Intra-firm diffusion of innovation: Evidence from Tunisian SME's in matter of Information and Communication Technologies

Adel BEN YOUSSEF*
ADIS and Univ. Paris Sud- France

Walid HADHRI**
ADIS and Univ. of Tunis-Tunisia

Hatem M'HENNI***
CEFI-ESSEC and Univ. of Tunis - Tunisia

Abstract

The aim of this paper is twofold: first, we want to explore the intra-firm diffusion of information and communication technologies (ICT) within the Tunisian firms and to characterize its general trends en matter of adoption and usage. Second, we want to emphasise the rank and epidemic effects stressed by the disequilibrium models of intra-firm diffusion of innovation following the traditional view of (Mansfield, 1963, Antonelli 1985). Based on face-to-face questionnaire of a random sample of 175 firms our article shows that:

(i) Three technological waves of ICT adoption are well characterized in the Tunisian manufacturing sector. This dynamic of adoption is linked to the age of the technologies. Time is the main explanatory variable for intra-firm diffusion of these technologies.

(ii) A positive correlation between the size of the firm, seniority and the depth of adoption is found. This econometric estimates show that the rank effect is well characterized within the Tunisian firms.

(iii) A positive correlation between technological absorptive capacity building and intensity of ICT usage is found. This correlation confirms the epidemic effect.

Our results show that disequilibrium models explanations of intra-firm diffusion of innovation are valid within the Tunisian manufacturing sector and seem more appropriate than the equilibrium theory for LDCs.

Key words: ICT adoption, depth of ICT adoption, Ordered Probit Model.
JEL Classification: L21, O31, O33

---

*adel.ben-youssef@u-psud.fr,**walid.hadhri@u-psud.fr,***hatem.mhenni@essect.rnu.tn

Introduction

Information and Communication Technologies (ICT) are widely considered as one of the most important engine of growth in the late 1990s (Bresnahan and Trajtenberg, 1995 Helpman, 1998 and Antonelli, 2003). They impact the nature and the scope of the firms by cutting costs and transforming the markets borders. Several studies have recommended that firms and governments must invest on those technologies and strong evidence linking between the adoption of those technologies and the increasing performances of the firms are found worldwide (EOCD, 2004).

These technologies offer effective opportunities for firms to reach bigger markets' share by allowing them to compete in the global market. They are offering the opportunity to cut costs by better coordination and by outsourcing some applications like human resources or accounting. They are also offering opportunities to build more efficient information systems and to do some tasks by workflows... However, in order to reach efficient outcomes, the adoption of these technologies is not sufficient. Some firms and their employees have access to all the ICT equipment whether they do not use them or use them not intensively. The question of usage, the intensity of usage and the nature of usage are becoming central.

Asterbo (2004), among others, propose that researchers must focus more on effective usage and the intensity of usage (depth of adoption) and less on adoption of ICT itself. In fact the intensity of usage reveals how people are engaging in better coordination, more efficient production systems and more flexible practices within the firms. Asterbo observation is highly important when we look at developing countries' firms. From the macroeconomic point of view, data gathered by ITU show that developing countries are bridging the gap of ICT equipment, however little is known about microeconomics of the usage and the intensity of usage. Difference in matter of expected effect of those technologies between developing and developed countries are important and may lead to different patterns of usage and need then an appropriate economic arguments.

Starting from these observations, the aims of this article are two folds. First we want to characterize different patterns between adoption of ICT and the depth of adoption of ICT in the context of a small open developing country (Tunisia). Our article relies on the theoretical background of intra-firm diffusion of technologies initiated by Mansfield (1963) and Antonelli (1985). Second we want to emphasise the relationship between the depth of adoption and main characteristics of the firms: size, age and time of adoption in order to validate the models of intra-firm diffusion of innovation.

The paper is organised as follows. Section two summarizes the related literature and examines some of the firms' features that, in the rest of the paper, will be used as explanatory variables of ICT adoption. Section three presents our main hypothesis. Section four presents the sample's characteristics and the descriptive analysis. Section five presents the econometric models. Section six discusses the results and section seven concludes.

1 Theoretical Background

The theoretical starting point for our analysis is the well-established literature on new technology adoption. This literature points the delays in the adoption of new technology and differences in adoption rates across firms, industries and countries. To understand the adoption and diffusion of ICT as a new technology it is therefore essential to uncover the factors that explain this delay and the variation in the rates of its adoption.

Two main theoretical backgrounds explain the intra-firm diffusion.

The first tradition is the epidemic models (Mansfield, 1963; Antonelli, 1985 Levin et al. 1992). In this approach it is assumed that the use of a technology increases over time as the risk attached to further adoption is reduced through learning. Thus, it's assumed that the usage pattern is S shaped curve following a logistic curve. Starting from this point of view the older the adoption of the technology the more is the intensity of usage. The usage of the technology is not related to the cost/benefits analysis and that's why this approach is called disequilibrium approach. Only time matters!

