Knowledge and Information: The Diffusion of ICT in the Argentinean Manufacturing Industry[1]

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Abstract

The objective of this article is to contribute to the discussion about information and knowledge in the economy and society of Latin America focusing on the use and the diffusion of information and communication technologies (ICT) in the Argentinean manufacturing industry. The article relates the use and diffusion of ICT to the performance of the firms (their capacity to innovate, to organize creatively and to compete).

The paper has three central aims: (i) to present an empirical map of the use and the diffusion of these technologies in the manufacturing industry, (ii) to link that diffusion with improvements of the endogenous capacities of the firms and (iii) to make a contribution to the theoretical discussion about the links between the information and the knowledge economies. The central argument of the paper is that the incorporation and use of these technologies should be analyzed not in isolation but rather in the context of the capacities previously reached by the firms. The paper is based on a field survey of 246 manufacturing firms, undertaken between July and September, 2002. The firms surveyed are located in the Northern portion of Metropolitan Buenos Aires (206), in Córdoba (25), and in Rafaela (15).

The paper concludes with some inferences regarding the way in which Argentinean companies use ICT, not only to improve what they are already doing, but also to generate new knowledge and capabilities.

The relevance of the topic can be appreciated as follows. Firstly, because the paper sketches a descriptive map which was unavailable until now in Argentina. That is, the paper is based on a field survey which sheds light on a topic for which there was very little empirical information. The survey measures the effective diffusion of these technologies in the Argentinean manufacturing industry. Secondly, because the paper departs from the argument that the degree of diffusion and use of these technologies is a function of capacities acquired by firms in other areas through a long evolutionary path. Lastly, the paper lays the ground for a discussion about the role of ICT in firm learning.

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The paper has four sections. The first section discusses the relationship between information and knowledge and links that discussion to the diffusion of ICT and to the development of firm capacities. The second section presents the analytical dimensions and indicators used to measure both ICT diffusion and firms' capacities. The third one describes general characteristics of the firms surveyed and the degree of ICT diffusion among them. The fourth section presents a cluster analysis. In it firms are grouped according to their similarities in terms of the variables chosen along the two dimensions of analysis (ICT diffusion and firms' capacities).

The analysis undertaken in the paper leads us to the following conclusions. (i) That diffusion is greater in administrative rather than in production areas. (ii) That diffusion is strongly related to firm size but, at the same time, that the previous evolutionary path (measured in terms of capacities reached) matters. (iii) That in most cases the full potential of these technologies has not yet been exploited (for example with regards to internal learning processes).

The paper also presents some reflections with regards to policy.

(i) If ICT diffusion is not independent of internal firm capacities then policies should aim at a broad spectrum of issues and not treat ICT diffusion in isolation.

(ii) Despite large differences among firms with regards to ICT diffusion, they converge in a limited number of clusters which could now be characterized as stadiums in a continuum of situations.

(iii) That ICT diffusion is a complex and long process which requires a number of different policies if we are to increase it across the manufacturing spectrum.

Introduction

This article has the objective of contributing to the discussion on information and knowledge in the Latin America context through an empirical study of the use and diffusion of information and communication technologies of (ICTs) in the Argentinean manufacturing industry. The text is organized around two axes: the actual use and diffusion of ICTs and their linking with the general performance of the firm (innovation capacity, work organization, and competitiveness).

Departing both from strong transformations in terms of ICTs and from the changes they bring about into Latin American societies, a group of queries emerges. We will try to walk through those questions in this article. On one hand, what is the degree of diffusion reached by ICTs in Argentinean manufacturing, especially when ICTs are considered from a systemic perspective? Is a threshold of previous codified and tacit knowledge needed to access ICTs, or is it possible to sidestep stages? This leap, is an automatic process or does it require specific policies? Additionally, what is the link between the diffusion of ICTs and the development of firms' endogenous capacities? Can the development of ICTs be generalized in an economy and society without a previous organizational change and without structures that facilitate learning? Can these technologies diffuse equally among the different segments of the economy and society?

This paper provides empirical evidence to approach these questions from two perspectives. First, the article sketches a descriptive map of the diffusion of ICTs in Argentinean manufacturing from the results of a survey of 246 firms. Second, the results of this survey are used to make some inferences regarding the effective capacity of the firms to use ICTs in generating knowledge. The central argument of the paper in this respect is that the incorporation and the effective use of these technologies is a function of other capacities attained by the enterprises, and that the use and diffusion of ICTs cannot be gauged without taking into consideration the evolutionary path of the firm. This paper takes on the view that the efficient and optimizing incorporation of computer and communication technologies it is only possible in those firms that have developed some innovation capacities and show features of competitiveness. This vision is sustained in the fundamental difference that exists between information and knowledge; a difference that it cannot be settled with a mere incorporation of uncontextualized ICTs. In such a sense, with the new technologies it is relatively easy to reproduce information, even in significant magnitudes and in the most varied formats (alphanumeric, graphic, visual), but it is much more difficult to do so with knowledge, and in particular with tacit knowledge, since to transform it into information it is necessary to code it previously. However, knowledge cannot be throroughly coded and for it to be reproduced other vehicles such as experience, teaching and training must also be used.

To contribute to this debate, the article presents a discussion on the differences between information and knowledge, and connects this discussion with the diffusion of ICTs and with the development of firms´ endogenous capacities. Subsequently, the analytic dimensions taken into account to estimate the diffusion of ICTs and the development of firms' endogenous capacities are presented. After describing the general characteristics of the firms' surveyed and the degree of diffusion of ICTs among them, the results of a cluster analysis are presented. Cluster analysis allows the identification of distinct groups within the sample. Lastly, the main conclusions are posed.

1. Information and knowledge: the links between endogenous capacities and the diffusion of information and communication technologies

In recent years, both the economic literature as well as the printed media are plentiful on information about emerging paradigms of technological and social change. This information is organized around two dimensions: on one hand, the so called information or knowledge society and, on the other, the diffusion and generalization of new technologies of information and communication (ICTs). According to different authors "knowledge society" (Lugones et to the., 2003), "information society" (Castells, 1998), and "new economy" sometimes appear as similar, sometimes as different and, in occasions, as complementary.

