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The evolution of the spatial digital divide: From internet adoption to internet use by french industrial firms

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Cahier n° 2005 - 25

Décembre 2005

L'évolution de la fracture numérique spatiale : De l'adoption à l'intensité d'usage d'internet par les firmes industrielles françaises

Résumé

Dans cet article, nous nous concentrons sur différents aspects de la « fracture numérique spatiale » et cherchons à répondre à trois questions. Existe-t-il encore aujourd'hui des inégalités spatiales dans l'adoption de ces technologies ? Existe-t-il une fracture spatiale dite de « second niveau» caractérisée par une faible utilisation d'Internet et du mail par des entreprises ayant pourtant adopté ces outils ? Peut-on observer des processus d'appropriation et/ou des logiques de diffusion distincts parmi les entreprises adoptantes selon leur zone de localisation (urbaines vs. rurales) ? Pour y répondre, nous construisons un modèle original de diffusion de technologies (de type Battisti et Stoneman, 2005) qui cherche à combiner les modèles se concentrant sur les effets de la contagion et ceux dits d'équilibre modélisant la décision de l'adoption comme le résultat d'un calcul économique des agents en fonction de leurs caractéristiques propres et de celles de leur environnement concurrentiel, industriel et local. Ce modèle est testé sur une enquête nationale récente (« TIC et commerce électronique », 2002). L'un des principaux résultats est que si, à taille et secteur des entreprises donnés, des inégalités spatiales liées à l'adoption des TIC ne sont plus à l'œuvre en France, elles demeurent en revanche toujours très importantes dans les processus d'appropriation et d'usage de ces technologies par les firmes.

Mots-clé : Internet, diffusion intra et inter-firme, effets épidémiques, 'rank effects', effets d'agglomération, inégalités spatiales

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Abstract

In this paper, we concentrate on different aspects of the « spatial digital divide » and seek to answer three questions : Are there still spatial inequalities in the adoption of these technologies ? Is there a so-called "second level" geographical divide characterized by important differences in the intensity of Internet use between firms that have adopted these tools? Do the appropriation processes and logic of diffusion of ICT adopters vary according to the type of area in which they are located (urban vs. rural areas)? To answer these questions we have constructed an original model of technological diffusion (of the type developed by Battisti and Stoneman, 2005) that merges two types of models: those that concentrate on epidemic effects, and the so-called equilibrium models that model the decision to adopt new technologies as the result of an economic calculation by firms, which depends on their internal characteristics and those of their competitive, industrial and local environment. This model uses data drawn from a recent national survey ("ICT and e-commerce" 2002). One of the main results is that, for a given size and sector, although there no longer are spatial inequalities in terms of ICT adoption in France, there are still important inequalities in firms' processes of ICT appropriation and use.

Keywords: Internet, inter-firm and intra-firm diffusion, rank and epidemic effects, agglomeration effects, spatial inequalities

JEL : L2, O3, O18

I. Introduction

In the early 2000s, some authors predicted that communication and information technologies (ICT) - which allow people to communicate over distance and thus lift the constraints of geographic proximity - would be "the death of distance" or even the "end of geography". More recently, studies of the spatial effects of ICT provide more cautious and qualified predictions. Indeed, the impacts of ICT cannot be analysed without taking into account how, downstream, they are adopted and used by firms. And these conditions have not yet been thoroughly explored and understood. Some authors have highlighted significant disparities – particularly spatial disparities - in the rates of ICT adoption. Various studies have shown that being located in a densely populated area influences firms' propensity to adopt these technologies (Karlsson 1995; Fisher and Johansson, 1994; Blaas and Nijkamp, 1994; Funck and Kolawski, 1990). Using a national database on industrial firms, Galliano and Roux also observed that in 1998, for a given size and sector, ICT adoption by French rural firms was negatively affected by their geographical location.

This geo-spatial digital divide, which merely emerges from inequalities of access to infrastructure networks (Rallet and Rochelandet, 2005[1]) has prompted the public authorities in low-density areas (particularly rural areas) to replace the private sector in providing the necessary infrastructures and ensuring that firms and individuals have equitable access to ICT. These initiatives are now bearing fruit, even though the level of telecommunication infrastructures is still inferior in low-density regions in France (Houzet and Grasland, 2004). Thus, it is expected that geographical inequalities in ICT adoption will eventually disappear (Cairncross, 2001). Monographic studies conducted in France (Galliano et al, 2004) have shown that a large number of rural firms now have access to Internet and e-mail facilities. However, these studies reveal that access to the Internet and email in these areas does not, in itself, ensure that these technologies are used. And this gap between rural and urban firms in ICT use might prove more durable than inequalities in ICT access, in particular those related to a lack of infrastructures in certain types of area. Thus, if this second level divide (Hargittai, 2002)[2] is real, ICT might reinforce the disparities between the economic performances of urban firms and those of rural firms at the expense of the latter, which might lead, at meso-economic level, to a slower development (both endogenous and exogenous) of rural areas. In terms of public policies, this question has important implications.

[1] For a definition of the digital divide and for a critical and exploratory review of the literature dealing with this question, refer to these authors.

[2] The first level digital divide opposes the actors who have access to ICT (Internet in particular) to those who do not. The second level divide opposes the connected actors who use these technologies to those who, despite being connected, do not use them.

In this paper, we concentrate on these different aspects of the geographical digital divide and seek to answer three questions. Firstly, are there still spatial inequalities in the adoption of these technologies? In other words, is being located in a low-density area an obstacle to the ICT adoption? Secondly, is there a so-called "second level" geographical divide characterized by important differences between Internet adopters in the intensity with which they use these tools? Finally, do the appropriation processes and diffusion logic of ICT adopters vary according to their location (urban vs. rural areas)?

To answer these questions, we have made use of recent theoretical economic studies (e.g. Karshenas et Stoneman, 1995; Geroski, 2000) and empirical works (Battisti, 2001; Hollenstein, 2004; Forman, 2003; Forman et al., 2005a; Battisti et Stoneman, 2005), that attempted to model the adoption (inter-firm diffusion) of new technologies, and, more recently, their use (intra-firm diffusion). Recent studies (in particular, that of Battisti and Stoneman, 2005) try to merge different approaches to analyse these processes: the models concentrating on the epidemic effects (Mansfield's epidemic models of technology diffusion (1968), which concentrate on the effect of the diffusion of information about technologies) and the so-called equilibrium models that model the decision to adopt ICT as the result of an economic calculation by firms of the net benefits they will reap from adopting and using these technologies.

After describing the characteristics of these processes and the factors likely to influence them, we empirically test our predictions using recent data from a thematic survey (« ICT and e-commerce ») conducted in 2002 by the main French statistical institutes (Insee, Sessi and Scees). The main goal of this survey was to assess the use of ICT by French industrial firms - in particular for electronic commerce - by identifying the nature and intensity of ICT use, as well as the appropriation of these technologies by the firms' employees. We have developed and estimated an original model that enables us to take into account both stages of the process of intra-firm diffusion of ICT: access to (or adoption of) the Internet and e-mail, and the intensity with which adopters use these technologies. We perform these tests by differentiating the firms according to their type of location (in rural vs. urban areas). One of the main results obtained is that, for a given size and sector, although the type of location in which French firms are located no longer influences their decision to adopt ICT, it still has a significant impact on the firms' processes of appropriation of these technologies.

This paper is structured as follows: The following section describes our theoretical framework and presents the specifications of the empirical model. Section 3 presents the determinants of Internet adoption and use. The data and variables used as well as their expected effects are described in Section 4. The results of both stages of the general model are presented in section 5. In section 6, we present the results obtained by distinguishing firms

according to the type of area in which they are located (urban vs. rural). Finally, we shall propose a synthesis of the results obtained and briefly discuss the limitations of our study.