The second type is called the equilibrium models. Stoneman and Battisti (1997) suggest that the pattern is not increasing monotonically from the first date of adoption. They rely to the equilibrium approach, which suggests a non-linear and discontinuous diffusion pattern. « *At each moment, technology use in time t will only extend to the point where the marginal expected profit gain from further adoption equals the cost of adoption (appropriately defined) of the new technology. Over time either the marginal gain and/or the cost of adoption may change and as they do so the level of use will change*» (Battisti and Stoneman, 2005). In this approach, the intensity of usage may be very different from one firm to another and vary each period depending on the cost/benefits approach. The perceived value of the marginal benefits may vary strongly.

An alternative approach where both inter and intra-firm margins are approached simultaneously is extensively explained in the Battisti & Stoneman view (Battisti, 2000; Battisti and Stoneman, 2003, 2005, 2009). The general idea is that the inter-firm phenomenon may be more important in the earlier stages of diffusion, whereas the intra-firm effect may become more relevant at the later stages of diffusion. This model is based on three theoretical trends: the diffusion view, the complementarity view and the neo-Schumpeterian approach. Diffusion models emphasize the impact of rank, stock and epidemic effects on the firms' ICT adoption. This work will emphizase these types of diffusion determinants. Through the neo-Schumpeterian approach, is introduced the notion of the firms' selection capacity and reinforced the role of technological capabilities and knowledge absorption capacity.

The debate between these opposite approaches is a debate about the determinant of depth of usage of these technologies over time. While the disequilibrium approach stresses time, learning and capabilities as basic determinants of the intra-firm diffusion of technologies, the equilibrium approach mention the return on investment, costs of technologies and the perceived value of the usage as the main determinants. Our article tries to contribute to this debate by examining two types of ICTs' determinants of adoption and usage (rank and epidemic effects). In fact the data gathered by our survey do not let us to explore the stock effect. This was the case also for other studies where rank effect and stock effects were computed together without lack of generality (Battisti and Stoneman, 2005).

Rank effect

In order to discuss the rank effect we will focus on two main determinants: size and firm seniority. These two variables are commonly considered by the intra-firm diffusion literature as the main variables able to detect the rank effect. Starting from the equilibrium theory of intra-diffusion of technology, size cannot matter. In fact, since the intensity of usage depends on the returns of the technology, there's no need to have a monotonic relation between size and usage. However, a positive relationship between size and intensity of use (depth of adoption) may confirm the disequilibrium and epidemic theory, which suppose a relationship between size and usage intensity (depth of adoption). The main argument relies on the capability of the firm to reduce uncertainty and risk associated with further usage of the technologies. This fact supported by a large empirical literature showing that the adoption of new technologies is more likely when the size of firms is larger. Firm's size is commonly used in the empirical literature on new technology adoption because it is easy to observe and it serves as a proxy for several arguments. Different explanations are given in order to justify why large firms are more able to adopt and use new technologies (Fabiani et al., 2005; Morgan et al., 2006; Thong, 1999). First, SME rather easily show a daily use of digital technologies, but they need to be assisted to reach the more efficient uses. They need to build a "technological absorptive capacity". Therefore, the larger a company the wider is its "technological absorptive capacity". ICT are general purposes technologies (Bresnahan and Trajtenberg, 1995). They are not mature by nature and need to be adapted to the specific needs of the firms. Larger firms are more able to dedicate people to these tasks and to the resolving problems linked to ICT usages. Second, it's well known that these technologies are network technologies. Since then, the size of the firm is an objective dimension of the size of the network. Firms use these technologies in more effective way when their size is big. There is a need for more coordination among workers and staffs. They need more information about these tasks. For example, the need for the implementation of Intranet application is correlated to the size of the firm.

From the equilibrium theory point of view there's no specific reason for a correlation between the firm's seniority and the intensity of usage. In fact, since the usage depends on the marginal expected revenue; different firms with different ages may use the technology differently. However, from the disequilibrium theory seniority may be correlated with the experience of usage and its absorptive capacity of using the technology. A positive relationship may be found between seniority and intensity of usage (intra-firm diffusion of the technology). This confirms then that the innovation follows an S shaped model of diffusion.

Epidemic Effect

Epidemic effect refers to the fact that the technology is more used when the other firms use it. Two main variables were selected in order to test the epidemic effect: adoption time and the website development. The adoption time considered is revealing that firms are more and more using these technologies when time is spent. The novelty of our approach is that most of the literature considers the evolution of the number of the firms adopting a considered technology. We prefer here to consider the speed of adoption of a technology by the firms for two main reasons. First, the number of firms adopting the considered technology is correlated with the speed of adoption. Since then the usage of one or the other of these variables is sufficient. Another argument is that in the context of our study, since the sample is not too large, the evolution of the proportion of firms using a particular technology may not reveals the true dynamics. The speed of adoption by firms is then more able to show this dynamics and the patterns of adoption and usage.

The second variable considered here is the possession of a website. In fact, firms invest in building website in order to have better communication of their production and in order to have better visibility. But the game seems here like a coordination game. Firms are moving from an equilibrium where no one have a website to a situation where all the firms have a website. An evolutionary dynamics of adoption seems working well. The more the proportion of firm adopting a website the bigger is the probability of a given firm to invest in making a website. It becomes a necessary condition since consumers are changing their habits. This variable is important in order to detect the epidemic effect in our study.