Lundvall (2003), for example, accepts the idea of a new era as a work hypothesis and shares the basic assumption that the ample and most extensive use of ICTs represents a fundamental change in the economy and in society. However, he criticizes the concept of "the new economy" because it frames the problem from a simplistic vision since it leaves aside the neeed to make significant changes and institutional reforms that effectively promote learning processes.

Cimoli and Correa (2003) point out that the debate between information and knowledge has been going on for at least three decades, and it has taken bigger impetus with the arrival of the new technologies (Cimoli and Dosi, 1995; Dosi, 1998; Dosi, Orsenigo and Sylos Labini, 2002). This discussion presents two very defined positions, one that argues that almost all information is knowledge (Cowan et al. 2000), and thus, more information necessarily implies more knowledge, and another position which is much more cautious because it puts emphasis on the differences that exist between information and knowledge, describing the production of knowledge as a complex process that not necessarily responds to an increase in information (Johnson et at the 2002).

The latter perspective is fundamentally the one which has been winning credibility because it points out that knowledge is, mainly, a cognitive capacity associated to the strenght to interpret and to transform information. Information, on the other hand, is an array of data, structured and with a certain format but inert and inactive until it is interpreted by those that have the basic capacities to manipulate that data (Lugones et to the, 2003).

This differentiation and, at the same time, interaction between information and knowledge, doesn't close on itself, but rather, it must be incorporated to learning as a cooperating factor. As Rullani points out (2000), knowledge only maintains its value if it is regenerated and enlarged continously through learning and through the diverse transformations of the cognitive cycle stylized by Nonaka and Takeuchi (1999), where information and knowledge interact continously. This cycle begins with the socialization of tacit knowledge in specific contexts; its diffusion to other contexts, after a previous codification; the combination among diverse planes of coded knowledge so as to increase their complexity and, finally, the internalization (transformation of coded knowledge to specific) to the the organization that carries out, in this way, learning processes. In that sense, ICTs could be functional to the development of learning processes if they acquire certain complexity and, also, if they allow the accelleration of the phases of the cognitive cycle mentioned above.

That is to say, ICTs can only exert a significant effect on competitiveness if a previous or simultaneous tecno-organizational change took place; a change that allowed an optimum use of ICTs and that involved the definition of strategies and policies of technological management, the development of systems of work organization that would facilitate knowledge generation and circulation, and an organizational structure that would facilitate communication processes and learning. In that line, it could be said that ICTs have a double impact on the coding of knowledge. Although, on one hand, they facilitate coding, on the other. they require more tacit knowledge to make possible this transformation from tacit to coded (Lundvall, 2003). As a result, ICTs facilitate access to the information that can become competences if a minimum threshold of knowledge exists

in individuals, firms, local agents, and society. Thus, the potential of ICTs emerges in the context of systemic developments that need to integrate endogenous competences in diverse planes. Otherwise, ICTs are limited and reduced to vehicles for the sole circulation of information. The points outlined allow us to hipothetize that ICTs constitute a dependent variable of other factors, among which stand out the endogenous competences firms build along their evolutionary paths.

This interdependence observed in many developed countries in a relatively systemic form, would adopt a disarticulated character in most of Latin American countries due to the reduced importance of knowledge in the public debate (and in the allocation of public resources) and in the economic structure. Diverse works reflect that, contrary to the predominant scenario in the developed countries (Reinert, 1996, Lall, 2001; Dosi, Pavitt and Soete, 1990), in Latin America, in a context of a significat structural heterogeneity, prevail: (i) reduced levels of technological competences, (ii) weak presence of and depth of production networks, (iii) a not very complex specialization profile, (iv) a limited institutional development, and (v) an absence of systematic policies. In this framework, Latin American firms, in particular those of smaller relative size, are characterized by their reduced innovative capacities and endogenous competences (Bisang et al., 2002; Cimoli and Katz, 2001; Milesi, 2002; OECD, 1995; Yoguel and Rabetino, 2002), their tendencies to self-centering expressed in the limited participation in global nets and in virtuous territorial systems, and the isolated character--both of the competitive dimensions that they sometimes are able to reach, as well as of their efforts in training and consultancy. This situation worsens in the face of the extreme weakness of the public space and the strong presence of direct foreign investment whose processes of decisions and investment in I&D are developed in their head offices or they are, simply, extralocal in nature.

This structural heterogeneity accentuated in the 90´s due to strong differences in growth rates and worsening of existing (and schewed) income distributions (Cimoli and Correa, 2002; Pérez and Stumpo 2001). As a result, in Latin America the production structures generated tend to lack the key factor of the new technological paradigm (knowledge), and they can be characterized by their lack of complexity and their high vulnerability. As consequence of this set of shortcomings, the market fails in the selection of the most innovative behaviors and this limits the development of learning processes and the generation of dynamic competitive advantages.

Cimoli and Correa (2003) explain how some of the above mentioned characteristics condition the diffusion and systemic use of the ICTs in the region. In the first place, these technologies are highly correlated with income levels; with Latin American income worsening in the last ten years this would become a barrier to the potential access (Peirano and Bianco, 2002). In second place, the interpretation and decoding of information demands minimum thresholds of coded and tacit knowledge which, as it was pointed out previously, are not very frequent in the region.

Therefore, the idea of “an innovation economy” or of a “knowledge society” has limited purchase insofar as the structural conditions of Latin American economies are concerned. The possibility to generate a virtuous circuit between these technologies and the advance in knowledge requires deep tecno-organizational changes to take place in firms and institutions. Therefore, ICTs should not be viewed as autonomous factors that, just because of their presence, would guarantee the unfolding of processes of knowledge development or of development of competences. That vision would be similar - under a new robe - to that dismissed conceptualization of the decade of the 80s that sustained certain technological determinism, by associating electronic automation to social and productive development.

