Abstract

Why do some small and medium enterprises (SMEs) adopt Internet broadband technologies (high-speed connection and complementary applications) and others do not? This contribution aims at analyzing the issue through an econometric investigation. Relying on the (thin) previous empirical literature on the topic and focusing on a large and representative sample of Italian SMEs we analyze the determinants of broadband connection and adoption of complementary applications. Results of the econometric analysis reveal that: i) among firm-specific characteristics, size and the firm’s need to communicate are major determinants both of broadband connection and use of complementary applications, while indicators of firm efficiency and of the competitive pressure suffered from the SME positively affect only the number of used applications, while do not exert any impact on the decision to connect; ii) among location-specific characteristics, the level of telecommunications infrastructure positively influences both connection and applications use, while the presence within the local labour market of young and skilled workforce makes SMEs adopt more applications; iii) time-specific variables like those related to the actual and future price of the high-speed Internet connection affect SMEs’ decision to adopt broadband. These findings have important implications for suppliers and policy makers.
INTRODUCTION

Broadband access to communication networks plays a crucial role for economic development. In particular, it is very important for small and medium enterprises (SMEs), in so far as it provides this type of firm with efficient and permanent connectivity to the global market at a price that many SMEs could not previously afford (OECD 2003). This has generated a policy debate on how to stimulate rapid and widespread adoption of broadband access technologies. However policy interventions can be effective only if adoption determinants are well understood.

Previous studies analyzed the most significant factors which influence SMEs’ adoption of Internet and broadband, highlighting that SMEs may encounter severe obstacles mainly related to firm-specific and environmental-specific characteristics (see among others Mehrtens et al. 2001, Arbore and Ordanini 2006). In particular, managers’ IT knowledge, as well as firm size, seems to positively affect SMEs’ adoption of broadband technologies. For what concerns environmental factors, external pressure on the organization (from customers or trading partners) to adopt the technology, are likely to have positive effects on firms’ decision. Moreover the geographical area where firms are located further influences availability of broadband connection and consequently SMEs’ decision to adopt (Prieger 2003).

Moreover, the adoption by SMEs of broadband connection is likely to have a negligible economic impact at firm level by and of itself. In order to generate positive feedbacks on firm productivity and, more generally, on firm performances it has to be associated with the adoption of complementary advanced communications (e.g. virtual private network, VoIP, video-conference) and management (e.g. customer relationship management, supply chain management, human resource and administration management systems) applications that allow firms to radically change the way they do business. In fact, broadband access like other ICTs, is a general-purpose and enabling technology (Bresnahan and Trajtenberg 1995) whose benefits can be fully captured only if it is used by adopting SMEs both to carry out the same transactions or activities in a more efficient way and also as an instrumental means to generate and develop new transactions and activities (Preissl 1995, Bertschek and Kaiser 2004). In turn, for most economic organizations a necessary condition for an effective deployment of the above mentioned applications involves deep changes in their management. It follows that as interesting as the analysis of the determinants of the adoption by SMEs of Internet broadband access is the study of the factors that foster or hinder firms’ adoption of broadband-based applications, including firms’ ability to transform their organizational structure and managerial practices.¹

¹ The analysis of the adoption of broadband applications is also important with regard to the “killer-application” theory. Factors hindering adoption of these applications negatively affect the demand for applications themselves, and consequently the demand for broadband connection (Aron and Burnstein 2003).
The paper investigates both aspects: on the one hand, we analyze the factors affecting the adoption by SMEs of broadband connection; on the other hand, we investigate the determinants of the adoption of broadband-based applications, once firms have adopted a broadband connection. The contribution focuses on Italy, where SMEs traditionally account for most of the wealth produced in the national economic system, and, in line with the extant empirical literature on the topic, gives special attention to firm- and location-specific factors as fundamental drivers of adoption. After a descriptive illustration of the diffusion of broadband connection and broadband-based applications among Italian SMEs, we study the determinants of their adoption through the estimates of a series of econometric models. For this purpose we take advantage of a new longitudinal dataset composed of 904 Italian SMEs (i.e. number of employees comprised between 10 and 249), that operate in both manufacturing and service sectors (excluding public administration, finance and insurance). The sample is stratified by industry, size class, and geographical area so as to be representative of the Italian population of SMEs, and it contains detailed survey-based information on firm-specific characteristics and about firms’ adoption of broadband connection and broadband-based applications over the period from 1998 to 2005.