Technological absorptive capacity effect

Technological absorptive capacity is linked to the uncertainty and risk reduction when using a particular technology. In fact, firms may invest in order to reduce this risk in human capital and built a technological absorptive capacity. The more the firms invest in human capital and in "framing" and the more the technology is spread over the firms. The rate of framing is then considered as a proxy for risk reduction and may be considered as a first step in order to have an epidemic effect. Several studies have pointed that in order to have an optimal use of a given technology firms capabilities in matter of technologies help her to better use other type of technologies. Lal (1999) pointed out that Indian firms manufacturing electric and electronic goods have a higher probability of adopting ICTs when: (i) the managing directors have a high level of education, (ii) the firm's skill intensity is high, and (iii) the managers have a clear strategic vision of R&D importance. Arvanitis and Hollenstein (2001) have provided clear evidence of these multiple effects. Using firm-level data for Swiss manufacturing. They underlined that AMT adoption is positively influenced by the share of employees with qualifications at the tertiary level. Hollenstein (2004) used an ordered probit model to test the ICT adoption behaviour of Swiss firms. He confirmed the influence of several determinants such as rank and epidemic effects, as well as new workplace practices. He also showed that the firm's absorptive capacity – captured by variables measuring the level of employees' qualification, the participation in ICT-oriented training courses, and the firm's innovative behaviour – has a significant positive impact on ICT adoption.

In our study we will approximate this technological absorptive capacity by the variable rate of frame. The higher is this rate the more the firm invest in capabilities in order to use ICT.

2 Hypothesis, Sample and Descriptive analysis

2.1 ***Hypothesis***

The aim of our work is to test three hypotheses related to the depth of adoption of ICT (intra-firm diffusion of innovation) in the context of an emerging country like Tunisia. The three hypotheses are formulated in order to confirm the

Hypothesis 1 (S shaped diffusion pattern): *The main determinant of ICT diffusion is time. This hypothesis confirms Mansfield (1963) view.*

Proposition 1: Three types of ICT clusters diffusion patterns are identified depending on the seniority of the technologies.

Hypothesis 2 (Rank Effect): The firm size, its seniority exert a positive effect on usages and equipment. They confirm the Rank effect and the disequilibrium theory.

Hypothesis 3 (Epidemic Effect): Depth of usage of ICT is positively correlated to adoption time and the possession of a website.

In order to demonstrate our hypothesis we will present the sample and the data first, and then we will confirm the first hypothesis by descriptive analysis and the two last ones by econometric estimations.

2.2 ***The Sample***

The data for this study were gathered by a face-to-face questionnaire administrated to a random sample of 175 firms in Tunis, the largest metropolitan cities in Tunisia during the period from June 2004 to February 2005. Out of 320 surveys prepared, 205 were completed and returned. However, only 175 usable surveys were retained for data analysis, providing a response rate of nearly 55%. Table 1 summarizes the size of the firms and their sectoral belonging.

In spite of this, the qualitative findings of the survey are very likely to hold in a much broader setting since our sample has all the characteristics that make it an ideal candidate to represent the central nucleolus of stable and viable Tunisian firms. And as we shall see below, there are no size and industry specific "traits" that would make it difficult to generalise our results. Firms belonging to high-tech industries are relatively rare (although not absent). This characteristic, in our opinion, makes our study particularly interesting when it comes to investigating ICT penetration and usage in the majority of Tunisian (and, to some extent, of South Med) regions, and not only in the most advanced ones.

Before its implementation, three professors checked the questionnaire in order to ensure its consistency. Each survey contained a cover letter explaining the purpose of the study. For each firm, the participation of the contact person was voluntary and participants were assured that their answers would be treated with confidentiality. All respondents were from top management staff.

The obtained dataset contains various types of information: (1) general characteristics of the firm such as size, sector, legal' status... (2) Usage and depth of use of the considered technologies (3) factors influencing (positively or negatively) the use of ICTs, (4) strategic use of ICTs, (5) adoption of new organizational practices and finally (6) ICT and workplace.

Table 1. Sample distribution by firm size and industry.

Industry / Size	Clothing & Footwear	Chemicals and Plastic products	Mechanical & Electrical Equipment	Food & Beverages	Total
5 to 24	6.45	32.35	35.90	10.00	18.86
24 to 49	16.13	41.18	30.77	7.50	22.29
50 to 99	33.87	17.65	15.38	17.50	22.86
More than 100	43.55	8.82	17.95	65.00	36.00
Total	35.43	19.43	22.29	22.86	100

Firms with less than 100 employees account for approximately 64% of the sample; for the reasons explained before, among them small firms (having between 5 and 49 employees) strongly prevail over micro-businesses. According to the definition of SMEs adopted by the EU, medium-sized firms should be added to the small ones, which leave us with a share of large firms in the sample of less than 5%.

As far as the industry distribution is concerned, it emerges that these SMEs are particularly concentrated in consumer goods industries such as Food & Beverages and Clothing & Footwear. There is always a quite realistic representation of two other sectors Mechanical & Electrical Equipment (22,3%) and Chemicals & Plastic products (19,4%).

