INFORMATION AND COMMUNICATION: STRATEGIES AND POLICIES FOR A SECTOR IN TRANSITION

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1 — A changing scene

Major structural changes have affected the information and communication technology (ICT) industry during the past two decades. These changes have encompassed technology, regulatory frameworks, market structures and industry output. The result of these profound changes is the transformation of this industry»s image from that of a protected sector offering a limited and often monopolistic service and operating in a stable and unchanging market structure, to an industry at the forefront of technological change, providing a host of different services and products, operating in a highly competitive market system and destined to transform societies and economic structures (Antonelli, 1991; Capello, 1994; OECD, 1988a and 1988b).

The significance of information and (tele)communication in a modern economy lies in its compatibility and «technological convergence» with advanced computing technologies, which has greatly expanded the economic potential of the ICT sector. By enabling computers to communicate over space (the «death of distance») and by enabling people to communicate through computers, the ICT emerging from this «technological convergence» lies at the heart of a compound set of technological and economic transformations conveyed by the general term «Information Economy» (Gillespie *et al.,* 1987; Jonscher, 1983; Porat, 1977; Williams and Gillespie, 1989).

The growing awareness of the changing role of information of (tele) communication in the economy raises a fundamental question about the reasons of these structural changes. Although technological dynamics are generally pinpointed as the major causes for modifications in the ICT sector, an analysis of this transformation process focusing only on the technological aspects would be misleading in trying to conceptualise the new characteristics of the ICT sector.

In this context, at least four factors can be regarded as prominent causes of the transformation of the ICT sector:

Technological dynamics — Although it is not the unique reason for change, the technological revolution is certainly playing an impor-

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tant role in the development trajectories of the ICT sector. A host of product innovations takes place, from digitalisation of switching and transmission equipments to a broad range of new services which offer high transportation possibilities of data, voice, text and images (section 2);

Institutional dynamics, changing the market structure from a mainly regulated market to a competitive market, imposing new «game rules», after decades of traditional static oligopoly (in manufacturing firms» market) and monopoly regimes (in the service market) (section 3);

Market dynamics, stemming from an increased awareness of users about the strategic importance of these new infrastructures, and stimulated through the customers' attempt to influence suppliers towards specific products and innovation, thus acting as «technological gatekeepers» (section 4);

New economic relationships characterising the information and (tele) communications «filière», representing the matrix of economic relationships among manufacturing firms, and between suppliers, operators and customers. The traditional oligopolistic rules which have historically governed manufacturing firms and their linkages with public operators have been substituted in the last decades for competitive rules, by low national protective barriers and by greater competitive threats from firms belonging to previous separated sectors (section 5).

After a sketch of the background factors which are of decisive importance for the development pace of the ICT sector, two important economic behavioural factors will be outlined, viz. the importance of *network externalities* in the ICT sector (which may explain an exponential growth in adoption) (section 6) and the strategic significance of the *timing of adoption of ICT technologies* in a competitive market (which may explain the phenomenon of forerunners and backrunners in technology adoption) (section 7). After this review of critical success factors, the paper seeks to pinpoint finally policy recommendations (section 8).

2 — Technological dynamics

It is undoubtedly true that a radical technological process is governing the ICT sector. This dynamics has some crucial and basic features which can be summarised as follows:

Pervasiveness to all countries and sectors;

Change in intersectoral barriers;
Specific national responses to modern technological development.

These elements will now concisely be described.

The technological changes taking place in the ICT sector encompass both the manufacturing and the service sectors, i. e., hardware and software. As regards the manufacturing sector, all three main branches of the equipment industry (switching, transmission and customer equipments) have been widely influenced by radical technological changes, increasing technological potentialities of products and new innovative output. In this field rather radical innovations are embodied in the transition from analogue to digital switching equipment, or from cables and wires to fibre-optics, or, more recently, from microwave systems to satellites (Monk, 1989). Even more evident is the host of radical innovations taking place in the service sector, offered on more advanced physical infrastructures and thus capable of transmitting text, voice, image and data.

In this regard, an important phenomenon is the *pervasiveness* related to the demand side. The diffusion of new information and communication technologies is taking place horizontally in all sectors of the economy, rendering a strategic importance to these technologies to pursue a better economic performance. Pervasiveness is also characterising the geographical diffusion of these technologies: both core and peripheral regions have an interest in developing these technologies. Peripheral regions are supposed to exploit information and capital and thus to need more strategic resources which are not equally distributed over space. By the same token, core areas are interested in infrastructural endowment, even more so if these infrastructures represent the strategic means towards comparative advantages.