The analysis highlights a number of interesting findings. As to the adoption of broadband connection, the econometric results highlight that larger SMEs, which have a multi-plant structure and belong to business groups are those most likely to be early adopters. Conversely, variables reflecting the skill level of the workforce, firms’ age and operational efficiency have negligible effects on the speed of adoption. Among the location-specific factors, the infrastructural development of the telecommunication network is the only significant determinant of adoption. As to broadband-based applications, firms’ size, organizational structure and ownership status have the same effects as those shown above. Moreover, quite interestingly, firms’ age positively influences SMEs’ adoption of broadband applications, confirming that younger firms face lower switching costs in implementing the new management practices and organizational innovations associated with these applications (or that they employee younger and more “IT-familiar” workers). In accordance with this result, the adoption of broadband-based applications is also found to be driven by location-specific characteristics that reflect the availability in the local labour market of younger and more skilled personnel.

In the next section of the paper we review the extant empirical literature on the determinants of firms’ decision to adopt Internet broadband connection and broadband-based applications, with particular emphasis on those studies that focus on SMEs. Then we describe the sample and provide some preliminary descriptive statistics on the diffusion of the phenomena under investigation among Italian SMEs. This will bring us to the empirical analysis: after a brief description of the
econometric models and of the dependent and independent variables used, we illustrate the results and the main implications of the econometric estimates. Some summarizing remarks and delineation of future research opportunities conclude the paper.

**BACKGROUND**

Relying on the extant empirical literature on the determinants of firms’ adoption of ICT capital, there can be isolated three types of factors which are likely to drive broadband connection and use of broadband-based applications among SMEs. This paragraph is devoted to synthesize previous studies on the topic and derive some hypotheses on these determinants.

*Firm-specific factors*

Among the factors which are more likely to affect the adoption of broadband connection and broadband-based applications, previous studies on diffusion of innovations (DOI) literature give particular attention to firm-specific characteristics.

Organization size is found to be a fundamental driver for innovativeness: slack resources, a large availability of tangible (i.e. financial) and intangible (i.e. managerial competencies) capital and a greater ability to access external resources and markets are often advocated to be main reasons for such a positive relationship (Rogers 1995). In our context, this relationship is strengthened by the specific nature of ICT, since larger SMEs, firms having a multi-plant structure as well as firms belonging to business groups are more likely to be in need of adopting advanced communication systems and applications. These results are confirmed by a number of studies.

Forman (2005) is the study most similar to the present one, except for the fact that it looks to generic Internet adoption without distinguish between narrowband and broadband connection. Using a discrete choice econometric approach, he analyses the determinants of Internet adoption and applications use by a large sample of US services firms in 1998. He finds that firm size measured in terms of employees has a scarce relevance in explaining access, while it positively and significantly affects applications adoption. Also a multi-establishment structure is found to exert a very large and positive impact on both access and adoption of applications. Moreover, the more the employee concentration within a small number of establishments the less is found to be the probability of Internet adoption and applications use. Similar results are highlighted by Arbore and Ordanini (2006). They use a logit model in order to analyse the probability of broadband connection in the year 2003 of a sample of 842 Italian SMEs. Their results confirm that small firms gain less access to Internet high-speed technology. This major role of size in affecting the probability of connection is moderated by other factors. In particular, the probability of connection decreases for
small firms located in rural areas except for those SMEs that extensively outsource their ICT activities.

Competitive pressure is another firm-specific characteristic which may potentially (and actually is found to) affect the “broadband decision”. Accordingly to evolutionary theories of the firm (see Nelson and Winter 1983), firms would deviate from “production routines” and introduce some product or process innovation only when their market position is threatened from external parties. Hence, a more intense perceived competition may induce the firm’s management to adopt Internet broadband technologies. Quite in line with this reasoning, Mehrtens et al. (2001) show in their case-studies analysis that external pressure is among the three major factors affecting Internet adoption behaviour by SMEs, together with perceived benefits and organizational readiness. Forman (2005) reaches the same conclusion: the probability of firms to connect and adopt applications raises with the percentage of competitors within the industry that have done so. Also note that a good firm financial performance may even represent an essential pre-requisite for investing in new ICT technology given the presence of capital market imperfections suffered from SMEs especially for financing the purchase of intangible capital goods (see among others for the high degree of imperfections characterising Italian capital markets, Becchetti and Trovato 2002, Colombo and Grilli 2006, Fagiolo and Luzzi 2006).

Finally, firms’ IT familiarity and firms’ prior investments in ICT capital may affect the probability of new (often related) investments in the same area and consequently may increase the likelihood of adoption of broadband connection and use of complementary applications. This evidence is documented by Forman (2005).²

Location-specific factors

Several studies highlighted that location matters.