2.3 ***Three waves of ICT and S shaped curve of ICT diffusion***

Our data processing confirms that ICT are general purposes technologies (GPT's) and a heterogeneous clusters composed at least of three main waves of technologies. All our indicators (adoption level of ICTs [1], depth of usage of ICTs [2] and time required to use particular ICTs [3] (see the following table)) show up that there is a:

[1] Estimated by the percentage of firms using each technology
[2] Evaluated by the average score of intensity of use indicated by respondents for each technology (likert scale)
[3] Calculated by the time gap between the creation date of the firm and the first use of each technology

- First wave called "*first generation technologies*" assumed to be relatively widespread (more than 80%), intensively used (between 4 and 5 on Likert scale) and rapidly introduced in all business sectors. These technologies are: fixed phones, fax, office computers and general purpose software,

- Second wave: "*intermediary technologies*" with high potential of use. In the mid of the nineties they were named « new » ICTs: Internet, E-mail, free software, and mobile phones.

- Third wave or "*up to date technologies*" based on networking. They are among the last technological generations of ICTs. Most of them need, to optimize their use, costly investments, know how and qualified human resources. These technologies are: Intranet, laptops, videoconference (VC) and Electronic Data Interchange (EDI).

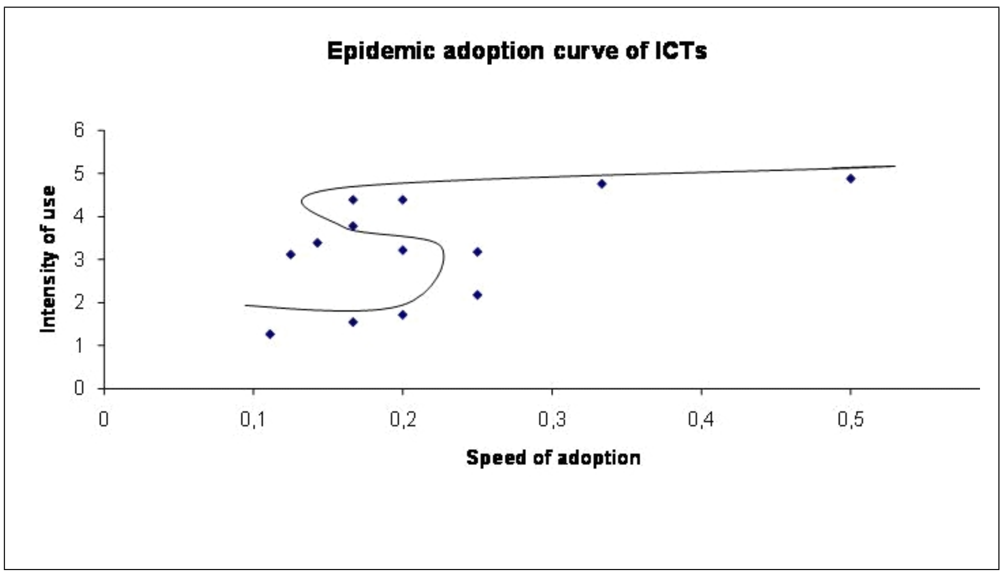
Table2. Adoption level, depth of usage and time required to use particular ICTs

	Penetration level	Intensity of use	Time required to use a particular ICT
Videoconference	11.5	1.27	8.76
EDI	14.2	1.55	5.67
Intranet	18.2	1.72	5.34
Laptops	36.5	2.18	4.34
Email	67.6	3.18	4.20
Internet	70.9	3.22	4.89
Mobile phone	79.1	3.78	5.84
Specific Softwares	58.1	3.12	7.88
Free Softwares	70.3	3.39	7.05
General Purpose Softwares	90.5	4.39	6.10
Office computers	95.3	4.49	5.43
Fax	96.6	4.76	2.87
Fixed phone	98.6	4.88	2.25

Our results are always in accordance with similar studies like those of Lucchetti and Sterlacchini (2004) typology. These authors identified three types of ICTs:

General-use ICTs composed essentially by our first and second generations of ICTs, Production-integrating ICTs basically Intranet and EDI and Market-oriented ICTs identified by the presence and the content of a firm's Web site [4] . However, our classification seems to be close to the disequilibrium dynamics where only time matters.

The figure below setup a link between the speed of adoption and the intensity of use of the chosen technologies. The relation takes the form of an S shaped curve (sigmoid) reminding the Mansfield hypothesis. In the first part of the plan we found those technologies with low intensity and low speed they are the newest one (third wave), than we found technologies characterized by low speed and more or less high intensity of use. They are the second wave of ICTs. Finally old technologies with high speed of adoption and high intensity of use are localized at the top of the curve.



It becomes obvious that in order to highlight the depth of adoption of ICTs and its main determinants we have to discriminate between these waves of technologies and to focus on the second and third waves.

The descriptive analysis shows clearly that there's a confirmation of the disequilibrium theory of innovation diffusion. Time seems to be the more important variable explaining the patterns of diffusion and the dynamics seems to be

[4] Only 12,8% of our sampled firms hashave a web site and none of them use it for any type of e-commerce even if the managers' perception of the importance of such kind of exchange (commerce) is very high (more than 90% of them said that electronic commerce will be very important in determining the competitively capacity of their firm).

cumulative. One of the most important reasons may be the rationality of the entrepreneurship in the Mediterranean area as regards the technology (Bellon, Ben Youssef et M'henni, 2006). Bounded rationality seems to be the rule and there's a lack of awareness about the possibility offered by ICT (Bellon, Ben Youssef and Mhenni, 2007) Further investigations are needed in order to understand whether the more stabilized effects are also confirming this theory.