Another characteristic of modern technological dynamics in the ICT sector is its ability to eliminate traditional inter-sectoral barriers, and opening up competition between previously separated sectors. The software component in new networks and services has risen to a high extent, legitimating informatics firms to enter the (tele)communication market. For traditional (tele)communications firms the threat from these new entrants was reinforced by two factors:

The lack of technical know-how required to produce new services with high software components;
The lack of managerial know-how to develop strategic corporate policies in highly competitive markets, originated by years of collusive oligopolistic rules that never stimulated aggressive market policies.

National responses to these recent challenges and changes have shown much variation reflecting in part differences in national market characteristics and also in market structure (monopolistic versus competitive markets). Technologi-

cal trajectories have thus followed national development patterns. These national differences have become crucial once countries have faced a liberalisation process of the sector, which has not prevented local industries from international competition. Internationalisation of the (tele)communication sector has in fact underlined national differences in the ICT industry's performance. The existing technological asymmetry in advanced networks and services among countries reflects at least different time trajectories of new investments rather than different intentions in investments (see also section 7).

3 — Institutional dynamics

In Europe, the EU has recognised the need to provide common rules to achieve equal institutional trajectories in the EU countries. For example, the EU proposal expressed in the Green Paper published in 1987, provides an intermediate model with regard to the two previous extreme models. In abstract terms, the *regulatory structure* is essentially based on the following two conflicting regulatory principles, viz. a *supply-led* approach governed by «universal service provision» and a *demand-led* approach governed by a differentiated development of key customers in value added, high growth markets. The EU has started the liberalisation process by adopting an intermediate position reflected by (see Camagni and Capello, 1989; Camagni *et al.,* 1993):

A competitive structure in customer equipments markets;
A competitive structure in advanced services markets;
A monopoly structure in basic networks (albeit with third party access).

Despite some advantages this model incorporated also some weaknesses:

The distinction between basic and advanced services is ambiguous, so that a protection of a basic service monopoly may hamper innovation;
The competition between private and public networks regarding value-added services leads to the problem of capacity re-sale from private companies.

In order to care for some of these shortcomings, the EU has in so-called «accompanying measures» added new guidelines to avoid distortion mechanisms:

An official list of basic network services to be offered under a protected regime, such as telephone, telex and data transmission;
A revision of tariff structures for private networks, which would be calculated on the basis of the volume of transported information — i. e., a tariff should be closer to costs and should not differ from one country to another;

An abolishment of cross-subsidy mechanisms between telecommunications and postal services, the second ones having always been heavily subsidised from the first ones, thus limiting financial resources available to be invested again in the public telecommunications domains.

The complex dilemma created by the two contrasting principles is witnessed by the fact that after many years of intense debate over the best market structure of the ICT sector only a few common agreements have been reached. But the regulatory movement has certainly induced many new initiatives which have affected the ICT sector in Europe mainly through two crucial elements, the first one represented by the *extreme national trajectories* of the liberalisation process — despite the EU efforts to ensure a new uniform process — and the second one by the *different timing* of the liberalisation process in different branches of the industry.

The existing differences in the national trajectories have become crucial, once liberalisation has been imposed in all countries and the specific innovative capacities of each single country is tested. Inevitably, firms which had to face competition for a longer period will have more advantages in terms of marketing policies than those used to operate in an oligopolistic market. Their privileged position stems from:

More consolidated market policies, based on their longer experience on the market and their longer contacts with customers;

More consolidated product innovation policies, based on greater technological, scientific and organisational know-how.

New strategic behaviours for these firms are in this respect a possible solution, i. e., the development of strategic agreements with more advanced international firms (see also Koski and Nijkamp, 1996). These corporate strategies have two important feedbacks:

To acquire technical, managerial and organisational know-how, destroyed during years of monopoly and oligopoly market structures, in a limited time period;

To maintain market shares, though divided with a previously selected partner, instead of risking to lose their market share.

Corporate external growth allows the decrease of technical and managerial gaps between advanced and backward firms, avoiding for the latter firms the negative effects from liberalised systems. An example of such negative effects of liberalisation on backward firms can be found in Great Britain, where British Telecom, faced by Mercury competition, changed its purchasing policies favouring Japanese and American technically more advanced customers premises

equipments, rather than national firms' products, thus destroying several British ICT manufacturing firms (Charles *et al.*, 1989).

Another asymmetry in the institutional process stems from the difference in the timing of liberalisation process in different industrial branches. This different timing in liberalisation helps in understanding the present corporate strategies put in place in different branches.

The customer premises equipments market has been the first sector governed by competitive rules, such as a high rate of product innovation and «price war». Cooperation agreements represent the best corporate strategies followed by these firms, especially by technologically backward firms, trying to obtain more advanced know-how, exchanging it with market shares.