First, broadband connection to Internet is less likely in rural areas as for the consumer segment (see Prieger 2003 and Tookey et al. 2006 for contributions that refers to broadband access by population in U.S. and in Scotland, respectively) as for the business one (see again Arbore and Ordanini 2006). The recent cross-country studies performed by Kim et al. (2003) and Garcia-Murillo (2005) confirm that broadband penetration is positively correlated with national population density. Allegedly, the socio-economic conditions and the quality level of the telecommunications infrastructure of the area on which SMEs are located may strongly affect the actual firms’ capabilities to connect and use complementary applications. Moreover, also local labour market characteristics may have an impact on a firm’s willingness to use broadband technology: clearly, a

² See Stoneman (2001) for a wider perspective on the reasons why current use of a technology may encourage further use.
great availability in the local workforce of young and IT skilled personnel may incentive firms to
connect and ease the adoption of broadband-based applications, while the reverse may depress
firms’ opportunity to do IT investments. Accordingly, a early research conducted by the Federal
Communications Commission in 2000 (FCC, 2000) indicated that broadband was less likely to be
available in rural and lower-income areas. Garcia-Murillo (2005) in her analysis on the
determinants of broadband adoption across several countries found per capita income as a major
driver for deployment. Again, the study of Kim et al. (2003) highlights that IT preparedness and
income are important determinants of broadband technology deployment in a country. Prieger
(2003) in his econometric study on U.S. broadband connection documents that the median level of
income of a geographic area has a positive, albeit not always significant, effect on the availability of
broadband services. A positive and more robust impact is found for variables capturing the
education profile of population. In this respect, the study conducted by Cava-Ferreruela and
Alabau-Muñoz (2004) on a sample of 30 OECD countries individuated education level of the
population as one of the most consistent factors explaining the level of broadband adoption,
followed by the availability and affordability of broadband access.

Time-specific factors

Prior research in the DOI literature has provided large evidence that time-specific factors like
price of a new technology and its expected variation along time are important drivers of a new
technology deployment in an economic system (see among others Stoneman 2001). Ceteris paribus,
high prices as well as expectations of a decrease in future prices slow down the diffusion process.
Both factors will be considered in the analysis of the determinants of broadband connection by
SMEs.

THE DATASET

In this paper we consider a sample composed of 904 Italian firms. The firms included in the
sample are small and medium enterprises (i.e. number of employees comprises between 10 and 249)
operating in both manufacturing and service sectors (excluding public administration, finance and
insurance). The sample has been developed by ThinkTel in 2005 and it is stratified by industry, size
class and geographical area so as to be representative of the Italian population of SMEs. Firms are
observed from 1998 to 2005.

The dataset contains detailed survey-based information on firm-specific characteristics (e.g.
single- or multi-plant structure, whether firms belong to groups or not) and about firms’ adoption of
broadband connection and broadband-based applications. This dataset has been complemented with
firms’ economic and financial data (source: AIDA), information on the socio-economic
characteristics of the area on which firms are located (source: Tagliacarne Institute and ISTAT) and longitudinal information on price levels of Internet broadband technologies (source: European Commission).

In this work we define broadband access as an Internet wired connection via ADSL or other dedicated lines with an upstream speed higher or equal to 256 Kbps (see among others OECD 2002, Arbore and Ordanini 2006). We identify 15 broadband-based applications ranging from very basic (e.g. E-mail) to advanced (e.g. Supply Chain Management system) Internet use:

1) VPN (Virtual Private Network);
2) Data and disaster recovery system;
3) Local protection system;
4) VoIP (Voice over Internet Protocol) system;
5) Video-communication, streaming, or video-conference system;
6) E-mail;
7) File-sharing or file distribution system;
8) E-learning system;
9) CRM (Customer Relationship Management) system;
10) SCM (Supply Chain Management) system;
11) Co-design system with suppliers and customers;
12) E-banking system;
13) Internet Access system;
14) Web Site;
15) Human Resource and Administration Management systems.

Figure 1 shows penetration rates of broadband connection among Italian SMEs: broadband diffusion rate has constantly increased over time, starting from 4.8% in 1999 and reaching 66.5% in 2005. Along with access, broadband-based applications use has increased from an average number of 0.3 applications per SME in 1999 up to 5.8 applications per firm in 2005. Allegedly, if access and use by firms of broadband technologies are sensibly increased since the initial period, these figures also suggest that market saturation is still far from materializing. The next sections of the paper are devoted to the investigation of which factors hamper and hinder SME’s decision to become a broadband adopter and applications user.