3 Econometric Analysis

3.1 ***Econometric models***

a. ICT adoption model

In order to study the relationship between ICT adoption and usage and their determinants (rank and epidemic effects) we use an ordered probit econometric model. The aim of the model is to determine the effect of a given factor on the probability of the ICT adoption and use by the firm... This method makes it possible to study the impacts of different factors on a multinomial ordered variable. This method is widely used nowadays for similar studies (Galiano and Roux, 2006, Bocquet and Brossard, 2007).

The basic variables of our study are binary and qualitative [5] . Firms' answers give us the information on whether they adopt a particular technology or not. For example, a firm indicates if it chooses the adoption of Intranet or not. Since we have various types of binary variables, they are gathered, then, in different types of scores, in order to formulate a total score of ICT adoption. This gives us the multinomial character of this distribution (because it is composed of various methods) and the ordered character (because it is deduced starting from other binary variables).

Starting from these hypotheses, we use the ordered probit models. The explained variable is subscripted from 1 to 13 for the adoption' score. These variables are thus discrete and ordinate. A probit multinomial model would thus neglect the ordinality of the dependent variable while a linear regression, on an opposite sense, would treat the difference between indices 3 and 4 in the same way that it treats the difference between indices 1 and 2, whereas this corresponds only to one classification. In these two cases, the estimators would be thus biased (Greene 2000; Thomas, 2000).

The models commonly used for this type of variables are thus the ordered

[5] They take the value 1 if the firm adopt an ICT tool and value 0 if not.

logit and probit models. These models are founded on the estimation of a continuous latent variable, subjacent with the subscripted variable of interest. In an ordered probit model, the residual associated with this latent variable is supposed to follow a normal law. Following this method, it's possible to study the influence exerted by series of factors on a multinomial ordered variable (Greene, 2000; Thomas, 2000). The ordered probit models are generally based on probability. The latent model is similar to a binomial probit.

$$y_i^* = \beta x_i + \varepsilon_i$$

Where $y_i^*$is unobserved, continuous and latent measurement of ICT use, x_i a vector of endogenous variables, β the vector of the parameters and, ε_i the residual error which follows a normal distribution. In the case of the probit multinomial ordered, one observes that for:

$$y_i = j \text{ if } c_j < y_i^* < c_{j+i}$$

Where $j = 0, 1, \ldots, J$ represent the various methods of the endogenous variable. The observed coded variable, y_i are determined by the following model:

$y_i = 1 \text{ if } -\infty < y_i^* < \mu_1,$

$\quad = 2 \text{ if } \mu_1 < y_i^* < \mu_2,$

$\quad = 3 \text{ if } \mu_2 < y_i^* < \mu_3,$

$\quad \vdots$

$\quad = n \text{ if } \mu_{n-1} < y_i^* < \mu_n,$

where μ_k is unknown parameters that must be estimated with the vector β.

The estimate of the model enables us to obtain the probabilities of realization of each index of the dependent variable. These probabilities are given by:

$Prob(y_i = 1) = \phi(\mu_1 - \beta' x_i)$

$Prob(y_i = 2) = \phi(\mu_2 - \beta' x_i) - \phi(\mu_1 - \beta' x_i)$

$Prob(y_i = 3) = \phi(\mu 3 - \beta' x_i) - \phi(\mu_2 - \beta' x_i)$

$\vdots$

$Prob(y_i = n) = 1 - \phi(\mu_n - \beta' x_i)$

With ϕ represents the normal distribution. The adjustment of the model is done by the Maximum likelihood estimation (Maddala & Flores, 2001) written like the followings:

$$L = \prod_{i=1}^{N} \prod_{j=0}^{J} F_{ij}(x, \beta)^{ij}$$

Let us note that the marginal effects of the explanatory variables x_i on the probabilities are not equal to the coefficients. Thus, only the sign of the coefficient will be interpreted here and not its value. We try to model first the intensity of adoption of ICT and second the intensity of usage of various ICT tools.

The basic model specification estimated for the ICT adoption score yi1 is as follows:

$$y_{i1} = \alpha + \beta_1\ Size + \beta_2\ Age + \beta_3 Adoption\ time + \beta_4 Web\,\mathrm{Si}\,te + \beta_5 Rate\ of\ \ frame + \varepsilon_{i1}$$

b. Intensity of ICT use model

Firms were asked to classify themselves, on a 5 points ordinal scale, according to the answer [6] that best described their intensity of usage of ICT tools. The ICT tools list included the fourteen tools listed in table 1. The weighted values were added across all ICT tools listed to yield a total intensity of ICT use score. Higher scores represented more intensity of use. Thus, a score of 65 indicated that a firm used all thirteen tools intensively.

Data were analysed using multiple regression analysis with a stepwise procedure used to determine the relative importance of a set of independent variables in determining the firm's intensity of ICT use score. We estimate a linear model of type:

$$y_i = \beta X_i + u_i$$

Where y_i is total intensity of ICT use score, X_i a vector of endogenous variables, u_i the vector of the parameters and, the residual error, which follows a normal distribution.