II. Modelling adoption and use behaviour

A. The models of intra and inter-firm technology diffusion

Information and communication technologies (ICT) are generic technologies used to reduce the cost of communication, coordination and information processing. In this regard they are considered as General Purpose Technologies (GPT) since they are useful in all sectors of the economy (Bresnahan and Tratjenberg, 1995). They are used differently by different users and even by the same user. Investments related to ICT adoption differ from other types of investments in that, although the Internet and e-mail are generic technologies, using them requires complementary organizational innovations by firms (e.g. Caroli and Van Reenen, 2001; Bresnahan et al, 2002; Greenan 2003). This points to the importance of firms' internal competencies and absorption capacity.

A great deal of literature has been written on the diffusion of new technologies. In particular, studies have tried to model the process of technology diffusion and to explain the so-called "S-shaped diffusion curve". A review of this literature, presented by Karshenas and Stoneman (1993), makes a distinction between two different types of models, each divided into two sub-sets. The first group of models (the so-called imbalance or epidemic models) concentrate on the effects of the epidemic. Another group of models (the so-called equilibrium models) interpret the decision to adopt ICT as the result of a rational economic calculation by individuals or firms. The latter estimate the return that they could obtain from using these technologies. The expected adoption payoffs will depend not only on the firm's own characteristics but also on its "position" in the adoption order (early or late adopter).

Epidemic models emphasize the predominance of the effects of information spillovers on the diffusion of technologies. The greater the number of adopters, the more information is available about the technologies for potential adopters, and the faster the diffusion rate. These models hypothesize that a potential user becomes a user through contact with an existing adopter (the greater the number of adopters, the higher the probability of a non-adopter to be in contact with an adopter and the higher his probability of being "contaminated"). Over time the population of non-adopters declines and the cumulated diffusion curve then becomes S-shaped. The implicit hypothesis underlying these epidemic models (and this is also one of their limitations) is that, once individuals know of the technology, they will use it.

In the so-called *equilibrium models* the decision to adopt the technology is the result of an economic calculation by potential adopters, who anticipate the benefits they could obtain from adopting and using these technologies. In these approaches, the S-shaped diffusion curve does not result from a market failure (uncertainty concerning the technology) but from differences between users. Firms anticipate the costs and benefits that will result from adoption and use before deciding to adopt a technology at time *t*. These expected costs and payoffs change over time, causing the number of adopters to evolve. Karshenas and Stoneman (1993) have identified three different mechanisms of technology diffusion. Firstly, the models based on the existence of *rank effects*: The users have different characteristics (in the case of firms, the difference can be related to their size, their financial resources, the industrial sector they belong to, their market share, the market structure, the costs and characteristics of the technology…). Depending on the latter, some firms will generate higher net benefits than others from the adoption of technologies. One of the pre-adoption rules is to compare the payoffs to the costs of adoption[3]. In the models based on the existence of o*rder effects or stock effects* ("game-theoretic models"), the benefits of adoption depend on the position of the actor in the adoption order. The gains or, on the contrary, the losses related to a firm's position in the adoption order is integrated in their calculation.

Once the new technology is adopted, the latter will be more or less intensely used within the firm[4]. Thus, according to Astebro (2004) the adoption of a new technology implies three types of decision: i) the adoption of a new technology; ii) the extent to which this new technology is used (the "depth" of adoption"); iii) the substitution of the old technology with the new one. Moreover, several authors have also shown the importance of the complementary organisational innovations that accompany ICT use. Caroli and Van Reenen (2001), Bresnahan et al (2002) and Greenan (2003) in particular have observed this phenomenon. Using these technologies is therefore an innovation and is costly.

What influences firms' decisions about how much they should use these technologies? The different approaches to inter-firm technology diffusion discussed above have been applied to intra-firm diffusion. Battisti and Stoneman (2005) propose an original model of intra-firm technology diffusion. Their hypotheses are the following: First of all, heterogeneity among firms implies that the use of technologies is more or less profitable, and therefore that the extent to which they are used within firms varies. The stock effect in the models of intra-firm diffusion reflects the idea that the profit gained from the use of one extra unit of the new technology depends upon the existing level of use by the firm. This implies that the marginal

[3] The term « rank » is used because in these models the net benefits can be classified according to the type of firm. The firms positioned in the higher ranks will be the first to adopt technologies.

[4] We concentrate here on the extent of intra-firm diffusion without making a distinction between the different uses of these technologies by the firm, which can potentially vary a great deal. Another study will address this question.

profit gained from an increased use of a new technology decreases with use. Finally, the order effects are believed to have no influence on intra-firm diffusion[5].

Battisti and Stoneman (2005) have modelled the intra-firm diffusion of a new technology as a two-stage process. In the first stage the firm decides to adopt, or not to adopt, the new technology. In the second stage the firm decides on the level of use of the technology.

The equation of intra-firm technology diffusion at a given time *t* is the following:

$$K_{n,t} / K_{o,t} = (\alpha_n / \alpha_o)(c_{o,t} / c_{n,t})$$

with $j = o, n$ representing the old and the new technology, $K_{o,t}$ and $K_{n,t}$ indicating the existing and the new technological capital respectively. Thus the ratio of the use of the new and old technology indicates the share of the new technology in relation to the old (the extent of intra-firm diffusion); α_n / α_o is the productivity of the new technology in relation to the old technology. $c_{o,t}$ and $c_{n,t}$ are the costs of capital for using each technology at time *t* [6].

After applying transformations and considering the percentage of investment in the new technology $k_{n,t} = K_{n,t} /(K_{n,t} + K_{o,t})$, we obtain:

$$\log(k_{n,t} /(100 - k_{n,t}) = \log(\alpha_n / \alpha_o) + \log(c_{o,t} / c_{n,t})$$

By integrating, in an ad hoc manner, uncertainty in the characteristics of the technology (or the Mansfield epidemic effects), Battisti and Stoneman (2005) obtain the following equation of intra-firm diffusion:

$$\log(k_{n,t} /(100 - k_{n,t}) = \log(\alpha_n / \alpha_o) + \log(c_{o,t} / c_{n,t}) + \log f(E_t)$$

[5] The data we have used do not enable us to take into account the stock and order effects. More particularly, we have no indication of the date of adoption of Internet or email by the firms. Consequently we shall not discuss them here.

[6] The authors use a standard production function extended to three factors: $Y_t = A_t L_t^{\beta} K_{o,t}^{\alpha_o} K_{n,t}^{\alpha_n}$ and a neoclassic standard model of investment with Y_t, the output level, and three inputs (L, the labour; $K_{o,t}$, the existing technological capital; $K_{n,t}$, the new technological capital), and constant scale returns $\alpha_o + \alpha_n + \beta = 1$.

B. A two-stage model

1) Inter-firm diffusion (or the process of technology adoption)

First of all, we characterise the process of adoption of the new technology. We consider the discrete binary variable d_i^t that takes value 1 if the firm possesses the new technology at time *t*, and 0 otherwise. At time *t*, a firm possesses the new technology if and only if the net profit it has anticipated from its adoption in relation to its non-adoption is positive. The expected net profit of adoption noted $\theta(x_i^t)$ is a function of the firm's specific characteristics as well as those of its sectoral, commercial, geographic environment (rank effects).

We now make the additional hypothesis that a spillover effect from the firm's local and sectoral environment influences its decision to adopt the new technology. The adoption of the new technology by other firms in the same sector or the same geographical area generates information spillovers that may lead the firm to adopt this new technology in so far as these spillovers reduce the uncertainty concerning its characteristics (epidemic effects). These epidemic effects are noted e_i^t.

All in all we consider that firm *i* possesses the new technology at time *t*, i.e. $d_i^{n,t} = 1$, if the expected net profit (in relation to non-adoption) is positive:

$$\pi(x_i^t, e_i^t) = \theta(x_i^t) + f(e_i^t) > 0 \qquad (1)$$

The first term of the expression represents the net profits anticipated by the firm, while the second is a corrective term that takes into account the existence of information spillovers about the technology's characteristics.