THE EMPIRICAL ANALYSIS

The specification of the econometric models

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A complete description of collected information is presented in Table 1.
Our econometric analysis is carried out in two steps. First, relying on the technology diffusion model developed by Karshenas and Stoneman (1993), we estimate a survival data analysis model of the determinants of the adoption by Italian SMEs of broadband connection. In this case, the observed spell (measured in years) needed for firms to adopt broadband connection is a function of firm-, location- and time-specific variables (see Table 1). The model is specified in terms of the duration of a SME not adopting broadband connection during its life, which represents the dependent variable of the model. The basic tool for modelling duration data, given the right-censored nature of the sample (i.e. the presence within the sample of firms that did not adopt broadband connection) are duration or hazard models. The probability distribution of duration can be specified by the distribution function \( F(t) = Pr(T < t) \), which specifies the probability that the duration variable \( T \) is less than some value \( t \). The hazard function is defined as \( h(t) = f(t)/S(t) \), where \( f(t) \) is the probability density function and \( S(t) \), which is equal to \( 1 - F(t) \), is the survivor function. The hazard function may be viewed as the instantaneous probability of adopting, provided that this has not occurred by \( t \). As is frequent in this type of literature we choose to model the hazard function by a semi-parametric approach (Cox 1972):

\[
h_i(t) = h_0(t) \exp(\beta x_{it}),
\]

where \( h_0(t) \) is the baseline hazard rate at time \( t \), i.e. the hazard rate when all explanatory variables equal zero, \( x_{it} \) is the vector of (possibly time-varying) firm-specific, location-specific and time-specific explanatory variables plus other controls and \( \beta \) is the vector of parameters to be estimated.

Second, we define a measure of the extent of adoption of broadband-based applications based on the number of applications adopted by firms up to time \( t \); then, conditional to connection, we analyze the enabling or hindering factors of applications use through a random effects panel data model. The model is structured as follows (Greene 2000):

\[
y_{it} = \beta' x_{it} + \epsilon_{it}, \quad \text{with} \quad \epsilon_{it} = v_{it} + u_{it},
\]

\( y_{it} \) is the variable that captures firms’ number of broadband-based applications at time \( t \) and the vector \( x_{it} \) includes again most of the explanatory variables used in the survival analysis. The effects of the covariates on the number of broadband-based applications possessed by SMEs are accounted for by the parameter vector \( \beta \). The error component \( u_{it} \) represents time invariant firm-specific effects not reflected by the independent variables, while \( v_{it} \) is the remainder time-varying disturbance. Both components are assumed to be normally distributed with zero means and independently of one another.

\[\text{Cox and Trivedi (2005).}\]
A summary of the explanatory variables used in the estimation of the econometric models is reported in Table 1. They include those firm-, location- and time-specific variables which are likely to influence firms’ adoption of broadband technologies (see again Section 2) plus other control variables. Some firm-specific time-varying variables, indicated by suffix \( t \), are one period lagged so as to mitigate possible reverse causality problems.

Among firm-specific variables we include firm size \((\text{Employees}_{i,t})\), affiliation to a business group \((\text{Group})\), the presence of more than a plant \((\text{Multi-plant})\). This group also includes firms’ age \((\text{Age}_{i})\), the average employee salary \((\text{Salaries/ Employees}_{i,t})\) and the ratio between value added and the number of employees \((\text{Value Added/ Employees}_{i,t})\). The former two variables capture “IT-familiarity” and the quality level of firm workforce, respectively. On the one hand, we claim that younger firms tend to select younger employees, which are more likely to possess good IT knowledge. On the other hand, SMEs characterized by a higher average employee salary are likely to have employed higher qualified personnel. The variable \(\text{Value Added/ Employees}_{i,t}^{t-1}\) measuring the ratio between the yearly firm value added and the number of employees is a proxy of the efficiency level reached by the SME. Finally, the variable \(\text{Cash Flow/ Total Assets}_{i,t}^{t-1}\) is a measure of the availability of financial funds, while \(\text{Employees Growth}_{i,t}^{t-1}\) is another indicator of firm performance and inversely proxies the degree of competitive pressure faced by SMEs.

As to location-specific variables, the variables \(\text{Employee Age}\) and \(\text{Employee Education}\) capture local labour market characteristics concerning the level of human capital of workforce. \(\text{Average Income}_{i}^{t}\) and \(\text{Telecommunication Network}\) catch the overall socio-economic conditions and the quality level of the telecommunications infrastructure, respectively, of the area on which SMEs are located. A geographical dummy \((\text{South})\) is included in order to control for the firm’s decision to locate in the South of Italy, which represents the most economic disadvantaged area in the country.