Nowadays, even the traditional network service providers face competitive rules in their markets. National carriers, traditionally operating in a monopoly market structure, start facing competition in both traditional telecommunications services (the telephone service) and advanced services markets, e. g. cellular telephone markets.

The two cases are in some respect different. In the case of the traditional telephone service, competition stems in general from other European carriers: since 1st of July 1997 British Telecom has entered the Dutch market and since 1st january 1998, no national barriers exist for traditional carriers. Competition at a European level favours countries with stronger supply structure, created through years of extremely favourable telecommunications public policy. This is, for instance, the case of Great Britain, historically more oriented towards competition. The other extreme case is represented by Italy, which has always denied resources to develop strong national telecommunications supply, and has favoured other sectors of public policy.

In the case of the new mobile telephone service, competition is mostly national, with new firms entering the market. While in the first case national providers face competition in their traditional market areas by firms with a long-lasting experience in this market, in the second case both providers and competitors enter a service market niche for the first time, competing even in the creation of the necessary infrastructure networks. These competitors are in general firms traditionally belonging to other sectors, and in particular to the informatics sector, generally based on competitive rules. This element can turn out to be a strategic advantage for new firms with respect to traditional telecommunication carriers, which are used to operate under monopolistic market conditions.

4 — Market dynamics

Through the development and use of private networks, users have recently acquired a steadily growing awareness of the strategic relevance of these infra-

structures for their day-to-day activities, as is witnessed by the growing number of fax and PC users in the last decades. They have developed over time the capacities for using these new and technologically complicated communication systems and, moreover, the capacities of specifying their needs on the basis of previous applications, personal experiences and personal learning processes.

The consequence of this growing awareness of the strategic relevance of these infrastructures is represented by the *active role* the demand plays in the diffusion of these new technologies. Demand can facilitate the diffusion of these technologies through the development of the following incentives:

Learning processes of technical systems characteristics;
Learning processes of possible applications of these technologies to solve corporate strategy problems;
Learning processes of possible integration of new technologies in an existing organisational structure.

Moreover, through such learning processes some users can even become «technological gatekeepers», being able to choose appropriately among a multiplicity of innovations. Thus, a corporate strategy oriented towards bridging supply and demand turns out to be the most appropriate policy in periods of rapid technological changes.

Through this bridging, cross learning processes between supply and demand can be put in place, providing great advantages for both demand and supply. It is clear, in fact, that cross-learning processes can be crucial for suppliers to produce communications services and computer networks tailored to each adopters» needs, thus satisfying at the same time the demand communications needs and the supply market penetration necessity.

Such successful and efficient communications systems can easily become a reference model for initiative adoption processes, these processes forming the basis of rapid cumulative penetration rates of these technologies.

5 — New economic relationships

Both the technological and institutional changes underlying the telecommunications sector have raised considerably the level of competition in the last decade and this change had some deep supply implications.

The collapse of inter-sectoral barriers generated by technological changes has offered informatics firms the possibility to enter the telecommunications market, thereby providing technical know-how in the production of value-added services and switching equipment software.

In the sphere of value-added services, the high technical requirements concerning software have implicitly given a great possibility to enter the market.

However, value-added services represent a sphere of activity where both (tele)communications manufacturing firms and public operators have tittle to lose. For manufacturing firms, value-added services represent a relatively small business area, where they could easily provide hardware (i. e., customer services equipment) to support these services, but where manufacturing firms would less be interested in directly producing these services.

A different perspective characterises the public operator»s position. For public operators the entrance of informatics firms in the telecommunications market by providing value-added services leads to:

A direct competition, in the provision of the same value-added services on the network;

An indirect competition, through the common — though sometimes informal — phenomenon of capacity re-sale.

Against this background phenomenon common in most European countries, competition in customer premises equipments increases international competition among manufacturing firms operating in this market, with severe implications for the present supply structure. Some considerations are noteworthy here:

Firstly, a major threat for all European firms is not represented by European competition itself, but by American and Japanese firms legally entering the European market. These firms represent a high potential threat in terms of more advanced technical products and more ad-hoc marketing policies developed through years of experience in competitive markets (especially for the American case);

Secondly, even at a European level, competition will favour countries with a stronger supply structure, created through years of extremely favourable (tele)communications public policy. This is, for instance, the case in France, with a historically strong supporting public policy devoted to the creation of «national champions».