2) Intra-firm diffusion (or the extent to which the new technology is used)

On the basis of this first stage, and by using Battisti and Stoneman's formalisation (2005) given in expression (1), the equation representing the firm's decision of how much it should use the new technology (intra-firm diffusion) can be modelled as follows. Knowing that $d_i^t = 1$ we have:

$$k_i^{n,t} / (100 - k_i^{n,t}) = (\alpha_i^{n,t} / \alpha_i^{-n,t}) \times (c_i^{-n,t} / c_i^{n,t}) \times g(e_i^t)$$

with $k_i^{n,t}$, the proportion of employees using the new technology; $(\alpha_i^{n,t} / \alpha_i^{-n,t})$, the relative probability of using the new technology (n) in relation to non-use $(-n)$; $(c_i^{-n,t} / c_i^{n,t})$ the

relative costs of not using the technology in relation to the cost of using it and e_i^t the epidemic effects, i.e. the information spillovers from users to non-users.

By applying a logarithmic transformation, the equation of intra-firm diffusion of the new technology simply becomes:

$$\log(k_i^{n,t}/(100-k_i^{n,t})) = \log(\alpha_i^{n,t}/\alpha_i^{o,t}) + \log(c_i^{-n,t}/c_i^{n,t}) + \log g(e_i^t) \qquad (2)$$

III. The explanatory factors of ICT adoption and use-related behaviours

In this section, we attempt to determine the factors that are likely to influence the process of intra-firm diffusion in both the stages described above. We divide these determinants into two main categories: the *rank effects* and the *epidemic effects* that have been described as the main factors explaining the adoption and diffusion of new technologies (Canepa and Stoneman, 2003; Hollenstein, 2004). Rank effects affect the costs of and payoffs from adopting or using the technologies. As mentioned previously, time lags in the adoption and use of a new technology can be explained by differences in firms' needs, objectives and capacities. Epidemic effects are related to uncertainty about the technology itself. Thus, even though the new technology is profitable, delays in the adoption and use of the technology may occur if the firms' knowledge of the technology's characteristics is lacking. What is more, information spillovers from users of the technology to non-users should increase firms' propensity to adopt and use the new technology. In the two following sub-sections we identify the *rank effects* that we shall retain for our econometric study, and distinguish the rank effects that are internal to the firm from those related to the firm's sectoral or geographical environment. The third sub-section describes the epidemic effects.

A. Rank effects (1): the internal characteristics of firms.

The size of the firm

Each firm has specific characteristics that influence both its adoption behaviour and the returns obtained from using technologies. Among these characteristics, the firm's size is described as having an impact on both stages of the adoption and use process. Generally speaking, the firm's size influences its capacity to innovate and adopt new technologies. Indeed, depending on their size, firms have different financial capacities, they do or do not benefit from scale economies and have a more or less wide diversity of skills. A small size increases the risks related to the adoption of new technologies and reduces the firm's capacity

to evaluate the potential benefits and consequences of the adoption. Furthermore, the benefits expected by a small firm from the adoption of a technology are often, *a priori*, reduced in so far as the needs for coordination are lower and the costs inherent to adoption higher (availability of competencies, costs of training, etc). However, size has a more ambiguous effect on the intensity of Internet use. According to Astebro (2004), the larger the firm, the higher the firm's probability of adopting the technology and of using it extensively. On the other hand, the process of replacement of the old with the new technology is thought to be faster in smaller firms (the pace of "intra-firm" diffusion). The author explains this inverse relation between size and pace of replacement by the existence of sunk costs related to the cost of training the staff to use the technology.

The influence of the firm's size on adoption (i.e. on the inter-firm diffusion of technologies) has been studied extensively in literature (Mansfield, 1968; Karshenas and Stoneman, 1993; Saloner and Shepard, 1995). Astebro observes that the size of the subsidiaries (of a group) also has an effect on the pace of adoption but that the size of the group itself does not, which points to the importance of the effects related to the technical concentration. Battisti and Stoneman (2005) also find that the intra-firm diffusion of new process technologies is greater in large firms. Hollenstein (2004) has observed that though the effects of the size on use intensity (measured by the number of ICT units used by the firm) are significant and positive, the rate of intra-firm ICT diffusion (measured by the proportion of employees using the Internet in 2000), is higher in medium-sized firms. This would seem to imply that size has no linear effect on the intra-firm diffusion of the Internet and thus highlight differences in uses between small and large firms: While the latter use ICT in order to better manage informational flows related to their production process, small firms use these technologies for essentially commercial purposes (Gretton et al, 2004 quoted by Hollenstein, 2004).

The qualification of the work force

Beyond the size, the forms of internal organisation and the modes of external coordination used by firms are important factors in the process of ICT diffusion. The lack of both general and ICT related competencies, and the absence of adequate training remain important obstacles to ICT adoption and use (Hollenstein, 2004). More generally, the idea is that a firm's capacity to innovate and learn is higher if it has a diversified and highly qualified workforce, as this increases its ability to benefit from external knowledge and technological opportunities (Cohen and Levinthal, 1989). The intensity of intra organisational ICT diffusion and the cost of use are proportionately related to firms' stock of competencies. Hollenstein (2004) finds a positive relationship between the level of qualifications and of ICT-oriented training and the intensity of adoption. Caroli and Van Reenen (2001) (using English data) and Greenan et al (2001) (using French data), also emphasize the complementarity between technology and human capital. Finally, Battisti and Stoneman (2005) using R&D

expenditures as an indicator of the firms' absorption capacity show that these expenses have a positive impact on the intra-firm diffusion of new process technologies.

Intra and inter-firm coordination

Information technologies are tools that facilitate communication and coordination at both intra and inter-firm levels. The greater the needs and costs of coordination, the higher the probability of using ICT. First of all, beyond the size, a multi-unit organizational structure implies high costs of coordination between the different units located in different areas. Thus, ICT are thought to be adopted and used in this configuration in order to facilitate coordination and communication (often long distance communication) between these different units. Fisher and Johansson (1994) show that the probability of adopting ICT is higher when the firms are multi-unit organisations. Having several units located in different geographical areas increases the probability of adopting ICT (Hwang, 1998; Galliano et al 2001; Galliano and Roux, 2004; Forman et al, 2005b).

Secondly, the effect of the intensity and nature of firms' informational exchanges with their environment on the decision to adopt ICT have been extensively described in literature. Indeed, ICT are used to manage inter-firm communication and coordination. Operating in a relational network should therefore increase a firm's propensity to adopt ICT whether they are used to facilitate the firm's production relationships with external partners or its internal relationships other units within the group it belongs to (if the firm is part of a group). This result is overall confirmed by studies that take this dimension into account (e.g. Karlsson, 1995; Galliano et al, 2001; Battisti and Stoneman, 2005). The size of the relational network logically influences the intensity of ICT use (Saloner and Sheppard, 1995), and we also note that the necessity to create and maintain stable and collaborative relationships with partners increases the firm's probability of using these tools. ICT enable firms to have more frequent and less costly interactions with their different partners.

B. Rank effects (2) : Environment-related factors

The area where the firm is located

The nature of the environment where a firm is located is generally believed to promote the diffusion of technologies by facilitating the development of relationships with technology suppliers and other economic actors directly or indirectly supporting the associated process of knowledge creation (Fisher and Johansson, 1994). The characteristics of the local environment can also directly influence firms' strategic choices (e.g. increasing returns of adoption, costs of infrastructure access) or, more indirectly, in situations of uncertainty, via

the information they will have access to locally. Two types of agglomeration economies are traditionally highlighted in literature (Malmberg et al, 2000). Agglomeration economies can result either from a geographical concentration of industrial activities (economies of location), or from an urban concentration (urban economies).