Time-specific variables are used in the survival data analysis model. In particular, \(\text{Price}_{t}^{t}\) and \(\text{Expected Price Change}_{t}^{t}\) represent the hedonic broadband price and the expected price variation over time. Finally, we add to models a set of control variables. They include \(\text{Sectoral Adoption}_{i}^{t}\), \(\text{Sectoral Adoption Change}_{i}^{t}\) and \(\text{Geographical Adoption}_{i}^{t}\), which provide respectively a measure of the within industry diffusion, of the expected change of the within industry diffusion in the interval \((t; t+1)\) and of the within regions diffusion. Moreover, we control for industry \((\text{Industry Dummies})\) in all models and for time of adoption of broadband connection \((\text{Year})\) only in the broadband-based applications model.

**Results**

The results of the econometric analysis are illustrated in Tables 2 and 3. In Table 2 we present the estimates of the survival data analysis model of the hazard rate of adopting broadband
connection. Table 3 reports the estimates of the random effects panel data model on the determinants of adoption of broadband-based applications. Let us first focus attention on the adoption of broadband connection by Italian SMEs (see Table 2). The key determinants of adoption appear to be variables that reflect the necessity by SMEs to communicate: both $\text{Employees}_{t-1}$ and $\text{Multi-plant}$ have a positive and significant at 99% impact on the hazard rate; the coefficient of $\text{Group}$ is positive and significant at 95%. Therefore, larger SMEs with a multi-plant structure and belonging to a business group are those most likely to be adopters. Among location-specific characteristics, the quality level of the telecommunications infrastructure is the only significant determinant of adoption (although at only 90% significance level). Conversely, the decision to adopt broadband connection does not seem to be affected by the socio-economic welfare of the area on which firms are located and by local labour market conditions in terms of human capital possessed by workforce. Quite unsurprisingly, diffusion of broadband connection is found to be driven by the decline over time of the (hedonic) price of broadband connection.

Results on the determinants of adoption of broadband-based applications, conditional to connection (see Table 3), reveal that that larger SMEs with a multi-plant structure and belonging to a business group are likely not only to be early adopters but also to use more applications: the estimated coefficients of $\text{Employees}_{t-1}$, $\text{Multi-plant}$ and $\text{Group}$ are positive and significant at 99%. However, the analysis reveals that many other factors that were found to not significantly affect broadband connection are important determinants of the SMEs’ use of broadband-based applications. In particular, everything else being equal, the number of applications is found to decrease with firms’ age and to increase with the efficiency level (proxied by the ratio between value added and number of employees) reached by the firm. The negative association between firms’ age and broadband-based applications adoption reveals that younger firms, often hiring younger people, are more likely to possess in-house valuable IT knowledge that lead them to more extensively use broadband-based applications. The importance of IT competencies is confirmed by the results concerning location-specific variables. In particular, applications use by SMEs is positively influenced by location in wealthy geographic areas characterized by a labour market with a predominance of young and highly educated workforce: $\text{Average Income}$, has a positive and significant at 95% impact on the number of broadband-based applications; the coefficients of $\text{Employee Age}$ and $\text{Employee Education}$ are negative and positive and both significant at 95% significance level. Quite interestingly, the $\text{Telecommunication Network}$ variable and the dummy variable $\text{South}$ have a statistically significant impact on the number of applications used by SMEs (99% and 95%, respectively); the former is negative and the latter is positive. At first glance these latter findings may seem counterintuitive if we compare them to those resulting from the analysis
on broadband connection, where we highlighted that a high quality level of telecommunications infrastructure helps broadband connection diffusion. In our views, the following line of reasoning may be applied in order to explain such evidence. On the one hand, firms located in economic disadvantaged and less-infrastructured areas may find serious obstacles in accessing broadband connection due to scarcity of suppliers and a possible low quality level of the delivered service. Clearly, this may negatively influence their broadband connection behavior. On the other hand, the firm’s opportunity cost to face and overcome these difficulties decreases along with the number of applications the firm decides to adopt. This means that once a SME located in less-equipped areas acquires broadband access, it will do it for using a large number of specific applications. Finally the analysis highlights that diffusion of broadband-based applications has been increasing over time: the coefficient of Year is positive and significant at 99%.

CONCLUSIONS AND FUTURE TRENDS

This study is an econometric investigation of the determinants of a) the diffusion speed of broadband connection, and b) the number of adopted broadband-based applications among Italian SMEs.

For this purpose we have taken advantage of a new longitudinal dataset composed of 904 Italian SMEs (i.e. number of employees comprised between 10 and 249), which operate in both manufacturing and service sectors (excluding public administration, finance and insurance). The sample has been developed by ThinkTel in 2005, it is stratified by industry, size class, and geographical area so as to be representative of the Italian population of SMEs, and it contains detailed survey-based information about adoption of broadband connection and broadband-based applications over the period from 1998 to 2005. Data provided by the Thinktel survey has been supplemented with firms’ financial data and location-specific data collected from other public and private sources.