The effects of internationalisation of customer premises equipment are profound, once radial technological differences among products exist. For «weaker firms» this means the development of some appropriate policies in order to face competition and protect market shares. The most appropriate policies are concerned with cooperation agreements with foreign advanced firms, such as joint ventures and other equity agreements. In this way, weaker firms would achieve:

At one side, more advanced technological know-how in less time, imposed by radical institutional changes taking place in the sector;

At the other side, the protection of markets, shared with a partner chosen on the bases of some delineated and precise agreements.

Even in the liberalised provision of advanced services, some changes will take place. In this case, competition increases between firms belonging to previously separated sectors. While informatics firms are legitimated to offer their technical know-how in the provision of value-added services, with a high software component, traditional manufacturing firms are often excluded from the provision of these services because of the lack of technological know-ho required.

The most appropriate corporate strategies for both informatics and (tele)communications manufacturing firms are, once again, cooperation agreements, this time with the unique aim of achieving technical complementary assets.

6 — Implications of network externalities

The products and services offered by the ICT sector are largely based on network configurations and operations. Networks are systematically organised structures aiming to serve user demands and efficient operator's principles. A network in the ICT sector is critical in generating competitive advantages among firms and comparative advantages among regions. In this section we will focus on the concept of network externality as a driving force for a rapid penetration and adoption of new ICT services. This concept has been introduced by industrial economists as the main explanation for diffusion processes of interrelated technologies. The key idea at the basis of all studies dealing with network externalities is that the rate of growth in the demand for interrelated technologies is dependent on the number of subscribers or clients already using that specific technology (see for details also Capello and Nijkamp, 1998).

Since 1974, with Rohlf's paper on network externality, this concept has become the subject of many studies interpreting it as a fundamental and strategic issue in the diffusion of new technologies (Katz and Shapiro, 1985).

The term «network externality» stems from the well-known economic concept of externality. In economic theory an externality is said to exist when an external person to a transaction is directly affected (positively or negatively) by the events of the transaction. The concept of network externality is related to a simple but fundamental observation that the user-value of a network is highly dependent on the number of already existing subscribers or clients. This means that the choice for a potential user to become a member of the network is dependent upon the already existing number of subscribers or clients. This basis but crucial statement has strong implications not only for the development trajectories of new networks but also for some crucial elements such as tariff structure, network interconnections, standardisation processes, optimal dimensions of networks and inter-network competition. In other words, the existence of network externality has some far-reaching consequences for the actual operation and policy choices regarding networks. The notion of network externality is thus

essentially related to the value of the network, depending on the already existing number of subscribers. This (varying) benefit of a network for a client is thus different from the given cost of access to the network for the advantage which an individual receives and does not pay once he joins the network.

From this perspective, network externalities are the economic motive for the adoption of and entry to the network and are becoming the essential explanation for the diffusion of new interrelated technologies. Firms' decisions to join a new network depend primarily on the number of already existing subscribers in the network and not solely on the cost of purchasing the technology itself.

The ICT industry seems to offer the most appropriate context for studying network externalities and all economic consequences they provoke. The ICT system is, in fact, characterised by some strategic features, which can explain the existence of network externality, namely:

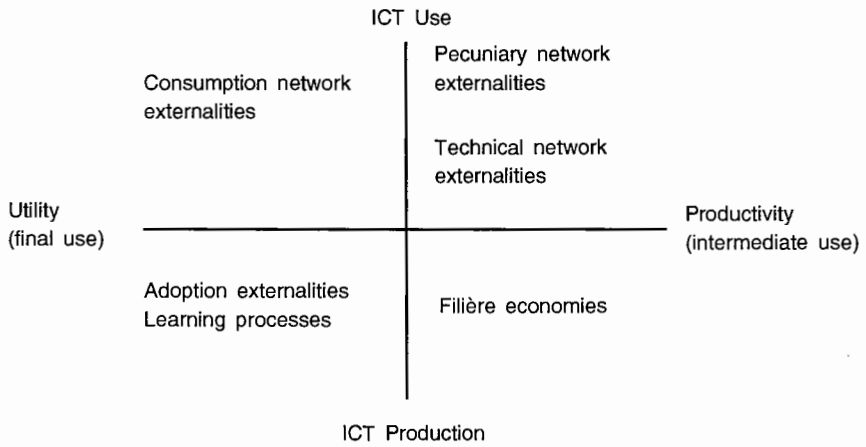
a) *Interdependence of consumer's utility*, since the choice of a person to joint the network is dependent on the behaviour of other clients;
b) *Interdependence between potential adopters and users of a new technology*, since the latter may create for the former a reduction of search costs and market prices for complementary inputs, maintenance and skills stemming from their experience in using the technology already adopted, through dynamic learning processes;
c) *Interdependence between potential users and suppliers* — on the one hand, the know-how and the experience accumulated by suppliers acts as a driving force in the adoption process. In fact, the adopting users are facilitated in the search for know-how and complementary inputs (i. e., organisational strategies) thanks to precise «guidelines» provided by the suppliers. On the other hand, the higher the number of adopters, the broader the know-how of the supply will be. In other words, the relationship between supply and demand generates cross-learning processes, via the bridging between demand needs and supply knowledge;
d) *Interdependence between producers of complementary technical components and products in the (tele)communication «filière»* — The interrelation of sub-markets may provoke externalities, since the profit function of a producer is influenced by the economic transactions of other producers whose behaviour affects the market prices of intermediary inputs;
e) *Interdependence between users' productivity*, since the advantages obtained by a firm on its productivity are dependent on the number of already networked firms. In fact, the advantages obtained through the use and exploitation of these technologies are a function of the number of firms already using them.

