackens off and the size of the network stabilises. Sometimes there is also a fourth stage, decline, where the technology/product/service becomes obsolete and better replacements consolidate.[45] Finally, scientific reference material has confirmed that the price, the expectations for success (company reputation, installed client base, ability to offer a valuable product, property rights, speed of reaction, ability to manage lock-in and strategic alliances) and complementary products become consolidated as the key factors which explain the success of technology/product/service adoption under network externalities.[46]

Once we have analysed the bases upon which the economy of network effects stands, we are ready to tackle the analysis of its demand function. Contrary to traditional functions, as we can see from the riders to Metcalfe's Law that we discussed above, the demand function for commodities with network effects is concave in shape, caused by the existence of: a) an initial, increasing raster which indicates the positive relation between the value of the network and the increase in the number of users; and b) a second, decreasing raster which reflects a marginal contribution to the smaller network from new users from a certain point on (congestion effects).

Within this context, the construction of a demand curve subject to network effects can be considered as follows.[47] Firstly, we must point out that the demand for a technology/product/service subject to network effects depends on the price and the number of network users. If n is the aggregate demand, p the price, and n^e the installed client base, we can express the aggregate demand equation as $n = f(n^e, p)$. Secondly, inverting this equation, we can express the price that consumers are prepared to pay through the number of people requesting it and the size of the network, i.e. $p = p(n, n^e)$. Thirdly, and depending on the different sizes of network (n_i^e), we can represent the various price curves as $p = p(n, n_i^e)$, $\forall$ i = 1, 2 ... n. Fourthly and finally, the demand curve is obtained from the intersection of each curve $p = p(n, n_i^e)$ with the installed client base (n_i^e). Figure 3 shows the demand curve for a technology/product/service under network effects. It should also be pointed out that the vertical axis is also part of the demand curve.

Although the representation of demand under network effects shown in figure 3 is one of the most frequent ones, studies[48]

Figure 3: The demand function of a technology/product/service under external network effects.



Source: Economides (1995). Reproduced from López (2006).

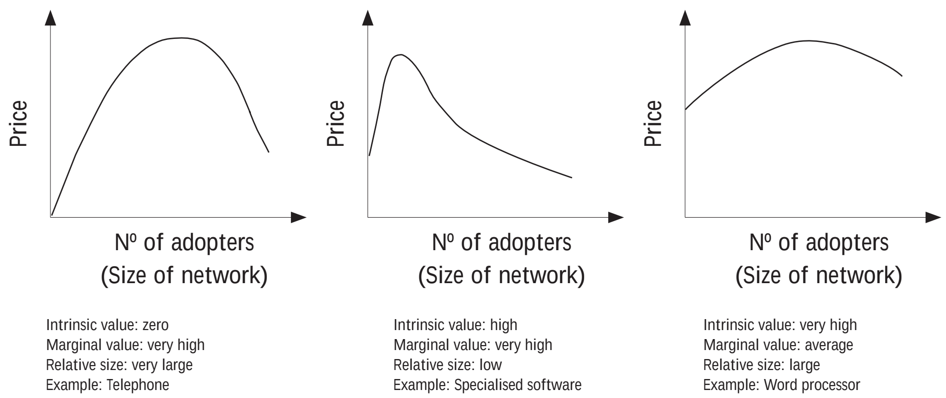
45. Goldenberg (2004).
46. Arroyo (2005).
47. Economides (1995).
48. McGee (2002).

have identified different forms in this function, based on the incorporation of three key elements: 1) the intrinsic value of the technology/product/service; 2) the marginal, or synchronisation value; and 3) the size of the network in relation to the size of the market. The term "intrinsic value" of a network commodity refers to the value that it provides to the network user. For example, e-mail provides value to the user of a network insofar as he/she can connect with other users, whereas software such as a word processor or a spreadsheet provides an intrinsic value to the user, regardless of whether or not he/she is connected. So, for our purposes, the intrinsic value is the value of a technology/product/service for a network size of zero. In the case of network commodities with an intrinsic value of zero, such as e-mail, we refer to pure networked commodities. The term "marginal" or "synchronisation value" means the value that the addition of other users to the network generates for a user. For example, in the case of mobile phones, marginal value will be high, because the value increases for network users with each additional new user. However, in the case of office suite software, the marginal value of the network is lower, since although the increase in value for network users is evident when there is a new user, the increase is lower than with pure network technologies/products/services. The reference material has identified these two characteristics of the demand for network commodities by formulating a value function, U, which is expressed as a function of the intrinsic value and the marginal value.[49] This function, $U = a + b(n^e)$, suggests that the demand for a network commodity depends on its intrinsic value, a, and its marginal value, $b(n^e)$, established on the basis of the size of the network. We should point out that a represents the ordinate at the source of the function, i.e. for pure network products $a = 0$, whereas $b(n^e)$ represents the ordinate which derives from the function, i.e. its marginal increase, with $b(0) = 0$. Finally, the value of the network also depends on the relation between its size and the size of the market. For example, statistics software or packages will generate a lower network value than an office suite software or package, because the potential number of users is smaller in the first case.