Industrial agglomeration economies are external to a firm but internal to the industry, and are related to the degree of industrial specialisation in the area where the firm is located. They enable firms to develop a network of dedicated suppliers, to gain access to a specialized work force and they facilitate the diffusion of information and innovation between competing firms (Glaeser et al, 1992). Thus, according to Antonelli (1999), the denser the industrial activity in the area where the firm is located, the denser its network of relationships with other firms, and the greater the level of information received, which increases the gains obtained from ICT adoption. Various studies have shown that industrial specialization has little effect on the use of technologies. (Glaeser et al, 1992; Harrison et al, 1996). Using a sample of about 8000 American firms (excl. low tech firms) Gale (1998) obtains the same result. Only Forman et al (2005b) have recently observed a positive effect of industrial concentration.

As for urban agglomeration, it has a positive effect in that it facilitates access to a qualified and diversified workforce (and therefore to a variety of skills) and to a variety of infrastructures and activities (particularly services) and it increases the amount of informational signals received by the firms. In particular, urban agglomeration increases the probability for a firm of finding, close by, suppliers of equipment, of new computer technologies and associated services, their number increasing with the number of potential clients present in the area (Karlsson, 1995). The relative absence of technology suppliers from rural areas - in relation to urban areas, in which they extensively contribute to the diffusion of ICT towards firms – is partly due to the low density of those areas. Deficiencies in telecommunication infrastructures can also explain why, until recently, the pace of ICT adoption by rural firms occurred more slowly. These deficiencies imply unequal access to the different types of connection (high bandwidth, medium speed, modem…), which, depending on the firm's location, reduces its capacity to use the tools. Finally the low density of rural areas implies a low diversity of industries and skills, which is not propitious to the implementation of these technologies by firms. In this respect, one of the greatest difficulties that firms have to deal with is the lack of qualification of the work force available in rural areas.

Generally, the authors of empirical studies offer similar conclusions concerning the effects of urban agglomeration on the diffusion of technologies tend to converge. Various studies have shown the positive influence of urban concentration on adoption (Karlsson, 1995; Fisher and Johansson, 1994; Blaas and Nijkamp, 1994; Funck and Kolawski, 1990).

Kusmin (2002) shows that firms' employees make more frequent use of computers in metropolitan areas (49% against 36% in 1993; 52% vs. 40% in 1997)[9]. Using a sample of almost 4000 American rural and urban firms - built from the US Rural Manufacturing Survey conducted in 1996 - Gale (1997) finds a "rural-urban gap" in the use of high technologies (particularly in the use of Internet, local networks or modems). Gale (1997) shows that firms located in areas with high education levels have a higher propensity to use ICT. Using a 842-firm sample built from the U.S Rural Manufacturing Survey of 1996, McGranahan (2002) also observes that small independent firms that have adopted so called advanced technologies are generally located in areas where the education level is high. Karlsson (1995) shows that the pace of adoption tends to be all the slower in peripheral areas (i.e. low density areas) as the field of application of ICT systems is complex. Being located in a metropolitan area is more propitious to ICT adoption, particularly in cases when these tools are used for the development of new products. Very recently, Charlot and Duranton (2003) find an increasing use of communication technologies among employees of French urban firms. Other studies have shown that being located in a peri-urban area, as opposed to a rural or urban area, increases the rates of adoption (see Little and Triest, 1996 particularly).

The commercial environment : competition pressure

The competitive pressure under which a firm operates can also partly influence its decision in both stages of the diffusion process. The firm's capacity to innovate and its pace of innovation depend on its position on the market (a firm that already has a large market share is more likely to have the required capacity) but also on the nature of the innovation and the type of market structure (see Reinganum 1989 for a survey). However when competition is intense the demand elasticities are also higher because of the existence of substitutes, which encourages firms to develop breakthrough innovations and / or reduce their costs by implementing more efficient production methods (e.g. Majumbar and Venkataraman, 1993), in order to protect themselves from competition pressure.

The conclusions of empirical studies concerning the effects of market structure are ambiguous and divergent. Thus, Karshenas and Stoneman (1995) find that the degree of industrial concentration (share of the first five firms) has no impact. Jamumbar and Vendkataraman (1993) also find that the effects of competitive pressure are not explanatory variables of adoption. Hollenstein (2004) finds that competitive pressure (approximated by the part of exports in the turnover), has no effect once a certain level of export is reached and thus evidence a non-linear effect of the export rate. Finally, Battisti and Stoneman (2005) observe that firms with a high export rate use new process technologies less intensely.

[9] This data comes from the Current Population Survey (CPS). The sample represents approximately 48000 American households.

The firm' industrial sector

The influence of a firm's sector of activity on its adoption behaviour is related to both the technical determinants that characterise the industry and to the type of relationships, downstream or upstream, developed by the firm. The nature of the product and of the production processes developed by the firm are associated to certain technical conditions and a technological level, and therefore to knowledge spillovers that play an essential role in the intensity of their ICT related needs and in the diffusion process (Forman, 2003…). The influence of the sector – and more precisely the sectoral structures of the location areas - also plays a role. Some authors show that the type of activities developed in an area has an influence on ICT adoption (Gale, 1997; Mitchell and Clark, 1999), and they make a distinction between rural market activities (agribusiness, textile, tobacco, timber) and urban market activities (electronic equipment, metallurgy…). Indeed, rural market activities tend to have low technological intensity, partly because they are located in rural areas (in order to have easy access to raw materials) and partly because these activities imply relatively low requirements in terms of information and/or knowledge transmission.

Gale (1997) finds that the urban/ rural gap tends to disappear when sectoral effects are taken into account. Using a sample of almost 4000 American (rural and urban) firms, Gale (1997) observes that the combination of a low qualified workforce with « raw material-intensive » industries has a negative effect on ICT adoption by rural firms. Analysing Internet adoption on the basis of a sample of 85000 American firms, Forman et al (2005b) found that after controlling for the sector, the probability of adopting basic Internet technology such as email is higher in rural than in urban areas. The intuitive conclusion from this result is that their being relatively isolated is a factor that pushes these firms to adopt and use these technologies (Forman et al, 2005b). Finally, Galliano et al (2005) have also observed that, after controlling for the sector, the most isolated firms in rural areas have a higher propensity to adopt ICT than those located in rural centres (average sized towns in rural areas).

C. Uncertainty about the technology: epidemic effects

Some authors have also emphasized that the decision to adopt a new technology can depend on the information available concerning its profitability (costs, benefits, availability…). In the epidemic approach initiated by Mansfield (1968), the central hypothesis is that the more a new technology is used, the more information is transferred between and within firms, and the lower the risk associated with its adoption. Thus, the information spillovers from firms that are already using the new technology to the non-users help reduce uncertainty about its characteristics. This generates a spillover effect on the non-users. The epidemic approach anticipates that a firm's propensity to adopt a new technology increases if the firm in question belongs to an economy or a sector in which a large proportion of firms

already use the new technology (Hollenstein, 2004). A firm's decision to adopt and use a new technology more or less intensively should also depend on the information available in its close geographic environment.

From an empirical perspective, the results concerning the process of intra-firm diffusion diverge. Stoneman and Battisti (1997) find that epidemic effects related to the firms' sector are not explanatory variables. Hollenstein (2004) finds that they have a positive and significant effect on the intensity of Internet use. In the case of technology adoption, Battisti and Stoneman (2005) find that a large number of adopters in the sector to which a firm belongs has a negative effect on the latter's probability of adopting the technology. Other studies have, however, shown that these effects are significant and positive in the case of adoption (e.g. Canepa and Stoneman, 2003; Karshenas and Stoneman, 2005). As for the epidemic effects related to the geographical area in which a firm is located, they have only been tested by Forman (2003) who finds that they have a positive impact on Internet adoption and use.