While the first three features affect the utility function of a final individual user, the last two act on the productivity of firms, the telecommunication service acting as an input factor in the production function. Moreover, there features are related to both telecommunication manufacturing firms and service providers (the telecommunication production sphere) and to the adopting firms using these technologies as final or intermediate products (the telecommunication use sphere).

Figure 1 presents a typology of network externalities on the basis of the previous ICT market features. In the top-left quadrant of figure 1, network externalities are related to the ICT adopters and are the typical *consumption network externalities* acting on the utility function of an individual final user. Here, the interdependence among utility functions of users of ICT networks is at the basis of the traditional network externality concept. ICT demand is more and more explained through interrelated decision making processes of adopters, a situation which influences the growth rate of the ICT market.

FIGURE 1

A typology of network externalities



Source: Capello, 1994.

A well-known example of consumption network externalities is the so-called hardware/software paradigm (Katz and Shapiro, 1985 and 1986), regarding the strong interdependent preferences dominating the choice of a consumer to buy a certain kind of hardware. In the words of Katz and Shapiro (1985:424): «An agent purchasing a personal computer will be concerned with the number of

other agents purchasing similar hardware, because the amount and variety of software which will be supplied for use with a given computer is likely to be an increasing function of the number of hardware units that have been sold.» Also in this case, the benefit that a consumer derives from the use of a good is an increasing function of the number and behaviour of other consumers, in this case the fact that they buy compatible items.

At the users side, another kind of network externalities is present, which is called in the literature *adoption externalities* (Antonelli, 1992). In the diffusion processes of these technologies a crucial role is also played by collective learning processes, like in all cases of complex technologies. Again, these processes seem to hide a sort of network externality mechanism, because of non-paid advantages that potential users of the technology gain from the experience of old adopters. For potential adopters, non-paid advantages may emerge from lower search costs of complementary inputs, or from specific know-how on how to use and maintain the technology, stemming from consolidated experience on the use of these technologies accumulated by previous adopters.

However, these features, recently interpreted as an externality mechanism (Antonelli, 1992), may be in reality only explained through the traditional concept of dynamic *learning processes*, similar for their effects, but different in nature from the traditional concept of network externalities. Learning processes stem in fact from the concept of dynamic economics of scale (Spence, 1981), while network externalities stem from the non-paid benefits obtained by interdependent mechanisms.

The same can be said for the case of ICT product firms acting on the utility function of ICT users through cross-learning processes (bottom-left quadrant). Again, users benefit from these learning processes, through dynamic economies of scale, which are different in nature from the concept of network externalities.

Network externalities in the ICT sector do not only affect the final user, by impacting on his utility function. In the ICT industry also the intermediate user (or supplier) acts under certain particular features (bottom-right quadrant).

As far as the ICT technologies production is concerned, ICT networks are built upon an array of interrelated technical components such as terminals, transmission facilities and switching equipments, as well as intermediate outputs in the extremely complex ICT *«filière»*. The interrelationship exists both in vertical relationships (intermediate inputs for ICT outputs) as well as in horizontal final products markets (advanced terminals whose development stimulates value-added services such as Minitel, and electronic mail).

In both horizontal and vertical interrelationships the behaviour on the market of each economic agent (reduction of prices, new market niches) affects positively the profits of the other interconnected producers. However, these kinds of advantages are typical «filière» economies, stemming from a vertical integration in a sector. In other words, these advantages may be associated with traditional

«economies of scale» generated in a vertically or horizontally strong market relationship (bottom-right quadrant in figure 1).

Another extremely appropriate example of these kinds of «filière» economies is presented by the hardware/software industry. Computers (hardware) and programs (software) have to be used together, and the greater the sales of hardware, the higher the profits for software producers will be via the technical interconnectivity of the two markets.