2. Analytic dimensions considered

As it was expressed previously, the incorporation of ICTs by the firms can be analyzed as a process dependent of the previous technological path. Therefore, a necessary condition so that the technologies of information and communication are functional to the development of firms competitive advantages is the existence of endogenous competences that can enhance the development of generation processes, circulation and appropriation of information associated to the diffusion of ICTs (Lundvall, 2003, Cimoli and Correa, 2003, among others).

In the perspective of the research completed, the dimension of ICTs use is viewed as the bundle of information and communication tools that are introduced in the firms with the objetive of circulating information both in administration as well as in the areas of production, at vertical and horizontal levels. Complementarily, the dimensions studied which are linked with the endogenous competences try to analyze the generation of knowledge and the learning possibility in those same enterprises. The main hypothesis of this work is that the diffusion of ICTs should be associated to the degree of development of endogenous competences. That is, that the use of ICTs (as a mechanism that facilitates the circulation of the information) is associated to the development of endogenous competences.

Thus, in this paper, besides evaluating the degree of diffusion of ICTs in the firms of the sample, we take into consideration other variables that analyze, in a proxy form, their technological behavior and endogenous competences. In this manner, the paper assesses the complexity of ICTS incorporated to the firms, in a way that enables to bypass a mere dichotomic count (of the type "has"/ "doesn't have") and, also, to establish a qualitative gradient to see in what measure the company is moving, first, toward the informatización of the existent processes and, second, towards the conscient use of most available information. The complexity of ICTs incorporated into the firms allows to make some inferences regarding the learning dynamics that are taking place inside the firms.

Therefore, for the analysis of the use of ICTs and for the identification of the possible circulation of information within firms, a series of indicators were defined. These include: equipment and computer infrastructure and communication (hardware), computer programs (software), the use and relevance of new communication tools as channels of internal and external linkages (in particular Internet, intranet and electronic mail)—and including their use for sales and procurement (e-commerce). For production activities, the complexity of the software and hardware used was evaluated in general, and the case of the software for design and for production planning and control was also assesed. Besides identifying the existence of these tools, the complexity of the diffusion of ICTs considers the proportion of the firm's personnel that interacts with these tools, the objectives with which they use them in terms of activities (general, innovation, quality, organization of the work and training) and the type of linkages taht these tools help to develop (commercial, institutional, etc). In particular, in the case of Internet the paper examines not only its use but whether the company developed a Web page and with what ends it uses it. On the other hand, with respect to intranet, the article takes into account which platform is used: whether it is internal to the firm or through Internet. Finally, an indicator is developed to evaluate the relevance of the electronic commerce.

To explore the endogenous competences of the firms, understood as the firms' potential to transform their generic knowledge in a specific one starting from initial competences and dynamic

accumulation that includes formal and informal learnings, both coded and tacit, diverse dimensions are included (Ernst and Lundvall 1997, Lall 1992, Yoguel and Boscherini 1996). On the one hand, are included the innovative capacity of the agents starting from the analysis of formal and informal efforts in research and development. In second place, we considered the efforts developed by the firms in quality assurance of both products and processes by taking into account the compliance of certified norms. Finally, the paper considers the pattern of work organization with regards to its influence in the possibilities of circulation of information and acquisition of tacit knowledge on the part of the workers to improve their competitions and to obtain results in development and quality. The work teams and the spaces of interaction, contrary to the individual assignment of positions, allow to exchange the experiences and opinions and potentiate the possibility to diffuse tacit knowledge among individuals, through observation, imitation and empirical experiences (Novick et al., 2002).

These three dimensions allow to evaluate the development and use of the competences of all the work force dedicated to production activities, quality and development. Therefore, workers' formal and informal training activities –at different levels and qualifications-- constitute another key element for the achievement of competitive advantages (Novick, 1999).

3. Main Results

3.1. The Diffusion Of Information and Communication Technologies in the Companies Surveyed

The panel surveyed is made up of 246 industrial firms located in the Buenos Aires Metropolitan Region, Córdoba and Rafaela, which were contacted between July and October of 2002. The median of occupation and sales of the firms was 49 people and 3 million dollars in the year 2001, respectively. The quotient average of sales by employee is of around 115.300 dollars of 2001 (although the median one is of 62.500), an amount similar to the Argentinean industrial average, if microenterprises are excluded. The distribution of firms by economic agents' typology is also similar to the Argentinean industrial structure. In this way, in the survey SMSEs prevail (69%), while the importance of very small firms (18%) and of large ones (13%) is more limited. Nineteen percent of the firms contacted are controlled in part or wholly by foreign capital. In sectoral terms, stands out the production of traditional goods (footwear, furniture, basic metalworks, etc., 44%) and, in smaller degree, that of goods of more technological complexity (23%), the one of those dedicated to the automotive complex (17%) and that of commodities (12%). Finally, 4% only produce durable goods, such as TV sets, laundry machines and the like.

The results of the survey indicate that the diffusion of ICTs in the companies included in the sample is important in quantitative terms, but significantly less so when it is evaluated from the perspective of the complexity of the software and of the systems used. Almost all of the firms of the sample invested in equipment and computer and communication systems between 1999 and 2001. The amounts involved in these investments where equivalent, on average, to 1,2% of the annual sales of each firm during the period.

However, most of the investments (78%) went to ICT tools for management and administration, in their majority of scarce complexity, and thus with a limited associated impact on the forms of managing, producing and exchanging. Despite this limited levels of complexity, the growing participation of ICTs, mainly in the firms' administrative areas, has confronted the firms with the need of generating a framework for the specific handling of these technologies.

It should be considered that along the 90´s a sustained incorporation of equipment took place, due to the opening of the Argentinean economy and a lowering of real exchange rates. However, this incorporation was not systemic. The proportions of local firms which have their own Web pages and declare to use electronic mail are even larger than those we find in developed countries. This shows that these instruments, in isolation, cannot be taken to be an indicator of competitiveness or of endogenous competences.

Most of the firms of the sample have acquired a wide array of equipments and systems in recent years. Thus, 87% of the firms have networks, in most of these cases LANs (75%) and a few WANs (15%); while more than the half have ISDN and/or ASDL connections that allow them a bigger speed and communication capacity. In the administration area, 78% of the firms have servers although in many cases these servers don't have database engines, which limits their use potential. The average age of the servers, as well as that of the PCs of the companies of the panel, is near three years.