Finally, it must be noted that the epidemic effects can lose some of their « purity » in situations where it is in the best interest of a firm to use a new technology if other firms in its environment, with which it interacts, use these new technologies. As Hollenstein noted (2004), in the case of the Internet, this phenomenon also reflects the existence of increasing returns to adoption.

IV. Data and method

A. The data

Most of our data come from the « ICT and E-Commerce » qualitative survey jointly conducted by the Insee, the Sessi and the Scees in 2002. They are cross-section data. The general goal of this survey was to observe how and how much French industrial firms use ICT, and particularly electronic commerce. The aim was to precisely determine ICT use intensity, the different types of uses and what they are used for. Particular attention was paid to the factors that influence firms into adopting ICT, to facilitate information exchanges, relationships with suppliers and external partners of the firms, as well as the development of e-commerce activities (purchase and sales) on the Internet. Of particular interest to us in the context of this study, is how firms use ICT (i.e. appropriation). Our sample (representative in size and sector) comprises approximately 5200 industrial firms.

We also use two other statistical sources (the Annual Survey on Firms of 2001, and the "Organisational Changes and Computerization" survey of 1997). The Annual Survey on

Firms ("EAE") gives us information concerning the structural variables (size, sectors, belonging to a group…) and spatial variables used. Our spatial indicators were built by merging our file with the « Zoning » file (Inra-Insee, 1998) that proposes a typology of French towns divided into various categories depending on their more or less urban or rural nature. The typology obtained comprises fifteen categories of *communes*, aggregated into three categories: Urban, peri-urban and rural areas (which can also be divided the three following sub sets: rural centres, rural areas under urban influence and isolated rural areas). Finally the "Organisational Changes and Computerization" survey (OCC) conducted in 1997 provided us with relatively precise data on Internet use by firms in 1997 at sectoral level. They also give us an approximate indication of the geographical diffusion of the Internet.

B. The endogenous variables : adoption and intensity of use of the Internet and email

Table 1. The characteristics of the sample

		Sample size	% of employees using the Internet or email	Std Dev.
Total		5227	31,61%	0,278
Types of area	Urban area	3231	36,88%	0,295
	Peri urban area	856	26,12%	0,242
	Rural area	1140	20,79%	0,210
Size	< 50 employees	1708	24,32%	0,265
	Between 50 and 199 employees	1798	28,29%	0,259
	200 employees or more	1721	42,30%	0,279
Belonging to a group	Subsidiary	3689	36,26%	0,283
	Independent	1538	20,44%	0,231
Spatial organisation	Single unit firm.	2462	37,31%	0,288
	Multi unit firm.	2765	26,53%	0,260
Sectors	Agribusiness	954	22,27%	0,216
	Consumer goods	1030	38,07%	0,326
	Automobile	158	31,25%	0,228
	Equipment	995	39,26%	0,299
	Intermediate goods	2060	28,57%	0,250

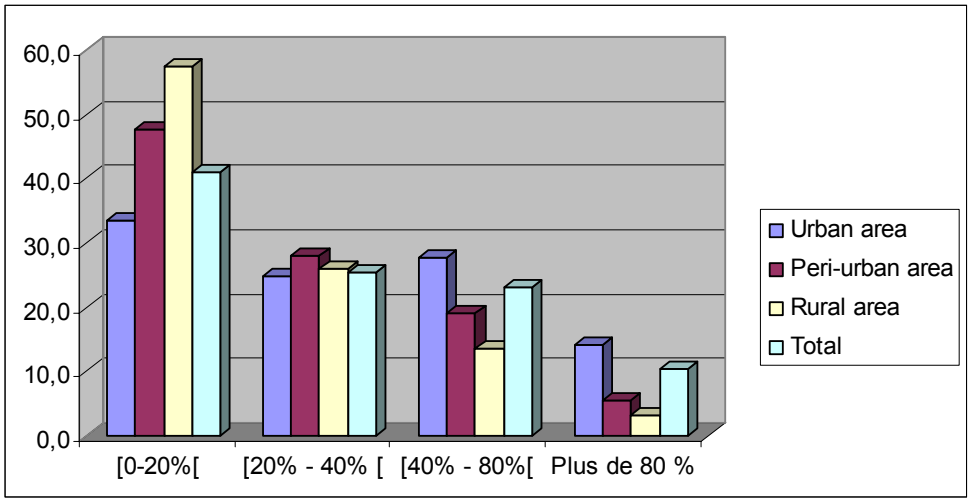
Sources: ICT and E-Commerce Survey, 2002 (cross section data) and EAE 2001

In 2002, the Internet is widely adopted in French industrial firms. Approximately 95% of all industrial firms were connected (that is a progression of over 25 points since 1999, according to the Sessi figures). Only a few sectors still lag behind in this process, with

adoption rates of about 80% (Textile industry, agribusiness or optical equipment). This growth of the Internet in French firms is due to the fact that these tools have become more accessible and affordable and that a simple Internet connection does not necessarily lead to organisational changes. We also observe that rural firms have, since 1998, caught up with their urban counterparts in terms of Internet adoption (OCC survey, see Galliano and Roux, 2004).

Though the average rate of Internet connectivity in French industrial firms is about 95%, the percentage of employees who use the Internet remains low. Indeed, we observe that in 2002 less than 30% of the employees used the Internet or email. In other words, although the Internet is widespread among firms, the actual use of the Internet within firms remains low. Here again, we observe that in rural areas, small firms still lag behind in terms of Internet use, this is true also of rural firms that belong to certain sectors of activity.

Figure 1. Percentage of firms' employees using the Internet or email according to their location



Sources: ICT and E-Commerce Survey, 2002 (cross section data) and EAE 2001

C. The empirical model: Heckman's two step estimation method

The variable of Internet/email use intensity is only observed for the firms that do possess the Internet and/or email. Internet and email adoption by firms depends on the characteristics of the firms and of their environment and on effects of information spillovers from their sectoral and local environment. Since the individuals observed were not randomly selected, we assume that there is a selection bias. Heckman's method (1979) makes it possible to correct for this selection bias.

Let the binary variable d_i takes on value 1 if the firm possesses the Internet and/or email, and value 0 otherwise. We first estimate a selection equation using a probit regression on all observations. From (1), the selection equation is formally written as follows:

$$\pi_i^* = x_{1i}^{'}\gamma_1 + x_{2i}^{'}\gamma_2 + e_i^{'}\gamma_3 + v_i \qquad (3)$$

where $x_{1i}^{'}$ and $x_{2i}^{'}$ are the vectors of the firm's internal characteristics and those of its environment respectively; where $e_i^{'}$ represents the epidemic effects; and with v_i N(0,1).

We observe a discrete variable $d_i = \begin{cases} 1 \, si \, \pi_i^* > 0 \\ 0 \, \text{sinon} \end{cases}$.

This first stage enables us to compute the inverse of Mills ratio $\hat{\lambda}_i$ (or hazard rate), the probability of being part of the selected sample (i.e. of possessing the Internet and email) estimated by the probit equation (See Greene, 2003, p. 780-785).

In the second stage, we estimate the equation of the intensity of internet/mail use by the firm's employees by introducing the inverse of the Mills ratio, in order to correct for the selection bias.

From equation (2) above, we obtain :

$$y_i^* = z_{1i}^{'}\beta_1 + z_{2i}^{'}\beta_2 + e_i^{'}\beta_3 + \beta_\lambda \hat{\lambda}_i + \varepsilon_i \qquad (4)$$

where $y_i = \log(k_i^{n,t}/(100 - k_i^{n,t}))$, the logarithm of the proportion of employees using the Internet/ mail to the proportion of employees not using the Internet / mail, with $k_{i,n} \in]0;100[$.

The latter is only observed in the case where $d_i = 1$. According to Heckman's specification, the error terms v_i and ε_i must follow the normal bivariate distribution with expected value zero.

The variables considered at each stage, the methods used for their calculation as well as the expected sign of their effects are summarised in Table 2. This model is tested in the general case, and then according to the type of area in which the firm is located (in rural vs. urban area).