Finally, an interesting situation concerns the interdependence among productivity of different intermediate users. In this case, we can again speak of *network externalities*, this time related to the use of the service as an input factor for other products, thus having an impact on the productivity level of firms (top-right quadrant in figure 1). In this framework, both the concept of *pecuniary* (network) externalities (Scitovsky, 1954) and *technical* (network) externalities (Meade, 1954) may be useful. Pecuniary externalities are provoked whenever the profits of one producer are affected by the actions of other producers. In other words, pecuniary externalities act on input factors decreasing their costs and thus having positive effects on the output. This category differs from the «technological external economies» defined by Meade (1954) as those advantages obtained by a firm on its output through the non-paid exploitation of the output and input factors belonging to other firms. The latter category sees external economics as a peculiarity of the production function, i. e., these external economies act on input factors productivity. Through the increase in the input productivity these external economies influence positively the corporate output.

For ICT network users, the use of the network generates an increase in input productivity (or profit advantages), only partially covered by the costs of joining the network. The non-paid advantages obtained by a subscriber joining a network provoke unintended positive effects on the economic performance of the new subscriber. Thus, if network externalities represent the (economic) motive for entering the network, a better economic performance of firms is the (economic) effect they produce at the productivity side.

In recent years, the broad definition given to network externalities has expanded it towards network externalities in the production sphere (manufacturing firms and service providers), thus losing the precise meaning of the concept and substituting it for more traditional economic concepts.

While consumption network externalities in the context of the use of telecommunications (top-left quadrant), as well as adoption externalities (learning processes (bottom-left quadrant) and «filière» economies (bottom right quadrant) have been widely identified and analysed in the literature, a still unexplored field of study is the measurement of the effects of network externalities on the productivity side. The non-paid advantages of users joining a network are reflected in the performance of these subscribers via the reduction of input factor costs or the increase in their productivity. An empirical analysis of network externalities and the related impact on both the regional and firm's performance can be found in Capello (1994).

7 — Timing of adoption of ICT technologies

Much research has been undertaken on entrepreneurial innovation and adoption of new technologies (e. g., Bertuglia *et al.,* 1995), but far less attention has been given to the dynamics of innovation processes. This raises in particular an intriguing question on *optimal timing* of the adoption of a new technology. For example, the early adopter (a firm or a region) may run the risk to choose a technology which either may be considerably cheaper in the near future or may soon be obsolete due to a new superior technology. Thus, modern firms in a competitive market are faced with a great many uncertainties regarding investments in new communications technologies. This issue of timing of technology adoption in an uncertain business environment will be dealt with in the present section.

The ICT sector is not only facing *adoption uncertainty*, but involves two additional characteristics which further complicate the adoption decision by a potential user: *i*) irreversibility of ICT investments and *ii*) interdependence of users' benefits from ICT, i. e., the presence of network externalities. This means that there is always a risk that a potential user adopts the technology which may have superior characteristics in the initial stage, but may turn out to be an incompatible substitute in the future, so that he may then be stranded by later adopters.

The issue of the timing in ICT adoption is only scarcely investigated in the literature. There are however, some interesting contraptions. First, we may refer here to Farrell and Saloner (1986), who showed that the present network externalities may inefficiently hinder the adoption of innovations. They pointed out that the incompatibility of technologies with network externalities and the installed base may lead to excess inertia — i. e., to a too late adoption of innovation from the society»s point of view — even with complete information. Later on, Saloner and Shepard (1995) provided empirical evidence for the presence of network effects in the adoption of automated teller machines. Another major new contribution was offered by Choi (1994), who compared the private and social incentives for the users to wait before adopting an irreversible new technology with network externalities. Unlike Farrell and Saloner (1996), Choi incorporated in his two-period model for adopting a new technology the option of waiting. He concluded that firms tend to adopt new technologies too early compared to the social optimum in the presence of network externalities; in particular, the early users of a modern technology appear to embrace a new technology too soon compared to the social optimum.

The time of the adoption of a new technology is likely to be critically dependent on the type and order of magnitude of *adoption externalities*. Adoption externalities are related to the diffusion process of a new technology. They arise from the interdependence between potential users and the previous adopters of a new technology. The recent literature (e. g., Antonelli, 1992; Capello, 1994)

points at the interdependence between different generations of technology adopters, but does not contain a systematic presentation of the different types of adoption externalities and their effects on the timing of the adoption of a new technology.