Data were analysed using multiple regression analysis with a stepwise procedure used to determine the relative importance of a set of independent variables in determining the firm's intensity of ICT use score. We estimate a linear

[6] The answers were weighted as (1) null, (2) weak, (3) average (4) important, (5) very important.

model of type:

$$y_{i2} = \alpha + \beta_1\ Size + \beta_2\ Age + \beta_3 Adoption\ time + \beta_4 Web\,\mathrm{Si}\,te + \beta_5 Rate\ of\ frame + \varepsilon_{i2}$$

The data were analysed using SPSS 13.0, to the principal component analysis, and STATA, v. 10.0, to the estimation of the models. The data were examined for violation of the assumptions underlying multivariate methods prior to the analysis.

3.2 ***Variables***

a. Dependant variables

In our study we considered two models for two different dependant variables. Our dependent variables are obtained starting from the calculation of a total score of ICT adoption and a score of ICT uses.

Variables measuring ICT adoption

Firstly, we calculate the stock of thirteen ICT tools cited above adopted by the firms: 1: Fixed telephone, 2: Fax, 3: Desktop machine, 4: Generic software, 5: Mobile phone, 6: Internet... Every firm has a score between 0 and 13. The variable used here is an ordered polytomic variable characterizing the adoption of the ICT (score of adoption).

These ICT variables are all binary, in which value '0' means that the considered technology is not adopted by the firm and value'1' that it is adopted.

Therefore this variable is presented as follows:

$$\begin{cases} y_i = 0 & \text{if zero equipment} \\ y_i = 1 & \text{if one equipment} \\ y_i = 2 & \text{if tow equipments} \\ & \vdots \\ y_i = 13 & \text{if 13 equipments} \end{cases}$$

y_i represent the dependant variable of the adoption of ICT by the firm i. This variable will be estimated by different explanatory variables (X_i).

Variables measuring intensity of ICT use

In this paragraph, we chose to analyse the intensity of ICT use, not according to the tool adopted (Internet, Computers, EDI…), but according to the firm' effective usage intensity. The variable used here is a continuous variable characterizing the intensity of the ICT use (score of usage). In our study we are going to use only the scores of waves 2 and 3 as previously identified. We suppose that the first wave is so general that all the firms use them intensively. Starting from this point we estimate four models: two models for the adoption and two for the intensity of usage.

b. Explanatory variables

The aim of our estimation is to characterise the adoption and usage of ICT by a sample of Tunisian firms. The related empirical studies have looked at three factors affecting new technology adoption: Rank effect (we select firm size and firm seniority as the main variables explaining this effect), 2) Epidemic Effect (we select the adoption time and the possession of a webpage) and 3) Absorptive Capacity Effect (we took into account the rate of frame).

"Firm' Size" is a variable, based on the number of employees, with four answer levels which measures a firm's size. If the firm has less than 25 employees it takes the value 0. If the firm has between 25 and 50 it takes the value 1. If the firm has a number of employees between 50 and 100 it takes the value 2. If the firm has more than 100 it takes the value 3.

A second explanatory variable is the firm seniority ("Firm Age"). This variable is continuous. It is in the form of number of years and refers to the creation date of the company.

The third explanatory variable is the rate of framing it corresponds to the percentage of senior executive, junior executive and technician of the total number of employees in the firm.

Concerning the time of adoption, it represents time since first adoption of ICT tools. This variable summarizes the speed of adoption of the ICT tools.

A fifth variable is the possession of a Website. This is a dummy variable which equal 1 if the firm has a Web site in 2005 and 0 if not.

4 Econometric Results

This section presents the empirical results of a probit ordered and linear model of the determinants, respectively, of ICT adoption and the use by Tunisian firms. These determinants are gathered according to the two different effects quoted above. In our empirical study we distinguish between ICT adoption and use of ICT.

In our econometric analysis, we estimated the four models by the two stages Heckman method take into account of the problem of selection biases. By estimating the models by the MMV, we noted that the coefficient of the reverse of the ratio of Millets is statistically non significant. This means that the substantial equation is independent of the equation of selection. The two decisions are thus made independently one of the other. This is why we can affirm that a model of selection does not make it possible to obtain more efficient estimators in our case.

The estimates obtained in the case of the discrete variables are shown in Table 3.

Table 3. Determinants of ICT Adoption and Intensity of Usages.