With regards to the use of software, most of the firms have an unsophisticated demand, which is concentrated mainly in standard office automation systems (78%). On the contrary, more complex software systems such as group work (for differente kinds of information and knowledge circulation and exchange), decision-making support systems for middle-level managers, and other expert systems for top managers and CEOs are used by a significantly smaller proportion of firms (around 22%).

In the area of production, on the contrary, the presence of computer equipment and the use of specific software is considerably smaller that in administration. The more widely diffused equipment is the PLC (programmable logical control) present in 23% of the cases, followed by the CNC (computerized numerical control), robots, the CN (numeric control), the FAS (automatic system for assembling) and the FMC (flexible manufacturing cell). In most of the cases these equipments and systems operate in isolation, without being integrated through software with other areas of the company. Only in design an important diffusion of such systems is observed as CAD (computer aided design), CAE (computer aided engineering) and other systems are present in 50% of the cases. The use of ICTs is smaller in activities of planning and control (MRP –materials requirement planning, MRP II , CAPP –computer aided planning processes - and other systems) and they are practically absent in the phases of production (only 4% of the firms use some software of CAM type, or computer assisted manufacturing).

On the other hand, the new communication tools are widely diffused, although their actual use or the objectives that lead to their incorporation limit, in many cases, their potential impact. In this sense, though 54% of the interviewed firms possess Web page, in most of the cases its actual use or the rationale that lead to its incorporation is not a very complex one (such as to offer institutional information, to disseminate products information, and to have presence in the Web).

Also, 96% of the companies have an institutional electronic mail address and, in 37% of the cases, more than 75% of the employees of the administration area possess e-mail. The presence of Intranet is also observed in a considerable number of firms (60%) although in two thirds of the cases these networks cannot be accessed via Internet and this limits its potential as a channel for relating to suppliers and clients.

In this framework, the relevance of these tools in connecting with suppliers and clients is important but uneven. The means more widely used is electronic mail, but telephone and personal visits retain places of importance demonstrating that personal contacts and face to face encounters are neither

easily nor completely replaceable by these new technologies. Intranet and Internet appear as less relevant in that they are still barely used in these connections; they appear in a level similar level to that of traditional mail--which has lost great part of its former importance. In the relationships of the firms with institutions (such as technological centers, trade associations, consultants, universities, and other institutions), a similar pattern is observed.

Finally, electronic commerce is moderately diffused in the firms of the panel: 5% carry out purchases and electronic sales, 10% only carry out purchases and other 14% only carry out sales. On the whole, 30% of the panel carries out some type of purchase or electronic sale. In the remaining 70% of the firms -that doesn't trade electronically -, 42% doesn't know either the possibilities, nor the way it operates, nor the basic regulations governing electronic trade. Other information collected in the survey complements these findings: more than half of the firms (54%) would not be willing to use this tool in the future, while 16% would only be willing to use e-commerce to buy, another 10% only to sell, and the remaining 20% to buy and to sell.

Summing up the empirical evidence discussed so far and connecting this evidence with some general aspects we discussed at the beginning of the paper, the process of incorporating ICTs in Argentinean manufacturing may be characterized as follows: i) from a quantitative point of view, the incorporation of these technologies can be considered important; ii) their presence is much more widespread in administration than in production; iii) most ICTs incorporated in the firms are relatively little sophisticated both in their intrinsic value and in their actual use and application; iv) a corolary to this last point is that the diffusion of ICTs appears to be closer to a simple administration and circulation of information than to a process that facilitates the generation and circulation of knowledge that are necessary for the improvement of firms' competences.

However, these general characteristics can be observed in the framework of a significant heterogeneity that should be kept in mind in order to enrich the discussion and to allow the introduction of the nuances that undoubtedly presents this new phenomenon. In this regard, in the next section the paper presents the results of a cluster analysis that identifies and sketches the main types of behaviors developed by the firms of the panel with regards to ICTs and the development of endogenous competences.

3.2. Cluster Analysis

Using a multivariate exploratory technique –Multiple Correspondence Factor Analysis (MCFA)–, homogenous groups (clusters) were formed taking into account various characteristics of the sample firms, associated with ICT-diffusion and the development of endogenous capabilities. By applying MCFA, all existing relationships between the variables included in the data matrix may be analyzed, the output being a set of categorical classes where individuals have a high intra-group homogeneity and also a high extra-group heterogeneity. The method offers the possibility of representing data in a lower-dimensional space retaining all, or almost all, of the information about differences i.e., determining factorial axes that concentrate information upon most relevant variables grouped according to the proximity of their attributes, thus offering a less cumbersome view of the information involved. (Roitter, 1991 and Crivisqui, 1993).

The output of MCFA was then submitted to Cluster Analysis, and different groups were constructed, each including "non-distant" individuals, "non-distant" meaning in this case "close" in

terms of the corresponding Euclidean distances computed from their coordinates to all factorial axes[3].

From two different statistical exercices carried out with this method, a gradient of situations was identified for each analytical dimension considered in this work. Thus, homogenous groups were identified which were different from other groups regarding: i) the degree of ICT-diffusion (presence and sophistication) and ii) the level attained in the development of endogenous capabilities. These two dimensions were later analyzed so as to determine their inter-relationship. The analysis was applied to the above-mentioned indicators which allow a simultaneous quantitative and qualitative estimation. In both cases –ICT-diffusion and development of endogenous capabilities– indicators reflect not only the presence of a certain attribute, but also its degree of complexity and its potential contribution to knowledge. Lastly, both aspects were combined for the final assessment of the hypothesis.