We refer here in particular to Choi (1994), who considers two types of network externalities, viz. forward externalities and backward externalities, which are related to the adoption decision of a new technology characterised by network externalities. *Forward externality* means that the early adopters make their investment in a new technology too early from a collective economic point of view, since they overlook that the late adopters may take into account also the existence of network externalities in their decision making. The late adopters could have based their investment decision on better or more reliable information if the early adopters would have waited. In case of a too early adoption however, inferior technology may become widely adopted due to the existence of positive network externalities, even though the late adopters observe that the intrinsic value of adopted technology is lower than the one with a smaller installed base of users (a case of path dependency). *Backward externality* means that the late adopters do not take into account the early adopters' preferences, but may strand them inefficiently. Backward externality has just an adverse effect on a firm's technology adoption decision compared to a forward externality: backward externality — the fear of being stranded — prevents the technology adoption, so that its introduction will occur too late from a social point of view. Studies on forward and backward externalities can also be found in Farrell and Saloner (1986).

Furthermore, Kamien *et al.* (1992) use the interesting definitions of competitive-advantage externality and combined-profits externality in their study on firms» R&D investments. *Competitive-advantage externality* originated from the firm»s R&D investment which both tends to reduce the firm's unit costs and also spills over to its rivals. The rivals' unit costs decrease then as well; the firm»s R&D spending makes the rivals tougher competitors. Competitive-advantage externality thus hinders the firm's investments in R&D. Competitive-advantage externality may also be decisive for the firm's adoption decision of the new communication technology. The late adopters of technology benefit from the information spilled over from the early adopters. Later adoption enables a more proper comparison of communication technologies; the late adopter may get more information on the characteristics — like quality — of the different ICT systems. It is also possible that a firm may witness the development of different ICT networks (e. g., the size of installed base) or new firms adopting ICT in various forms. In addition, the late adopters may benefit by hiring workers who have already the ability to utilise the new technology.

Uncertainty is also likely to play a prominent role in the firm's adoption decision of ICT. Paradoxically, the new technology which is used for the reduction of the firm's uncertainty is also contaminated with uncertain aspects itself.

For this reason, it makes sense to investigate more systematically such uncertain aspects. Therefore, we will at the end of this section consider the types of uncertainty which may be related to the firm's ICT adoption decision. We will focus in particular on the relationship between network externalities and the uncertainty stemming from the new communication technology. The literature presents a number of potential sources of uncertainty related to a new technology:

Uncertain profitability of a new technology (e. g., Jensen, 1992); such a new ICT technology may involve:

Market uncertainty; uncertain price of information;
Technical uncertainty; uncertain productivity effects of a new technology;
Uncertain quality of information.

Uncertain arrival rate of future innovations or uncertain timing and significance of future improvement I technology (Weiss, 1994);
Strategic uncertainty; uncertainty of the rivals» decisions (Marner an McCardle, 1987);
Uncertainty on the other firm»s preferences concerning the new technology (Farrell and Saloner, 1985) or uncertain number of network users (Koski, 1995).

8 — Policy conclusions (1)

From a European perspective, appropriate ICT policies are oriented towards the following objectives:

The rapid diffusion of modern infrastructures and advanced services over time and space;
The minimisation of territorial (regional, national, international) asymmetries in the infrastructure endowment;
The minimisation of discontinuities, in terms of «missing networks»;
The exploitation of new infrastructures and applications for innovative uses, thus trying to achieve product and process innovations, and enhanced competitive advantages for firms, cities and regions;
The stimulation of competitive capacities of national suppliers.

(1) Though the paper is the result of a common research effort of the two authors, R. Capello has written sections 3, 4, 6, P. Nijkamp has written sections 1, 2, 7, while the remaining sections have been jointly written.

The previous arguments suggest that «appropriate policies» regard different areas of application. The first ad more general area is concerned with public policy, the second regards demand policy and, finally, the third one is related to appropriate corporate strategies of ICT suppliers.

8.1 — Public policy

The technological complexity and difficulty in the use of modern technologies suggest that the development of ICT technologies is a difficult process in which its diffusion over time and space requires «public policy» stimuli.
Public policy support should create a stimulus for those mechanisms that in diffusion processes generate accumulation rates through spin-off effects. Public policy should thus encourage computer networks development in areas with high potential demand density, i. e., central regions, where mechanisms such as network externalities could generate positive cumulative effects and, thus, where a critical mass could be achieved in shorter time.

Positive network externalities, in fact, arise because the total number of subscribers has an important effect on the user value of each additional subscriber, and each additional connection has important effects on the user-value of the network of existing subscribers. This mechanism is more efficient when applied in central areas, where the user-value of the network of subscribers is higher.

Related to this idea is the assumption that most economically developed areas are legitimated to be «networked» first, in order to develop a cumulative process. A top-down public policy is thus suitable, implementing «information highways» between metropolitan areas. A bottom-up development policy, focusing on network development in local areas, runs the risk to generate a development model with few possible inter-linkages among islands of «networkers» and thus presenting a high risk of failure because of its local characteristic.