Table 2. The model's variables

	Calculation methods	Source	Expected sign Adoption.	Intensity
The variables to explain				
– Adoption	Dummy variable : Adoption of internet and email in 2001 (yes vs. no)	ICT and EC 2002		
– Use intensity	Logarithm of the percentage of employees using the internet or e mail / (100 - % of employees using the internet or e- mail)	ICT and EC 2002		
Explicative variables				
Iinternal characteristics of the firm				
– Size	Logarithm of the number of employees in the firm	EAE 2001	+	?
– Average level of remuneration	Logarithm of the wage bill to the number of employees	EAE 2001	+	+
– Belonging to a group	Dummy Variable : yes (subsidiary) or no (independent firm)	EAE-LIFI 2001	+	+
– Single/multi unit organisation	Logarithm of the group's number of units	EAE 2001	+	+
Characteristics of the firm's environment				
– Degree of spatial agglomeration in the areas where the head office is located	3 (or 4) - modality qualitative variable : location in urban area, peri-urban area or rural area (employment centre or periphery of rural area, other *communes* in the EDR)	EAE 2001	?	+
– Industrial agglomeration economy	Logarithm of the rate of the weight of the total workforce in sector x (naf) on the total workforce in the *departement*, to the same rate calculated for France. If this rate is superior to 1, we consider that the activity is more specialized in the *departement* than on the national territory.	EAE 2001	?	?
– Level of competition in the sector	Logarithm of the C4 : cumulated market shares of the first four firms in the sector considered	EAE 2001	?	?
– Rate of openness on international markets	Logarithm of the export rate : export turnover/ total turnover of the firm	EAE 2001	+	+
Epidemic effects				
– Level of investment in the local geographic environment	Logarithm of the average expenditures in computer equipment in the *departement* (excl the firm itself)	EAE 2001	+	+
– Level of investment in the firms of the sector	Logarithm of the average expenditures in computer equipment in the firms of the sector. (id.)	EAE 2001	+	+
– Level of adoption in the local geographic environment	Average rate of Internet use by the firms located in the *departement* in 1997	OCC 1997	+	+
– Degree of adoption by the firms in the sector	Average rate of internet use in the sector in 1997	OCC 1997	+	+
Types of connection	3-modality qualitative variable : modem, medium and high flow.	ICT and EC 2002		+

V. The determinants of adoption and of intensity of internet and email use by French industrial firms

The studies carried out in the mid 1990s have shown that the process of ICT diffusion has translated in France into a very fast and wide diffusion of technologies in firms, and by a significant modification of the components of the digital divide (Galliano et al, 2001; Galliano and Roux, 2003; Galliano et al, 2005).

The results of the Heckman's model performed show, first of all, that the correlation between the two equations is significant. This suggests that both stages of the ICT diffusion process are interdependent and that the process of adoption of these tools, a phase that necessarily precedes their use, influences the intensity of ICT use by firms.

As regards the spatial determinants and their impacts on the adoption of ICT tools (the Internet and e-mail) by French industrial firms, the results tend to show that the factors of the digital divide are not related to the density of the area where the firm is located. The degree of agglomeration - or more precisely being located in an urban, peri-urban or rural area - no longer significantly influences French firms' adoption behaviour. However, though the geographical digital divide in ICT adoption no longer exists, there is still a divide at the second stage of the process, i.e. in the intra-firm diffusion of Internet and e-mail: being located in a rural area significantly reduces the intensity of ICT use by firms. As for the peri-urban effect observed in the mid 1990s (Galliano and Roux 2003), it is no longer significant in either stage of the diffusion process. It therefore appears that being located in a peri-urban area no longer hinders the adoption and use of these tools by firms. With regards the impact of externalities related to an industrial specialisation of the area in which the firm is located, they are non-significant or even negative. This is in keeping with the results obtained by Glaeser et al (1992). These results tend to show that both types of agglomeration have different effects: It is the diversity of the firms present in an area, and not industrial specialisation, that plays on the intensity of ICT use. Industrial agglomeration, with firms of the same sector, seems to imply that firms have less productive interactions and lower coordination needs, which is unpropitious to a high intensity of ICT use.

The digital divide has shifted from Internet adoption to Internet use; but the digital divide is also strongly related to organizational factors, and in particular to firms' internal structures and characteristics. Thus adoption behaviour is significantly influenced by the firm's size and its belonging or not to a group of firms. Both these factors imply important needs in terms of internal coordination, which in turn is propitious to ICT adoption. However, firms' behaviour is also significantly affected by a multi-unit spatial organisational structure,

which has a negative effect on adoption. This negative effect is contrary to the results expected in so far as a multi-location structure implies important needs in terms of coordination, which is propitious to an intense use of ICT. This effect, observed in rural firms, might be related to a reduction in information/coordination needs caused by the localisation of one of their units in an urban area. On the other hand, though size is an important determinant of adoption, it has no impact on use intensity. More generally, Internet and email use intensity seems to result less from needs for internal coordination (size, multi unit organisation…) than from the spillover effects generated by the different characteristics of the environment (rural/urban, competitive environment, international…). With regard the commercial environment, although the degree of competition in the firm's sector does not influence the adoption process, it does have a significant effect on the intensity of use. As for export performance, it has a positive impact on both the adoption process and intensity of use. Furthermore, the type of connection, which reflects the technological level of the telecommunication infrastructures available in the firm's location area has a significant effect on the degree of ICT use. Thus, the external environment of the firm significantly influences the extent to which firms use ICT; Nevertheless its impact is dependent on the qualification level of the work force, which plays a significant and permanent role in both stages of the process.

As regards *epidemic effects,* their role varies depending on the stage of the process. A firm's adoption behaviour is influenced by the level of adoption and investment that prevails in the sector to which it belongs but is little affected by spillovers emanating from firms in their proximity. On the other hand, use intensity is highly influenced by the level of adoption in local firms and in other firms of the same industry. Let us note in this respect that epidemic effects, at this stage of the process, can actually be interpreted as network externalities since, as we have seen, it might be in a firm's interest to use a new technology – particularly the Internet- if the other firms in its geographic environment, with which it is more likely to interact (commercial or productive interaction), use these new technologies[10]

[10] Our data does not enable use to distinguish and isolate these two effects.

Table 3. The general determinants of adoption and use intensity in French industrial firms: general model

Endogenous Variables	Adoption of Internet and e-mail (first stage)	Intensity of Internet and e-mail use (second stage)
I. The internal characteristics of the firm		
Size	0.211 ***	- 0.019 ns
Average level of remuneration	0.244 ***	0.302 ***
Belonging to a group or not	0.311 ***	0.599 ***
Multi unit spatial organisation	- 0.154 ***	0.028 ns
II. The characteristics of the environment		
Spatial externalities		
Urban economies (type of area where the head office is located): Urban	(Ref.)	(Ref.)
Peri-urban	- 0.048 ns	- 0.001 ns
Rural	- 0.088 ns	- 0.216 ***
Industrial agglomeration economies	-0.032 ns	- 0.069 *
Commercial determinants :		
Level of competition in the sector	0.238 ns	0.437 *
Rate of openness to international markets	0.603 ***	0.850 ***
III – Epidemic effects		
Level of adoption in the local environment	0.080 ns	0.272 **
Level of adoption in the sector to which the firm belongs	0.366 ***	0.957 ***
Level of investment in the firm's local environment	0.172 ns	0.588 **
Level of investment in the sector	0.513 **	0.702 ***
III – Type of connection		
Modem	--	(Ref)
Medium flow	--	0.647 ***
High flow	--	1.042 ***
Constant		
Mills	2.0615 ***	
Number of observations	5018	
Number of censored observations	387	
Wald Chi2 (ddl)	881.34 (28)	

Main sources : EAE and TIC surveys, 2002.