In the ICT-diffusion cluster, two groups were obtained with the following characteristics:

1. *High ICT-diffusion*: it includes 28% of the panel. Firms in this group are characterized by the vigorous presence and high integration of most information and communications tools under consideration. Firms having sophisticated management software prevail, although the percentage of firms having sophisticated production software is also significant. The inclusion of computer tools follows a systemic rationale, tending to embrace all business areas. Internet, intranets and e-mail are used extensively.
2. *Limited ICT-diffusion*: this group includes 36% of the firms surveyed and its characteristics are almost the opposite. In terms of the attributes under consideration, they have a relatively lower complexity level. Firstly, the relevance of intranets, e-mail, e-commerce and Internet is low[4]. Secondly, most firms do not possess a server of their own and do not use networks. Besides, basic software prevails in management, and new ICT-based tools are rare in production.
3. *Medium-level of ICT-diffusion*: this group includes the remaining 36% of the firms surveyed, and is not as homogenous as the two former groups. As regards some of its traits, it is similar to the high-diffusion group, whereas it resembles the low-diffusion group considering other characteristics. Among its main features, the following may be highlighted: lack of software/hardware in the production area of most companies, prevalence of basic software in management, presence of servers and networks in most firms, and a very high use of e-mail together with an almost absolute absence of intranets.

A similar statistical exercise was performed on endogenous capabilities, and three clusters were formed, according to their degree of development.

1. *High development of endogenous capabilites*: this group includes 38% of the firms in the panel, where highly-qualified human resources prevail. Outstanding endogenous capabilities are: a significant presence of quality systems implemented throughout the whole production chain and clearly perceptible in process and product standardization, in the relevance of (highly autonomous) cells in work organization[5], and in medium/high training efforts. A significant proportion ot these firms carry out research and development activities in formal and/or informal teams involving full- or part-time personnel. Finally, in 55% of the cases included, "new" products account for a significant percentage of total sales.

[3] For a proper interpretation of results, the following should be taken into account: the "similarity" of the variables associated with a certain group indicates that individuals possessing that characteristic are (significantly) more represented in that group than in the sample as a whole, which –needless to say– does not necessarily mean that all firms included in that group have the characteristic in question.

[4] 93% of the firms included in this group either do not have intranets or, if they do, only 25% of the employees use them. Internet is used by less than 25% of the personnel in a similar percentage of these companies. In 80% of the firms, e-mail is used by less than half the total payroll.

[5] In 76% of the cases, workers sometimes at least participate in programming or re-programming automated machinery.

2. *Limited development of endogenous capabilities*: this group includes 41% of the firms in the panel; the average qualification of human resources is low. Prevailing characteristics in the group are: lack of quality assurance systems and R&D teams. As regards the management of human resources, work is organized by assigning jobs individually, and training activities are scarce or non-existent. The introduction of new products is hardly ever observed.
3. *Intermediate development of endogenous capabilities*: this group includes 20% of the firms surveyed. As in the corresponding ICT-diffusion cluster, this group is less homogeneous than the two former ones. 40% of the firms have quality assurance systems but, where R&D activities were identified, they were carried out by part-time personnel despite the significant weight of new products in turnover. With respect to human resources management, cellular organization is widespread in the group but cells are scarcely autonomous and, therefore, learning processes are limited. Besides, in half the cases human resources receive no training at all. Nevertheless, the presence of highly qualified personnel in many firms clearly differentiates this cluster from that of lesser endogenous capabilities.

3.3. Joint Analysis

Starting from the two groups of clusters thus constructed, a joint analysis was performed so as to assess different kinds of circumstances shown in Tables 1 and 2[6]. The central hypothesis of this work posits a strong correlation between the endogenous capabilities developed by the firms and the level of diffusion of information and communications technologies[7]. As may be noticed, in the low ICT-diffusion cluster, firms having scarce capabilities are over-represented and firms with high capabilities are sub-represented. Just the opposite is the case of the high ICT-diffusion cluster, where firms having low endogenous capabilities are sub-represented and firms with high capabilites are over-represented. Finally, only 24% of the firms with medium ICT-diffusion belong to the cluster of medium endogenous capabilities. In this group of firms, covering approximately half of the panel surveyed, the hypothesis of a systemic association between endogenous capabilities and ICTs-difussion is certainly verified[8].
However, there are two remarkable hybrid cases where this hypothesis is not verified: i) in 28% of the firms, endogenous capabilities are higher than the level achieved in ICT-diffusion whereas ii) in the remaining 26% the opposite situation occurs (Table 2)[9].

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[6] In exploring the relationship between two categorical variables, the Chi-square test is used to contrast the significance of the association between them. Besides, the Z-test is used to contrast differences in proportions between each pair of variable attributes. The Z-test compares the contribution to Chi-square of each categorical pair: the association is considered as significant (over or sub-representation) when the corresponding test has a 10% significance level.

[7] Since the value of Pearson's Chi-square test is 25, the hypothesis of lack of association between the variables may be rejected with a 1 % significance level.

[8] In order to test the hypothesis that ICTs-diffussion depends on the development of endogenous capabilities, a linear regression analysis between both variables was performed including firm size as an additional independent variable. For estimation purposes, data from the 246 firms surveyed were included in the model through a numerical index obtained by adding up, on the one hand, ICT-related categorical values and, on the other, categorical values related with the endogenous capabilities. Besides, the amount of firm sales in 2001 was used as a proxy for firm sizes. As may be seen in the Appendix, Table 7, a positive correlation between endogenous capabilities and ICTs might exist, as well as a correlation between size and ICT-diffusion. Similar results were obtained by using an ordered Probit regression model where the independent variable is the ICT-diffusion level. However, the analysis above prevents exploring what is *behind* the estimated coefficients, i.e., the variance of ICT-diffusion. Therefore, a non-parametric analysis was favored for examining extant information.

[9] Should only these cases be considered for estimating the regression model suggested in the previous footnote, the endogenous capabilities variable is no longer significant to account for ICT-diffusion behaviors. Consequently, qualitative analysis is still the most relevant analytical tool for these groups.