The results of the econometric analysis on broadband connection highlight that quite unsurprisingly, diffusion is driven by the decline over time of the (hedonic) price of broadband connection. Moreover, key determinants of adoption are structural characteristics of SMEs that affect their need to communicate. Larger SMEs, that have a multi-plant structure and belong to a business group are those most likely to be early adopters. Among location-specific characteristics, the development of the telecommunication network is the only significant determinant of adoption.

See again results of Table 2, where the coefficient of the variable South was positive but statistically insignificant, and the variable Telecommunication Network was found to negative affect (albeit at 90%) the probability of SMEs to adopt broadband connection.
Conversely, all variables that proxy firm’s “IT familiarity”, its efficiency and performance turn out to be insignificant determinants of SMEs’ broadband connection.

Turning attention to broadband-based applications, we find that firms’ structural characteristics have the same effects as those shown above. However, there are several factors which are found to substantially influence SMEs’ adoption of applications, though they do not affect adoption of broadband connection. In particular, the adoption of applications turns out to be higher for younger and more efficient firms, as well as for firms with high-quality personnel. In addition, the adoption of broadband applications is driven by location-specific characteristics that reflect the availability in the local labour market of younger and more skilled individuals. Lastly, a high degree of competitive pressure is found to exert a positive effect on firms’ decision to adopt broadband applications.

If we are conscious that our empirical analysis is only a first step towards a full understanding of the decision of firms to access and to use broadband-based applications and other investigations are needed on the issue, nonetheless we think that the findings illustrated above may already suggest important reflections for both broadband technologies suppliers and policy makers.

As to broadband applications suppliers, they should fill the skills and competencies gap of potential adopters if they want to promote the demand for broadband applications from SMEs. In this respect, the ability to create value for the customer through customer care, consulting and training activities may play a key role. In so far as applications suppliers are capable not only to sell products but also to offer to customers those competencies needed to properly use and fully exploit products, this business strategy may exert an important and significant effect on the willingness of potential adopters to purchase broadband-based applications (and in turn broadband connection).

As to policy makers, subsidies to the adoption of broadband connection should be accompanied by more structural and medium-long time horizon policy interventions. First of all, the quality level of telecommunications infrastructure turns out to be a significant determinant of broadband adoption, allegedly policy effort should be directed to re-balance the IT infrastructural divide across the country. Secondly, policy makers should target and try to fill the IT skills and competencies gap potentially suffered from SMEs, which in turn prevents adoption of (advanced) broadband applications. In the medium term there is the need for policy schemes favouring employees training activities, the purchase of other supporting services, and the recruitment of skilled personnel.

Taking a longer term view, the results of this research confirm that investments in human capital play a crucial role for economic development. While making it easier for Italian SMEs to adopt broadband-based applications, they may enable them to increase their efficiency, innovativeness and competitiveness in international markets. Finally, according to our findings, industrial policy
measures aiming at raising firm size may also be helpful for increasing broadband penetration rate within the Italian industrial system.

This study on the determinants of broadband connection and adoption of complementary applications among SMEs raises many new questions for future research. First of all, we (as most of the extant empirical literature on the topic) have not considered possible determinants that may hinder a firm’s willingness to use broadband technologies, such as security issues and management’s concerns about a possible increase through the use of the new technology of unproductive activities by employees. Absence of this information may help justify the relatively low amount of total variance explained by our models. Then, it would also be interesting to investigate not only the number of applications adopted by the organizations but also the “intensity” of adoption of these applications within firms. Finally, this is a research on access to broadband technologies. The analysis on the effects of broadband connection and applications on firm performances (i.e. productivity and growth) will be even more interesting. In this respect, since broadband connection is an enabling and general purpose technology, we do not expect it to have any direct effect on a firm performance. Furthermore, the adoption of broadband-based applications is likely to have a positive effect on productivity and growth, but this is conditioned on the firm’s ability to efficiently use the applications themselves. The productivity rise caused by applications may pass through both an increase in a firm’s efficiency in already existing activities and also the possibility to develop new operations that bring value to the firm. It follows that, especially for what concerns more advanced complementary applications, we would expect that much of their potential could only be exploited if managerial and organizational changes took place in the adopting firm (for a similar argument see among others Brynjolfsson and Hitt 2000, Bertschek and Kaiser 2004).
REFERENCES


FIGURES AND TABLES

Figure 1. Diffusion of Internet broadband connection among Italian SMEs.