Explanatory Variables	**ICT adoption**		**Intensity of ICT use**	
	Wave 2	***Wave 3***	***Wave 2***	***Wave 3***
Rank Effect				
Firm size				
- 5 to 25	Ref.	Ref.	Ref.	Ref.
- 25 to 50	0. 6356**	0.2564	2.6921***	0.3153
- 50 to 100	0.7968***	1.3287***	3.0589***	1.2924**
- more than 100	1.3485***	1.9544***	4.5815***	2.6705***
Firm Age				
- less than 2 years	Ref.	Ref.	Ref.	Ref.
- 2 to 5 years	0.3425	0.0289	3.2656	0.1901
- 5 à 10 years	0.6887	0.0936	5.8622***	1.3260
- more than 10 years	0. 8782*	0.4220	6.4928***	2.1599*
Epidemic Effect				
Adoption time	11.7976***	67.9030***	4.2614***	71.3444***
Web site				
- No	Ref.	Ref.	Ref.	Ref.
- Yes	0.3856	0.9652***	1.4436*	1.7860***
Technological Absorptive Capacity effect				
Rate of frame	2.1176***	2.3756***	6.6630**	4.5047***
Constant			5.9610***	4.0709***

One can observe that most of the explanatory variables are significant. It can be outlined that almost all variables have a statistically significant effect on the adoption and use of ICT. Our results confirm most of the theoretical expected effects. Moreover, our results confirm the expected effects stated in our Hypotheses. Let discuss them starting by the rank effect.

Rank effect

Firstly, we demonstrate that firms' adoption and use of ICT is a positive function of their size. As it was expected, there is a positive correlation between firm's size and ICT capital stock (adoption), showing the existence of scale economies for digital investment. Similar to industrial technologies, large firms have more incentives to adopt ICT, as they have the chance to spread adjustment costs over a more substantial output volume. Larger firms are more likely to adopt digital technologies because they show lower levels of financial constraints. This effect is relatively stable whatever are the types of the technology considered.

At the same time firm's size has a positive and significant effect on the intensity of use of ICT (intra-firm diffusion). Our results confirm the expected effects stated in Hypothesis 2. The raking effect of diffusion seems validated here since we have shown that firms' size matter in intra-firm diffusion. This is mainly because larger companies need relatively more internal or external (wave 2 and 3) coordination tools.

Concerning firm's seniority effect, we show that ICT adoption and uses differ according to the models. Globally, the age of the company does not have a significant effect on the adoption of the second and third waves ICTs. And only more than ten years old firms have a significant effect. On the other hand, the effect of this variable in the intensity of use's case is more important for aged firms than for the others. Within our sample and especially for the companies that are older than ten years we find a significant effect.

These findings seem very interesting and show, in some way, that the disequilibrium theory is validated. In fact, the correlation between the intensity of use (intra-firm innovation diffusion) and the rank variables (seniority and size) indicate that firms' behavior can't be independent of its size and seniority even if expected returns of the marginal use of the technology considerations are not to be forget.

Our results show also that the dynamics followed by the adoption of the technology differ from the ones followed by the depth of adoption. These findings are shared by most of the new literature in matter of ICT usage nowadays. The challenge to verify the epidemic variables seems to be more attractive in this context.

Epidemic Effect

The time adoption variable is significant to explain the adoption and the depth of adoption of ICTs. We had defined this variable as the speed of adoption of each technology by individual firm that is the inverse of the time taken by each firm to adopt a new technology. The correlation between the two variables indicates that a propagation effect exist and confirm our first intuition that the intra-firm hypotheses are suitable to descript the adoption phenomena.

Moreover, when we look at the variable having a website we find that the correlation is significant with adoption and use of ICT. The effect is positive which is evident. These findings show that the contagion dynamics are working and the epidemic effect will be confirmed.

Technological Absorptive Capacity Effect

When we introduce the frame rate variable we reach the same result that is a strong correlation with the diffusion variable. Rate of frame is a proxy variable. Technology propagation is dependent of the capacity of the firm to be aware of the new technologies, to be able to adopt and adapt them to the local context (if any). For Tunisian SMEs this is more the case of firms with high frame' rate. In recent studies we have mention several problems as regard ICT adoption by Tunisian firms (Bellon et al. 2006 & 2007). The entrepreneurs play a crucial role in this dynamics. However, most of them were unaware about the possibilities offered by these technologies in 2003. More than 50% answer that these technologies are not relevant for their activities despite their general purposes! Since that the only variable seeming to play a role for technological absorptive capacity of these technologies is the qualification of the employees. The more they are qualified, the more the usage is important. Our estimation confirms this intuition and all the estimates are significant and positively correlated. The lack of information gathered by this survey does not let us to go further and to understand the real dynamics behind this relationship. We have no access to the training programs and volume for the employees that are better correlated with the usage of ICT in most of the empirical works.

5 Concluding Remarks

This paper has emphasized that the adoption and effective use of ICTs among Tunisian firms depend, firstly, on the types or "waves" of ICT and, secondly, on different firm characteristics. In terms of penetration level, intensity of use and time required to introduce in the firm, these technologies range (in increasing order) from first generation technologies (fixed phone, fax and Office computer) to intermediary technologies (Internet, email, software) and, finally, up to date ICTs (Videoconference, Intranet and EDI).

Our work confirms the rank effect and the epidemic effect mentioned by the disequilibrium theory. Our contribution gives an empirical findings for this theory and argue that time is still the main explanation of innovation diffusion in LDCs. This contrast with the findings for developed countries like Italy, France or United Kingdom.

In terms of policy implications, the above findings suggest that actions aiming to increase the use of ICTs among Tunisian firms should be based on a well-aimed policy mix. If the objective is to help firms increase their productivity, then the development of third wave ICTs should be given the priority. In this case, a key factor is the improvement of the human capital within SMEs, which can be achieved by lowering, through different types of policy instruments, the hiring and training costs of educated workers, and especially university graduates. Building an absorptive capacity in matter of ICT is prior to any efficient use.