Table 1. Distribution of ICT-diffusion clusters according to endogenous capabilities (Percentages of the total number of firms in each diffusion cluster)

ICT- diffusion	Development of Endogenous Capabilities ***			Total
	Low	Medium	High	
Limited	59**	18	23**	100
Medium	42	24	34	100
High	21**	17	62**	100
Total	42	20	38	100

***: Chi-square test significant at 1%; **: Z-test significant at 1% (see note 18)
Source: Author's elaboration based on the ICTs' Use and Diffusion Survey in the Argentine Manufacturing Industry IDEI-ICO (UNGS)

Table 2. Firm-distribution according to ICT-diffussion and endogenous capabilities clusters (percentages of the total number of firms)

ICT-diffusion	Development of Endogenous Capabilities			Total
	Low	Medium	High	
Limited	21	7	8	36
Medium	15	8	13	36
High	6	5	17	28
Total	42	20	38	100

Source: Author's elaboration based on the ICTs' Use and Diffusion Survey in the Argentine Manufacturing Industry IDEI-ICO (UNGS)

By combining achieved endogenous capabilities and ICT-diffusion, then, four groups may be identified[10]: 1) high endogenous capabilities and high ICT-diffusion; 2) low endogenous capabilities and limited ICT-diffusion; 3) endogenous capabilities higher than ICT-diffusion; 4) endogenous capabilities lower than ICT-diffusion.

1. High endogenous capabilities and high ICT-diffusion (17 % of the panel)
Firms included in this group show most attributes characteristic of "virtuous" clusters having high endogenous capabilities and high ICT-diffusion levels. In this sense, they differ clearly from intermediate cases (numbered 3 and 4 in the previous list) as regards attributes associated with information and communications technologies, and also with endogenous capabilities. With respect to ICTs, these firms differ from the rest because they use sophisticated software both in management (decision-making support for intermediate and managerial levels) and production areas, and also because of the relevance they assign to their staff's ICT training (see Table 8, Statistical Appendix). Considering besides the high level of their endogenous capabilities, it may be argued that ICT-diffusion may be a positive contribution at some stages of knowledge metabolism, such as the transformation of tacit knowledge into information or the blending of information from various sources into new tacit and codified knowledge. In other words, this group's high endogenous capabilities may reflect learning processes involving rather sophisticated codified and tacit knowledge. Besides, the degree of development of ICTs might favor connections between different areas and groups within the firm and thus contribute to disseminate knowledge in general and to codify tacit knowledge generated at the work-site.
In this group, there is a high relative proportion –both in terms of sales and number of employees– of medium- and large-sized firms with a significant foreign capital share. From the sectoral

[10] This analysis does not take into account the 8% of firms having an intermediate level of ICT-diffusion and medium endogenous capabilities.

viewpoint, the group might be characterized as remarkably specialized since 65% of its firms are concentrated into five sectors (chemicals; auto parts; rubber and plastic products; machinery; electric appliances, and medical and measurement instruments).
Most companies in this group are characterized by a significant degree of openness evidenced in high export ratios and the importance of inputs importation (see Table 8, Statistical Appendix). Finally, and regarding market dynamism, the group is characterized by a significant relative weight of firms whose sales increased during the 90's.

2. Low endogenous capabilities and limited ICT-diffusion (21%)
Firms included in this group summarize the prevailing traits in clusters of limited endogenous capabilities and scarce ICT-diffusion. In short, neither learning processes nor the information received and processed seem to be relevant. Regarding ICT-diffusion, these firms are characterized by the use of basic office software and their lack of sophisticated software in production. With respect to the endogenous capabilities achieved heretofore, most ot them neither have certified quality assurance systems, nor R&D teams. Besides, their efforts in personnel training are scarce, and their employees have a low average qualification.
In this case, limited endogenous capabilities suggest weak learning processes which, added to scarce ICT-diffusion, may involve that extant tacit knowledge is hardly codified.
Firms of national capital origin prevail, which are small both in terms of sales and number of employees. Their export ratios are also very low as well as the proportion of inputs importation in their purchases. Almost two thirds of them had negative performances in the 90's, with a still worse impact on employment. From the sectoral point of view, they are less specialized, and firms with a sophistication level lower than the previous group prevail (rubber and plastic products, auto parts, metal products, food, and furniture).

3. Endogenous capabilities higher than ICT-diffusion (28% of the panel)

Most firms in this group are in a stage of their technological path where ICT-diffusion is still not very high though they have medium or high endogenous capabilities. Even though the group does not significantly differ from the more virtuous one as regards endogenous capabilities, some attributes correspond to a lower category, such as a lesser relevance of quality assurance systems and a lower relative weight of training.
Given the definition of this group, it is interesting to examine further the various attributes associated with ICT-diffusion that entailed firm categorization in a lower level group, as compared to the more virtuous one. The following characteristics should be noted: first, their lesser degree of development is not restricted to a particular area (e.g., management, production, or communications) but it involves a rather generalized backwardness in such technologies.
As regards management, this group differs from the first one in the scarce sophistication of its software and equipment[11], a more limited use of servers, and the lesser importance they attach to training in ICTs.

Similar trends may be noticed in manufacturing, where the limited use of these tools is compounded with their low degree of sophistication and a lack of integration to the firm as a whole. Thus, the number of people interacting between various areas is significantly lower than in the first group. Hence, sinergy is more limited and learning not so fruitful.
Finally, concerning their differential characteristics as regards ICT-use for communication purposes, the scarce importance they attach to the use of Internet, intranets, and e-mail should be highlighted (see Table 8, Statistical Appendix).

[11] Basic office software prevails almost exclusively, resembling this group to the least virtuous in the panel.

Considering size, small companies prevail[12], and as regards the sectors involved, the following stand out in decreasing order: auto parts, metal products, machinery and equipment, rubber products and chemicals, which aggregatedly account for 67% of the firms in the group.
In this case, the relatively high development of endogenous capabilities is evidenced by the generation and dissemination of codified and tacit knowledge of a certain relevance. However, the weaknesses detected in ICT development curtail the possibility of its further diffusion.