VI. Firms' behaviours according to their location (rural vs. urban areas)

In this section, we aim to analyse the differences in ICT adoption and use behaviour that exist between both categories of firms, according to whether they are located in rural, urban or peri urban areas[11]

First of all, the results show that the determinants of adoption are overall similar in urban and rural firms. As in the general model, the factors related to firms' internal characteristics play a central role in the process of adoption, which is little affected by the environment's characteristics. The type of area in which urban and peri-urban firms are located no longer has an effect on their behaviour. However, the results show that in rural areas, there remains a residual divide between firms in isolated areas and those located in rural centres. The epidemic effects are essentially sector related and adoption is little influenced by the behaviour of local firms.

However there are significant differences between rural and urban firms in the transition from the adoption to the use of ICT. Firstly, we note that although the Mills ratio is positive for urban firms, it is non significant for rural firms. This tends to show that for rural firms, there is no direct relation between the process of adoption and the intensity of use. The latter depends more on the firm's own motivation or capacity to use these tools (in particular to solve problems of internal coordination) than on possible problems of access to these tools. The obstacle is no longer technical but is related to the firm's openness to the information and competencies associated with the tools. This is particularly true when the firm belongs to a group.

Concerning the extent to which firms use the Internet, we find again that rural firms are little influenced by their commercial environment (the degree of concentration has no effect), by its technological environment (non significance of the degree of adoption in the local environment), or even by its spatial environment. At this level, being located in an isolated rural area has the same effect as being located in a rural centre. Industrial agglomeration economies have no significant effect.

[11] This was done in order to avoid overloading the results section. This was appropriate in so far as the general model shows that there are no longer any significant differences between firms located in urban areas and those located in peri-urban areas in terms of adoption and use. However, we retain this type of location.

Table 4. The determinants of use intensity according to the type of location (urban vs. rural areas)

Endogenous Variables	Adoption		Intensity of Use	
	Urban firms IIa	**Rural firms IIIa**	**Urban firms IIb**	**Rural firms IIIb**
I. The internal characteristics of the firm				
Size	0.202 ***	0.230 **	- 0.043 ns	0.026 ns
Average level of remuneration	0.277 ***	0.173 *	0.296 ***	0.250 *
Belonging to a group or not	0.304 ***	0.328 ***	0.568 ***	0.575***
Multi unit spatial organisation	-0.129 **	-0.282 ***	0.033 ns	0.019 ns
II. The characteristics of the environment				
Spatial externalities :				
Type of area where the head office is located: Urban	(ref.)	-	(ref.)	-
Peri-urban	- 0.0 28 ns	-	-0.0 21 ns	-
Rural : rural pole		(ref)		(ref)
Other types of towns		- 0.229**		0.001 ns
Industrial agglomeration economies	-0.037 ns	- 0.012 ns	-0.085 ***	-0.010 ns
Commercial determinants :				
Level of competition in the sector .	0.431ns	-0.275 ns	0.529 **	-0.028 ns
Rate of openness to international markets	0.603 ***	- 0.439 ns	0.790 ***	0.866 *
III – Epidemic effects				
Level of adoption in the local environment	0.064 ns	0.170 ns	0.271 ***	0.285 ns
Level of adoption in the sector to which the firm belongs	0.296 ***	0.579 ***	0.910 * **	1.074 ***
Level of investment in the firm's local environment	0.337 ns	- 0.699 ns	0.715 ***	0.503 ns
Level of investment in the sector	0.883 ***	- 0.308 ns	0.729 ***	0.335 ns
III – Type of connection				
Modem			(ref)	(ref)
Medium flow			0.649 ***	0.613 ***
High flow			1.068 ***	0.927 ***
Constant	-0.050 ns	0.230 ns	-3.816 ***	-4.201 ***
Mills			1.499***	2.313 ns
Number of observations			3894	1124
Number of censored observations			269	118
Wald Chi2 (ddl)			1021.33 (26)	147.94 (26)

Main sources : EAE and TIC surveys, 2002.

The only external determinant is related to the sector: the fact that other firms in the same sector use ICT generates a major spillover effect on rural firms' intensity of use. This effect seems to reflect the importance of technical and commercial, sector related logics in which rural firms operate. The strong presence in rural areas of agro-food firms that must manage a double constraint – access to raw materials and access to urban consumption markets - is significant in this result. These firms reach urban consumer markets either directly or through the retail industry, which implies important needs of coordination through ICT. This sector related logic necessitates, internally, that the firm be part of a group, that its workforce be highly qualified and that it be equipped with a high bandwidth connection.

In the case of urban firms, the user profile is inversed. Thus, it is more sensitive to the different dimensions of its external, commercial or spatial environment; and the modes of internal coordination do not play the same role as they did at the adoption stage. The epidemic effects, whether they are sector related or geographic, play a significantly positive role on the intensity with which urban firms use ICT. Nevertheless, when the effects considered are geographic, the latter might reflect network externalities or a pure epidemic effect.

VII. Conclusion

The aim of this study was to analyse the evolution of the « spatial digital divide » by making a distinction between the two stages of the process of ICT diffusion, and by trying to determine whether firms' processes of appropriation and / or logics of diffusion differ according to the type of area in which they are located (urban vs. rural). To answer this question, we have constructed an original model of technology diffusion in which we have merged the models concentrating on epidemic effects and the so-called equilibrium models modelling the decision to adopt ICT as the result of an economic calculation by firms, depending on their own characteristics and those of their competitive, industrial and local environments. This model is tested using data from a recent national survey ("ICT and electronic commerce", 2002).

One of the main results is that, for a given size and sector, though spatial inequalities related to ICT adoption are no longer significant in France, they remain very important in the processes of ICT appropriation and use by firms. Although the Internet and email tools have been widely adopted by firms, the intensity of ICT use varies significantly according to the firms' location. Moreover, urban and rural firms have inverse adoption behaviours: indeed, urban firms are more sensitive to the different dimensions of their external environment (commercial or spatial), and their internal modes of coordination do not have the same impact as they did on the adoption process. The epidemic effects, whether they are geographic or

sector related, tend to increase the intensity of ICT use by urban firms. Rural firms, on the contrary, are little influenced by external determinants, with the exception of spillover and sector related epidemic effects.

More generally, the results show the importance of epidemic effects and of information spillovers on technologies in ICT diffusion in French industrial firms. These epidemic effects are related to the firms' internal characteristics but also to the nature of their industrial environment, with a negative effect of industrial agglomeration. This seems to indicate that ICT differ from other types of technologies in that they are used differently by firms depending on their local environment. In this respect, it would be interesting to conduct further studies on the nature of local industrial structures and to go beyond the observation of a more or less high spatial concentration.

References

Antonelli C., 1999, *The microdynamics of technological change*, Roultlege.

Astebro T., 2004, Sunk cost and the depth and probability of technology adoption, *Journal of Industrial Economics*, 52(3), pp.381-399.

Battisti G. et P. Stoneman, 2003, Inter and intra-firm effects in the diffusion of new process technology, *Research Policy*, 32, pp.1641-1655.

Battisti G., P. Stoneman, 2005, The intra-firm diffusion of new process technology, *International Journal of Industrial Organization*, 23, pp.1-22.

Blaas E., Nijkamp P., 1994, New technology and Regional Development in the European snowbelt towards a new emerging network? in Johansson B., Karlsson C., Westin L., eds, p*atterns of a network economy*, Springer Verlag, pp.275-291.

Bresnahan T.F., Brynjolfsson E., and Hitt L.M., 2002, Information technology, workplace organisation, and the demand for skilled labor: Firm-level evidence, *Quarterly Journal of Economics*, 112, pp.339–376.

Bresnahan T., Trajtenberg M., 1995, General Purpose Technologies: 'Engines of Growth'? *Journal of Econometrics*, 65 (1), pp.83-108.