A top-down approach is in this respect a more appropriate public policy to generate cumulative adoption processes. Nevertheless, to be efficient, these policies have to consider the geographical asymmetry in networks, which are created by following a top-down approach, only as a timing difference in investments among regions. These asymmetries must not turn into discontinuity, reflecting different investment intentions. In this case, in fact, discontinuity would become a structural difference between central and peripheral regions, the last ones being penalised by the lack of modern infrastructures, losing the possibility of achieving advantages typical of central locations, i. e., agglomeration economies, and thus the possibility of overcoming limits of a peripheral area.

8.2 — Demand policy

As already been said, the innovative use of advanced technologies provides major opportunities for users to achieve the highest economic benefits and advantages from these new technologies. However, the simple adoption of these technologies does not provide an immediate positive effect on corporate performances. The rather complex and relatively new technological possibilities embodied in computer networks have drastic implications for potential users, imposing profound changes on the organisational structure of a firm. Because of their capacity to support the transactional structure of a firm, these networks are inevitably able to reshape inter- and intra-corporate information flows with profound effects on the organisation. To achieve higher economic performances without the use of computer networks, corporate users have to adjust their organisational structure to the new «routines» and organisational rules (Nelson and Winter, 1982).

The development of modern networks is thus related to the capacity of firms to change their organisational routines, and to link the technological trajectories to organisational changes. It is very much the case that a high rigidity of attitudes and behaviour exists, which hampers an adjustment to new conditions and the exploitation of technologies to achieve higher economic performances. The best way for the demand to adopt these technologies rests on the assumption that technology and organisation are two intrinsically interwoven variables and that changes in one of the two inevitably provoke changes in the other. A trade-off exists between the speed of technological development, the profitability obtained by the exploitation of new and advanced technologies, the organisational costs required to sue them and the complexity of economic objectives achieved through the adoption of computer networks.

The complexity of technological systems reflects high economic objectives and requires profound organisational adjustments and changes to new technologies and a long penetration speed. Consequently, we can expect a lower speed of diffusion for technologies implied to achieve more complex objectives, such as higher efficiency and effectiveness and, moreover, competitive advances. These last objectives imply, in fact, a relevant capacity to use these systems to achieve innovative products and to adapt the organisation to new ICT technology.

The best way for users to handle the complex interrelation between technology and organisation is the development of *learning* processes regarding the following issues:

Technological potentialities of the new technologies;
Possible applications of these new technologies to solve corporate problems;
Possible integration of these technologies in the organisational structure.

These learning processes are the mechanisms to develop among users adoption processes of these new technologies, overcoming the rigidity of attitudes and behaviour associated with a transition phase, which hampers and adjustment to new conditions.

8.3 — **Supply policy**

Also at the supply level some policy considerations can be offered, in particular regarding two aspects:

Policies related to corporate strategies to enter the market, i. e., marketing policies;

Policies related to best corporate strategies to face increasing competition from other manufacturing ICT firms, from e. g., strategic market policies.

The need for a strong interaction between technology and organisation brings into focus the changing nature of computer network markets. The distinction between products and systems market is important for developing strategic policies by ICT suppliers. Product markets, i. e., traditional services and equipment markets, are relatively homogeneous and characterised by standardised and mass produced outputs and the achievement of economies of scale playing an important role in defining competitiveness of individual firms. Technological knowledge required to produce such output is linked to the traditional background of ICT producers and suppliers. Thus, competition can be based on traditional mass advertising and marketing policies designed to separate an individual producer's output from its competitors.

Regarding computer networks and their applications, the characteristics of their market are different from those of traditional (tele)communications product markets, thus obliging suppliers to put in place different competitive strategies. Because the adoption of computer networks is dependent upon an interaction of organisation and technology, the marketing strategies need to be tailored to individual users, so that these technologies are essentially customised products.

The adoption process becomes a «bricolage» process, where new technological possibilities meet the needs of users, generating larger markets for computer networks and their applications. This «bricolage» process can also be developed by manufacturing ICT suppliers without strategies of cooperation agreements with:

Some large organisational experts;

Some large firms users, strong in their learning processes;

Some experts in the field of software and integrated systems;

Some value-added resellers, or experts in telematics applications.

In this way, complementary technological, organisational and strategic know-how can be exploited and most appropriate marketing policies developed.

Finally, the interest in understanding and promoting the ICT sector and its diffusion over time and space stems from the important role this sector is increasingly playing in generating competitiveness of firms and comparative advantages for regions. In the so-called «information economy», new ICT strategies are the strategic means to achieve better economic performances for economic agents and all regions.

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