4. Endogenous capabilities lower than ICT-diffusion (26% of the panel)

This group is placed in the lower level since the endogenous capabilities of the firms included in it are lower than ICT-diffusion. As previously mentioned, the fact that these companies have succeeded in introducing these new technologies –lacking even a previous base– justifies their relative position on a step higher than firms with low endogenous capabilities and low ICT-diffusion. As compared with this latter group, they show better performance both in the domestic and the foreign markets and possess a higher level of ICT-diffusion than the remaining groups, except the first one. This is generally evidenced by a greater presence of servers with database engines, interconnected networks, ICT training, a high relevance of Internet, e-mail, and intranets, sophisticated management software, design software in production integrated to other areas, and –to a lesser degree– by their use of integrated planning and control software. However, it should be noted that they differ substantially from the first group concerning these latter key factors for defining the sophistication of ICT-diffusion.
From the point of view of endogenous capabilities, this group may be placed above group 2 and below the two remaining groups (see Table 8, Statistical Appendix).
Therefore, considering their low endogenous capabilities, the generation of codified and tacit knowledge is scarcely relevant. Thus, the higher relevance of ICTs is curtailed by the above-mentioned defficiencies even though, potentially, it might enable a greater interconnection between different areas and better knowledge dissemination.
Among structural traits that significantly differentiate this group from the weakest one, the following is worth noticing: their higher relative size, since medium and large firms prevail in the group. Additionally, the group shows the widest sectoral diversification: among the main five sectors, chemicals, electrical applicances and machines, machinery and equipment, auto parts and printing are the most relevant. Structural heterogeneity explains why in this group endogenous capabilities are lower than what may be expected according to firm sizes and sectoral considerations.

Conclusions

In this paper we have presented a characterization of the use and diffusion of ICTs in Argentinean manufacturing based. The article centers on two objectives: (i) to present an empirical map of the use and diffusion of these technologies in manufacturing, and (ii) to connect that diffusion with the development of firms' endogenous capacities.

The article shows that ICTs are widely spread in the Argentinean manufacturing industry and that the majority of the firms have made significant investments in these technologies during a period (such as the 1990s) when hardware and software costs were relatively low with respect to other inputs. However, both the diffusion of these technologies as well as their applications show limitations which may be summarized as follows. In general, the diffusion is greater in administrative as opposed to production areas. In both areas, we tend to find that, at the same time, the ICTs actually incorporated are relatively unsophisticated and are applied to simple uses.

[12] Their annual turnover in 2001 was approximately 3 million dollars and the number of employees did not exceed 50.

The empirical evidence we have gathered shows that inside the firms surveyed the incorporation process is incomplete and uneven and that the majority of the firms are far from computerizing most of their processes and are also a long way from integrating through digital devices different areas of the organization (production, marketing, procurement, among others). In their relations with other firms and institutions the incorporation process of ICTs is even more incipient. Thus, for example, although a large proportion of the firms have Web pages, only a few have made electronic sales or relate to their suppliers through them. The paper has not found evidence of more complex uses of these technologies, such as the construction of networks among SMSEs for the interchange of information or for local or sector-specific cooperation. Neither are there evidences to believe that the incorporation of ICTs has provoked substantial changes in the way production is organized (be it inside the plant o among different establishments owned by the firm and where different processes take place).

These general characteristics, however, manifest themselves with a high degree of heterogeneity. This variability in ICTs diffusion and in the development of endogenous capacities was captured and systematized using cluster analysis. As we connected the firms classified with respect to their endogenous capacities and the diffusion of ICTs we found a high degree of overlap between these two dimensions. Thus, a little less than 50% of the firms are placed in the extreme groups of both classifications (i.e. high endogenous competencies and high diffusion of ICTs; low endogenous competencies and low diffusion of ICTs). The differences between these extreme groups are very significant in each of the indicators analyzed. While 60% of the firms of the first group train their employees in the use of computers, only 6% of the second do the same. Similar percentages were registered in the case of the use of complex software management tools: 65% against 4%. These indicators reveal striking differences between firms placed in both extremes of the sample of firms surveyed.

Thus, in the firms contacted there is a strong and direct relationship between endogenous competencies and diffusion of ICTs. At the same time, however, these same data reveal that the incorporation of ICTs and their applications is not only a consequence of the endogenous capacities attained although these capacities are a powerful predictor of ICTs diffusion. The size of the firms is also a relevant variable which speaks of the existing indivisibilities in the acquisition of software and hardware.

Clearly, the more interesting cases are those which belong to the two intermediate groups where the working hypothesis is rejected: high/ low endogenous competencies and reduced/ high diffusion of ICTs. The two in-between groups show very clearly something already highlighted in existing works, that is the uneven rhythm shown by firms in their incorporation of digital tools. The existence of these two groups inside the sample suggests that the incorporation of ICTs may “lag” or “lead” with respect to the path already taken by the firms with respect to the capacities to use and take full advantage of these new technologies. We may then appreciate, inside the firms, unbalances which may either be the ballast or the new engine in the firm’s trajectory. It is possible to envision that the firms with more endogenous competencies than ICTs incorporation, could profit from these competencies though a more systemic incorporation of these technologies.

To sum up, the process of incorporation of these technologies is unbalanced and uneven in a number of ways: inside the firms (for example, between production and administration), among firms, and among sectors. The diffusion process has advanced over the axes that seem to offer less resistance, linked to such things as firm size and the competencies acquired though time. The data gathered in the survey allow us to infer that, in most cases, the greatest potential of ICTs (such as

the possibilities they offer to boost internal learning processes) is only realized in a very incipient and limited way.

In order with this line of arguments, it seems appropriate to contrast the previous conclusions with the recommendations of some international experts in the process of making digital all processes within manufacturing and service firms. Despite some unreal visions formulated in the past with respect to the immediate potential of these technologies, many of these experts are much more cautious in their recommendations. They point out that the incorporation of ICTs in all organizations should be guided by a joint reflection that involves, at the same time, firms' business strategies AND the incorporation of these technologies. The degree of digitalization of a firm should not be assessed in isolation but rather it should be analyzed within its business strategy (Slywotzky and Morrison 2000).