The nature of the present study is mainly descriptive. Further work is necessary to investigate; in particular, to what extent the investment in different types of ICTs affects the organizational practices and improves, for instance, the performance of Tunisian firms. For this purposes, we plan to explore the other parts of our survey.

References

[1] Acemoglu, D., & F. Newman, F., A. (2002), "The labor market and corporate structure" *European Economic Review*, Elsevier, vol. 46(10), pp.1733-56, December.

[2] Antonelli, C. (1985), "The diffusion of an organizational innovation", *International Journal of Industrial Organisation* 3 109-118.

[3] Antonelli, C. (1999), "*The micro dynamics of technological change*", Roultlege.

[4] Antonelli, C. (2003), "*The economics of innovation, new technologies and structural change*", London, Routledge.

[5] Astebro T. B. (2004), "Sunk costs and the depth and probability of technology adoption", *Journal of Industrial Economics*, 52 (2004), pp. 381–399.

[6] Battisti, G. (2008), "Innovations and the economics of new technology spreading within and across users: gaps and way forward", *Journal of Cleaner Production* 16S1, S22-S31.

[7] Battisti, G., Canepa A. & Stoneman, P. (2009), "e-Business usage across and within firms in the UK: profitability, externalities and policy", *Research Policy* 38, pp.133–143.

[8] Battisti, G. & Stoneman, P. (2003), "Inter- and intra-firm effects in the diffusion of new process technology", *Research Policy* 32, pp.1641–1655.

[9] Battisti, G. & Stoneman, P. (2005), "The intra-firm diffusion of new process technology", *International Journal of Industrial Organization* 23: pp.1-22.

[10] R. Bocquet, O. Brossard (2007), "The variety of ICT adopters in the intra-firm diffusion process: Theoretical arguments and empirical evidence", *Structural Change and Economic Dynamics* 18, pp: 409–437

[11] Bresnahan, T., Brynjolfsson, E. & Hitt, L. (2002), "Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm-Level Evidence", *The Quarterly Journal of Economics*, vol. 117, n° 1, pp. 339-376.

[12] Bresnahan, T, & M. Trajtenberg (1995), "General purpose technologies: "Engines of Growth'?", *Journal of Econometrics*, 65(1), pp. 83-108.

[13] EOCD (2004), "*The Economic Impact of ICT, Measurement, Evidence and Implications*", Paris: OECD.

[14] Fabiani, S., Schivardi, F. & Trento, S. (2005), "ICT Adoption in Italian Manufacturing: Firm Level Evidence", *Industrial and Corporate Chang*e, 14(2), pp. 225-249.

[15] Forman, C. (2005), "The corporate digital divide: Determinants of internet adoption", *Management Science*, 51(4), pp. 641-654.

[16] 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.

[17] Geroski, P.A., (2000), "Models of technology diffusion", Research Policy 29, pp: 603–626.

[18] Greenan N. and Mairesse J. (2004), "A Firm Level Investigation of the Complementarity between Information and Communication Technologies and New Organizational Practices", *Miméo Centre d'Etudes et de l'Emploi, juin.*

[19] Greene, W.H. (2000), "*Econometric Analysis*", Fourth Edition, Prentice International Hall Edition.

[20] Helpman, E. (1998), "*General Purpose Technologies and Economic Growt*h", MIT Press.

[21] Ichniowski, C., K. Shaw et G. Prennushi. (1997), "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines", *American Economic Review*, 87, 3 : pp. 291-313.

[22] Levin, A., & Linn, C. F. (1992), "Unit root tests in panel data: asymptotic and finite sample properties", *University of California, San Diego*, Discussion Paper no. 92-93.

[23] Lucchetti R., Sterlacchini A., 2004. "The Adoption of ICT among SMEs: Evidence from an Italian Survey," *Small Business Economics*, Springer, vol. 23(2), pages 151-168, 09.

[24] Maddala G. & Flores-Lagaunes A. (2001), “Qualitative Response Models”, in B. Baltagi, ed ALTAGI ED., *A Companion to Theoretical Econometrics.* Oxford: Blackwell.

[25] Mansfield E. (1963), “The speed of response of firms to new techniques”, *Quarterly Journal of Economics* 77 290-311.

[26] 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: 447-455.

[27] Morgan, A., Colebourne, D., B. Thomas (2006), “The Development of ICT Advisors for SME Business: An Innovative Approach”, *Technovation,* 26(8), pp. 980-987.

[28] Nelson, R. & E. Phelps (1966), “Investment in humans, technological diffusion, and economic growth”, *American Economic Review*, 56(1/2), pp. 65-75.

[29] Stoneman P. & Battisti G., (1997), “Intra-firm diffusion of new technologies: the neglected part of technology Transfer”, *International Journal of Industrial Engineering* 4 (2): 270-282.

[30] Thomas, A. (2000), “*Econometric of the qualitative variables*”, Dunod, Paris.

[31] Thong, J.Y.L. (1999) “An Integrated Model of Information Systems Adoption in Small Business”, *Journal of Management Information Systems*, 4(15), pp.187-214.