Figure 2. Diffusion of Internet broadband-based applications among Italian SMEs.
Table 1. Definition of explanatory variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Firm-specific variables</strong></td>
<td></td>
</tr>
<tr>
<td>Employees$_{t-1}$</td>
<td>Number of firm employees at time t-1 (source: AIDA).</td>
</tr>
<tr>
<td>Group</td>
<td>One for firms belonging to business groups (source: ThinkTel).</td>
</tr>
<tr>
<td>Multi-plant</td>
<td>One for firms with a multi-plant structure (source: ThinkTel).</td>
</tr>
<tr>
<td>Employees Growth$_{t-1}$</td>
<td>Percentage growth of firm employees between time t-2 and time t-1: (\frac{\text{Employees$<em>{t-1}$} - \text{Employees$</em>{t-2}$}}{\text{Employees$_{t-2}$}}) (source: AIDA).</td>
</tr>
<tr>
<td>Age$_{t}$</td>
<td>Number of years since firms foundation at time t.</td>
</tr>
<tr>
<td>Value Added/ Employees$_{t-1}$</td>
<td>Ratio between the value added generated by the firm at time t-1 and the number of firm employee at time t-1 (source: AIDA).</td>
</tr>
<tr>
<td>Salaries/ Employees$_{t-1}$</td>
<td>Ratio between the total salaries paid by the firm at time t-1 and the number of firm employee at time t-1 (source: AIDA).</td>
</tr>
<tr>
<td>Cash Flow/ Total Assets$_{t-1}$</td>
<td>Ratio between the cash flow generated by the firm at time t-1 and the total assets value of the firm at time t-1 (source: AIDA).</td>
</tr>
<tr>
<td><strong>Location-specific variables</strong></td>
<td></td>
</tr>
<tr>
<td>Employee Age</td>
<td>Weighted average of employees’ age by province (Average is weighted on the number of employees). Employees’ age is measured on a scale from 1 (15-19 years) to 13 (more than 75 years) (source: ISTAT Italian census, 2001).</td>
</tr>
<tr>
<td>Employee Education</td>
<td>Weighted average of employees’ level education by province (Average is weighted on the number of employees). Employees’ level of education is measured on a scale from 1 (low level of education) to 6 (high level of education) (source: ISTAT Italian census, 2001).</td>
</tr>
<tr>
<td>South</td>
<td>One for firms located in the South of Italy.</td>
</tr>
<tr>
<td>Average Income$_{t}$</td>
<td>Ratio between the provincial income per inhabitant and the national income per inhabitant at time t. Data are available over the period 1991-2001. Missing data have been estimated (source: Tagliacarne Institute database).</td>
</tr>
<tr>
<td><strong>Time-specific variables (only for broadband connection)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Expected Price Change</strong>&lt;sub&gt;t&lt;/sub&gt;</td>
<td>( Price_{t+1} - Price_t ), where ( Price_t ) is defined as above.</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>

**Control variables**

**Sectoral Adoption**<sub>t</sub> <br> \( \frac{N_{adopt,t}}{N_{firm,t}} \), where <br> • for **Broadband Adoption**, \( N_{adopt,t} \) is the expected within industry cumulated number of adopters and \( N_{firm,t} \) is the within industry number of firms; <br> • for **Application Count**, \( N_{adopt,t} \) is the expected within industry cumulated number of adopted applications, and \( N_{firm,t} \) is the within industry number of firms adopting a broadband connection; <br> • for **Application Indexes**, \( N_{adopt,t} \) is the expected within industry cumulated number of adopted applications which belong to the set, and \( N_{firm,t} \) is the within industry number of firms adopting a broadband connection.

**Sectoral Adoption Change**<sub>t</sub> <br> \( \frac{(N_{adopt,t+1} - N_{adopt,t})}{r} \), where \( N_{adopt,t} \) is defined as above and \( r \) is the interest rate.

**Geographical Adoption**<sub>t</sub> <br> \( \frac{N_{adopt,t}}{N_{firm,t}} \), where <br> • for **Broadband Adoption**, \( N_{adopt,t} \) is the expected within region cumulated number of adopters and \( N_{firm,t} \) is the within industry number of firms; <br> • for **Application Count**, \( N_{adopt,t} \) is the expected within region cumulated number of adopted applications, and \( N_{firm,t} \) is the within industry number of firms adopting a broadband connection; <br> • for **Application Indexes**, \( N_{adopt,t} \) is the expected within region cumulated number of adopted applications which belong to the set, and \( N_{firm,t} \) is the within industry number of firms adopting a broadband connection.

**Year** <br> Value of the index measuring the year: 1=1998, 2=1999, …. 8=2005.

**Industry Dummies** <br> 7 Industries Dummies: <br> Sector1: One for Science Based manufacturing firms; <br> Sector2: One for Scale Intensive manufacturing firms; <br> Sector3: One for Specialized Supplier manufacturing firms; <br> Sector4: One for Traditional manufacturing firms; <br> Sector5: One for Utilities and Construction firms; <br> Sector6: One for Trade firms; <br> Sector7: One for Other Services firms.