Some of the literature that reflects about actual experiences of ICTs diffusion provides interesting elements for the issues discussed in this paper. On the one hand, that ICTs incorporation is a process that faces a number of resistances within firms and in the interface of suppliers and clients. These resistances include the difficulties of communication between ICTs experts and those who manage diverse areas of a firm, the fear to change and the unknown, and the difficulties to choose among technologies. On top of this we should add the difficulty to find digital solutions to improve manufacturing processes –which tend to be less generic than those developed for administrative uses and purposes. The full incorporation of these technologies requires a time frame and a time sequence that is dependent on the evolutionary path of each firm (Slywotzky and Morrison 2000; Windrum and de Berranger 2002).

Lastly, the data and analysis presented let us identify a number of points which are useful for policy design. First, the systemic incorporation of ICTs cannot be thought as a process which is independent from the development of firms' endogenous competencies. Second, we should take into account that the Argentinean manufacturing sector, as well as the region's is made up of very diverse organizations that have very dissimilar chances of incorporating ICTs in their internal processes and in their links with suppliers and clients. In this sense, the identification of four groups through cluster analysis highlights the existence of a limited number of stadiums or types of ICTs diffusion, and this could be taken as a guide for the purposeful incorporation of these technologies in Argentinean manufacturing. Third, that the policies oriented to foster ICTs incorporation in firms and organizations should depart from the acknowledgement that this incorporation is something more than the mere addition of an entry in the balance accounts. Therefore, it does not seem reasonable to propose isolated policies that do not take into account the diffusion of these technologies and an effective exploitation of them as something complex and relatively slow to undertake.

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STATISTICAL APPENDIX

I. Characteristics and distribution of computer equipment

Table 1: General infrastructure and ICT equipment used in management

Infrastructure and equipment	Firms (%)
Networks	87%
LAN	75%
WAN	15%
ISDN / ASDL lines	56%
Servers	78%
Database driven servers	41%
Networked printers	79%
Shared scanners	31%
Shared plotters	13%
Shared disks	68%

Table 2: Software used by firms

Kind of software	Firms (%)
Management software	
Standard software systems	78%
Sophisticated software (CASE tools, Cube	22%

tools, Datawarehose)	
Production software	
Manufacturing software	4%
Planning and control software	30%
Design software	50%

Table 3: Computer equipment used in production

Equipment	Firms (%)
PLC	23%
CNC	11%
Robots	8%
Numerical control	6%
Assembly system	4%
FMC (Flexible Manufacturing Cell)	2%

Table 4: New communications tools used by firms

Tool	Firms (%)
Web page	54%
Internet access	96%
75% of the staff have Internet access	18%
E-Mail	96%
75% of the staff have personal e-mail accounts	37%
Intranet	57%
75% of the staff have Intranet access	28%

Table 5: Kind of links with other firms and institutions

Medium	Firms (%)		
	Total	With other firms	With institutions
E-mail	95%	93%	80%
Phone	90%	87%	74%
Personal calls	46%	38%	36%
Internet	24%	22%	16%
Intranet	13%	12%	3%
Mail	17%	14%	10%

Table 6: Regression-analysis output
Model: Diffusion Cluster Index = a + b (Endogenous Capabilities Index) + c (Sales in million pesos)

	Regression analysis Total of firms	Regression analysis Intermediate groups
a	11,4 (11,9)**	18 (15,1)**
b	0,53 (7,1)**	$8,3*10^{-3}$ (0,09)
c	$9,7*10^{-3}$ (3,6)**	$2,6*10^{-2}$(3,4)**
R^2 (adjusted)	0,23	0,06
F	35,0**	5,8**

Note: Between brackets: Student's t-test
** Student's t-test significant at 5% level

Table 7: Percentage of firms in the four groups according to various attributes

Attribute being considered	1.High endogenous capabilities and high use of ICTs	3.High endogenous capabilities and low use of ICTs	4.Low endogenous capabilities and high use of ICTs	2.Low endogenous capabilities and low use of ICTs
1. Structural features				
Sales below 0.5 million	0**	15	10	41**
Sales between 0.5 and 3 millions	12**	48**	37	26
Sales between 3 and 8 millions	29*	17	13	20
Sales between 8 and 20 millions	33**	9*	23	11
Sales above 20 millions	26**	11	18	2**
Less than 20 employees	0**	27	27	39*
Between 21 and 50 employees	21	39*	18	29
Between 51 and 100 employees	28*	19	11	14
More than 100 employees	51**	15**	44**	18*
DFI	40**	18	22	6**
Exporters	80*	70	75	45**
Merger or acquisition	42**	21	23	22
Does not import inputs	17*	40	26	47*
Sales increased in the 90´s	56	40	66*	39
Automotive sector	18	24*	6**	14
2. Endogenous capabilities				
Fully deployed quality system	91**	55	31*	10**
Research and development team with full-time personnel	44**	36*	16	6**
New products since 1995 account for more than 30% of sales	50	56	41	34
In cells, at least sometimes workers do machine programming	81**	55	34*	33*
Medium-high training efforts (more than 40% of employed personnel involved)	69**	55	31	16**
High percentage of technical personnel	67**	54**	20**	18**
3. ICTs' diffusion				
Server and database engine	67**	30*	55	24**
Back-up system and UPS	93**	49	70	49
Having at least an in-house interconnected network	33**	10*	27*	6 **
Sophisticated management software	65**	3**	31	4**
Only basic office software	33**	92**	58	92*
Complementing or subcontracting computer services	35*	70*	42	71
Computer training	60**	14**	34	6**
Fully integrated planning and control software	77**	9**	17	10**
Sophisticated systems in	47**	18	20	14

production hardware/software				
Lacking design software	28**	55	48	77**
Design software integrated into production itself	42**	5**	20	6*
Internet slightly relevant	12**	49	13**	84**
Internet highly relevant	30	25	31	0**
Intranet slightly relevant	35**	78	67	96**
Intranet highly relevant	35**	8	13	0**
Medium relevance of E-mail	2**	39	2**	75**
High relevance of E-mail	98**	58	98**	22**

** Z-test significant at 5% level

* Z-test significant at 10% level

Source: Author's elaboration based on the ICTs' Use and Diffusion Survey in the Argentine manufacturing industry IDEI-ICO (UNGS)