Figure 4 represents different forms of a demand function under network effects, in accordance with the three properties explained above. In all cases, the demand function is concave, i.e. in the shape of an inverted U, although with various manifestations, depending on its intrinsic value (ordinate at source), its marginal value (slope) and the maximum point of the curve (which tells us the maximum point of balance after which negative externalities appear).

Finally, after characterising the demand function of a technology/product/service under network effects, in table 2 we have summarised the link between the analysis conducted on network effects and knowledge commodities. We have already discussed above the fact that, broadly speaking, there are two kinds of knowledge commodity (technology/service/product): observable knowledge commodities and tacit knowledge commodities. Basically the former are maintained under the effect of direct and indirect network externalities, whereas the

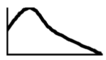
Figure 4: Demand functions of a technology/product/service under external network effects in accordance with their intrinsic value, marginal value and size of network



Source: McGee (2002). Reproduced from López (2006).

49. Kauffman (2000).

Table 2: A taxonomy of the demand function of knowledge commodities under network effects

Type of knowledge	Basic network effects	Types (+/-) of network effects	Properties of demand
Observable knowledge	Direct network externalities Indirect network externalities	+ Increases in value + Falls in pricing + Increases in variety + Improvement of conditions of access and use - Effects of congestion - Saturation of information - Dominant market positions - Restrictions to competition	Low intrinsic value High marginal value Relatively large size Function shape: 
Tacit knowledge	Learning network externalities	+ Accumulation and diffusion of knowledge + Dilution of learning costs - Barriers to gaining expert knowledge - Changeover costs - Learning opportunity costs	High intrinsic value Low marginal value Relatively small size Function shape: 

Source: bespoke creation.

latter, heavily implicated in people's hard-to-codify knowledge, associate under the effect of learning network externalities. They both have the potential to develop positive and negative effects, depending on the interactions established between the network agents/nodes. However, the true distinction between these two kinds of commodity can be found in the form of their demand function. Observable knowledge commodities base their creation of value on the potential that the arrival of new members of the network offers (marginal value) and their large size. However, the creation of value in tacit knowledge commodities is based in the high intrinsic value that these products have. In this sense, it should be pointed out that this dissociation in demand generates two distinct business strategies. For business based on observable knowledge commodities, the network effects determine a strategy basically built on a maximum number of agents joining the network. For business based on tacit knowledge commodities, the network effects determine a strategy basically built on the contribution of value to the network through the commodity itself.

4. Conclusions

In the course of this article, we have analysed how the growing productive application of information and communication technologies (ICTs) has opened the gates to change within the technical-economic paradigm, which we call the "knowledge-based economy", and contains the resource and the commodity which explains the progress in productivity and, therefore, in economic growth and material wellbeing on the threshold of the 21st century. We have also seen how important network effects are in explaining the dynamics of production, consumer affairs and markets in the knowledge-based economy. Summing up, and taking into consideration the growing link between knowledge, networks and economic activity, we have reached the following ten conclusions:

- One. ICTs and streams of information, communication and knowledge are the material basis for a process of radical economic change, which we call the "knowledge-based economy".
- Two. ICTs increase the allocation of observable knowledge, change tacit knowledge into observable knowledge and allow the economic agents to develop new skills within a context of the virtuous circle between production and the use of knowledge.
- Three. Observable and tacit knowledge commodities have the economic properties of a public good and experience, with a high level of externalities. Moreover, as knowledge becomes easier to transmit, the decreasing marginal usefulness of access (the congestion effect) and the barriers to release tend to grow.
- Four. The term "network externalities" is considered to mean the increase in value that a user of a technology/product/service obtains as the number of users of the same technology/product/service increases. There are three

large groups of network economies: 1) direct network economies, linked to the increase in the number of network users; 2) indirect network economies, linked to the standardisation of products and markets; and 3) learning network economies, linked to the expert knowledge which is generated on the network.

- Five. Contrary to some excessively-optimistic contributions, all network externalities can have positive and negative effects, depending on the dynamics of interaction established between their nodes, and between their nodes and the outside world.
- Six. The adoption/purchase curve of a technology/product/service in the presence of network externalities depends on how far a critical mass of users has been achieved. The sigmoidal form (S) of this curve covers three stages: launch, take-off and saturation, with a periodicity and intensity different from the adoption curve of a technology/product/service without network effects.
- Seven. Contrary to the traditional form, the demand curve of a technology/product/service under network effects is concave in shape (inverted U). The specificity of this demand curve is determined by the intrinsic value (value that it itself contributes), the marginal value (value contributed to other users of the network) and the relative size (size of the network in relation to the size of the market) of the technology/product/service being dealt with.
- Eight. Observable knowledge commodities are governed by the effect of the direct and indirect network externalities. Tacit knowledge commodities associate under the effect of learning network externalities.
- Nine. The demand curve of observable knowledge commodities builds their potential through new members joining the network (marginal value) and their large size. However, demand in tacit knowledge commodities is based on their high intrinsic value.
- Ten. The different form of the demand function in observable and tacit knowledge commodities also determines differentiated business strategies. For observable knowledge commodity businesses, the value is generated through the maximum number of users joining the network. For tacit knowledge commodity businesses, value is generated by the commodity itself being added to the network.

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