Cairncross F., 2001, *The death of distance: how the communications revolution will change our lives*, Harvard Business School Press, Cambridge.

Canepa A., Stoneman, P., 2003. Comparative international diffusion: patterns, determinants and policies, *Economics of Innovation and New Technology*, 13, pp.279–298.

Capello R., Nijkamp P., 1996, Telecommunications technologies and regional development: Theoretical considerations and empirical evidence*, The Annals of Regional Science*. Special issue on Information and Communications Networks in Space, 30(1), pp.7-30.

Caroli E., Van Reenen J., 2001. Skill biased organizational change? Evidence from a panel data of British and French establishments, *Quarterly Journal of Economics* 116, pp.1447-1492.

Charlot S., Duranton G., 2003, Cities and Workplace Communication. Some French Evidence, Mimeo, London School of Economics.

Chevassus-Lozza E., Galliano D., 2003, Local Spillovers, Firm Organization and Export Behaviour: Evidence from the French Food Industry, *Regional Studies*, 37(2), pp.147-158.

Cohen W., Levinthal D., 1989. Innovation and learning: the two faces of R&D, *Economic Journal*, 99, pp.569- 596.

Fischer M.M., Johansson B., 1994, Networks for process innovation by firms: conjectures from observations in three countries, in Johansson B., Karlsson C., Westin L., eds, p*atterns of a network economy*, Springer-Verlag, pp.261-272.

Forman C., 2003, The Corporate Digital Divide: Determinants of Internet Adoption, Working Paper.

Forman C., Goldfarb A., and Greenstein S., 2005a,Technology adoption in and out of major urban areas: When do internal firm resources matter most?, Working Paper.

Forman C., Goldfarb A., and Greenstein S., 2005b, How did location affect adoption of the commercial Internet? Global village, urban density and industry composition, forthcoming in *Journal of Urban Economics*.

Funck R.H., Kolawski J.S., 1990, Innovation, new information technologies ant the structure of urban regions, in Cappellin R., Nijkamp P., eds,*The Spatial Context of Technological Development*, Avebury, pp.75-93.

Gale F.H., 1998, Rural manufacturing on the crest of the wave: A count data analysis of technology use, *American Journal of Agricultural Economics*, 80, pp.347-359.

Gale F.H., 1997, Is There A Rural-Urban Technology Gap? Results of the ERS Rural Manufacturing Survey, *Agriculture Information Bulletin*, Number 736-01, United States Department of Agriculture.

Galliano D., Roux P., 2003, Spatial externalities, organisation of the firm and ICT adoption: The specificities of French agri-food firms, *International Journal of Biotechnology & Industrial Journal of Technology and Management*, 5(3/4), pp.269–296.

Galliano D., Roux P., and Filippi M., 2001, Organisational and spatial determinants of ICT adoption: the case of French industrial firms, *Environment and Planning A*, 33, pp.1643-1663.

Gaspar J., Glaeser E.L., 1998, Information technology and the future of cities, *Journal of Urban Economics*, 43, pp.36-156.

Geroski P., 2000, Models of technology diffusion, *Research Policy*, 29, pp.603–625.

Glaeser E., Kallal H.D., Scheikman J.A., and Sheifer A., 1992, Growth in cities, *Journal of Political Economy*, 100(6), pp.1126-1152.

Greenan N., 2003, Organisationnal change, technology, employment and skills: an empirical study of French manufacturing, *Cambridge Journal of Economics*, 27, pp.287-316.

Greenan N. and Mairesse J., 1999, Organizational change in French manufacturing: what do we learn from firm representatives and from their employees?, Working Paper 7285, NBER, Cambridge.

Greene W., 2003, *Econometric Analysis*, Macmillan IPG, New York, 5ème édition.

Hargittaï E., 2002, Second level digital divide. Difference in people's online skills, *First Monday, Peer Reviewed Journal on the Int*ernet.

Harrison B., Kelley M.R., and Gant J., 1996, Innovative Firm Behavior and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects, and Technological Change, *Economic Geography*, 72(3), pp.233-258.

Heckman J.J., 1979, Sample Selection Bias as a Specification Error, *Econometrica*, 47, pp.153-162.

Hollenstein H., 2004, The determinants of the adoption of ICT, *Structural Change and Economics Dynamics*, 15, pp.315-342.

Houzet S., L. Grasland, 2004, Les dimensions spatiales de la fracture numérique en France, *Réseaux*, Numéro spécial sur La fracture numérique, 22(127-128), pp.115-140.

Hwang J.H., 1998, Computer networks and the reorganization of corporate space: the case of the Korean electronics industry, *Papers in Regional Science: The journal of the RSAI*, 77(2), pp.131-154.

Insee-Inra, 1998, *Les campagnes et leurs villes*, Collection Contours et Caractères, Insee.

Karlsson C., 1995, Innovation adoption, innovation networks and agglomeration economies, in Bertuglia C.S., Fischer M.M., Preto G. (eds.), *Technological change, economic development and space*, Springer, pp.184-206.

Karshenas M., Stoneman P., 1995, Technological diffusion, in Stoneman P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, Blackwell, Cambridge.

Karshenas M., Stoneman P., 1993. Rank, stock, order and epidemic effects in the diffusion of new process technologies: an empirical model, *RAND Journal of Economics*, 24(4), pp.503-528.

Katz M.L., Shapiro C., 1985, Network externalities, competition and compatibility, *American Economic Review*, 75(3), pp.424-440.

Kusmin L.D., 2002, Wage premiums for on-the-job computer use: A metro and nonmetro analysis. Food and Rural Economics Division, U.S. Department of Agriculture, Rural Development Research Report No. 95.

Little J.S., Triest R.K., 1996, Technology Diffusion in U.S. Manufacturing: the Geographic Dimension. Proceedings of Technology and Growth Conference, Boston Federal Reserve Bank.

McGranahan D.A., 2002, The new rural Economy: Local context and advanced technology use by small, independent manufacturers in rural areas, *American Journal of Agricultural Economics*, 84(5), pp.1237-1245.

Majumdar S.K., Venkataraman S., 1993, New technology adoption in US telecommunications: the role of competitive pressures and firm-level inducements, *Research Policy*, 22, pp.521–536.

Malmberg A., Malmberg B., Lundequist P., 2000, Agglomeration and firm performance: economies of scale, localisation, and urbanisation among Swedish export firms, *Environment and Planing A* 32, pp.305-321.

Mansfield E., 1968, *Industrial Research and Technological Innovation*, Norton, New York.

Mitchell S., Clark D., 1999, Business adoption of information and communication technologies in the two-tier rural economy: some evidence from the south Midlands, *Journal of Rural Studies*, 15, pp.447-455.

Newlands D., Ward M., 1999, The adoption of new communication technologies by firms in rural areas: a Scottish case study, in Fischer M.M., Suarez-Villa L., Steiner M. (eds.), *Innovation, networks and localities*, Chapter 12, Springer-Verlag.

Ota M., Fujita M., 1993, Communication technologies and spatial organization of multi-unit firm in metropolitan areas, *Regional Science and Urban Economics*, 23, pp.695-729.

Rallet A., Rochelandet F., 2005, ICTs and Inequalities: The Digital Divide, in Brousseau E., Curien N. (eds.), *Internet and Digital Economics*, Cambridge University Press, to be published.

Reinganum J.F., 1989. The timing of innovation: research, development and diffusion, in Schmalensee R. et Willig R. (eds.), *Handbook of Industrial Organisation*, vol. 1. Elsevier, New York, pp.849-908.

Saloner G., Sheppard A., 1995, Adoption of technologies with network effects: An empirical examination of the adoption of automated teller machines, *RAND Journal of Economics*, 26(3), pp.479-501.

Stoneman P., Battisti G., 1997, Intra-firm diffusion of new technologies: the neglected part of technology Transfer, *International Journal of Industrial Engineering*, 4 (2), pp.270–282.

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