*Legend*: Monetary values adjusted for inflation.
Table 2. Determinants of SMEs adoption of broadband connection.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1$ Employees$_{t-1}$</td>
<td>0.06 (0.015)*****</td>
</tr>
<tr>
<td>$\alpha_2$ Group</td>
<td>0.257 (0.12)**</td>
</tr>
<tr>
<td>$\alpha_3$ Multi-plant</td>
<td>0.412 (0.111)*****</td>
</tr>
<tr>
<td>$\alpha_4$ Employees Growth$_{t-1}$</td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td>$\alpha_5$ Age$_t$</td>
<td>0.001 (0.001)</td>
</tr>
<tr>
<td>$\alpha_6$ Value Added/ Employees$_{t-1}$</td>
<td>0.00004 (0.00027)</td>
</tr>
<tr>
<td>$\alpha_7$ Salaries/ Employees$_{t-1}$</td>
<td>-0.001 (0.001)</td>
</tr>
<tr>
<td>$\alpha_8$ Cash Flow/ Total Assets$_{t-1}$</td>
<td>-0.06 (0.115)</td>
</tr>
<tr>
<td>$\alpha_9$ Employee Age</td>
<td>-0.082 (0.347)</td>
</tr>
<tr>
<td>$\alpha_{10}$ Employee Education</td>
<td>0.151 (0.594)</td>
</tr>
<tr>
<td>$\alpha_{11}$ South</td>
<td>0 (0.222)</td>
</tr>
<tr>
<td>$\alpha_{12}$ Average Income$_t$</td>
<td>-0.042 (0.082)</td>
</tr>
<tr>
<td>$\alpha_{13}$ Telecommunication Network</td>
<td>0.002 (0.001)*</td>
</tr>
<tr>
<td>$\alpha_{14}$ Price$_t$</td>
<td>-0.08 (0.039)**</td>
</tr>
<tr>
<td>$\alpha_{15}$ Expected Price Change$_t$</td>
<td>-0.002 (0.001)</td>
</tr>
</tbody>
</table>

Log-likelihood: -3075.31
Likelihood ratio test: $\chi^2(22) = 114.54***$

Legend. *Significance level greater than 90%; **Significance level greater than 95%; ***Significance level greater than 99%. Robust standard errors and number of restrictions in parentheses. Cox proportional hazards model. Breslow method for ties. Number of firms: 904; number of observations: 3678. Control variables coefficients are omitted for sake of synthesis.
Table 3. Determinants of SMEs adoption of broadband-based applications.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$ Constant</td>
<td>-0.431 (3.565)</td>
</tr>
<tr>
<td>$\alpha_1$ Year</td>
<td>0.504 (0.022)*****</td>
</tr>
<tr>
<td>$\alpha_2$ Employees$_{t-1}$</td>
<td>0.536 (0.091)*****</td>
</tr>
<tr>
<td>$\alpha_3$ Group</td>
<td>1.162 (0.212)*****</td>
</tr>
<tr>
<td>$\alpha_4$ Multi-plant</td>
<td>1.025 (0.187)*****</td>
</tr>
<tr>
<td>$\alpha_5$ Employees Growth$_{t-1}$</td>
<td>-0.011 (0.004)**</td>
</tr>
<tr>
<td>$\alpha_6$ Age$_t$</td>
<td>-0.014 (0.006)**</td>
</tr>
<tr>
<td>$\alpha_7$ Value Added/ Employees$_{t-1}$</td>
<td>0.247 (0.103)**</td>
</tr>
<tr>
<td>$\alpha_8$ Salaries/ Employees$_{t-1}$</td>
<td>0.006 (0.006)</td>
</tr>
<tr>
<td>$\alpha_9$ Cash Flow/ Total Assets$_{t-1}$</td>
<td>0.361 (0.491)</td>
</tr>
<tr>
<td>$\alpha_{10}$ Employee Age</td>
<td>-1.868 (0.684)*****</td>
</tr>
<tr>
<td>$\alpha_{11}$ Employee Education</td>
<td>2.746 (1.224)**</td>
</tr>
<tr>
<td>$\alpha_{12}$ South</td>
<td>1.029 (0.45)**</td>
</tr>
<tr>
<td>$\alpha_{13}$ Average Income$_t$</td>
<td>2.241 (0.867)**</td>
</tr>
<tr>
<td>$\alpha_{14}$ Telecommunication Network</td>
<td>-0.447 (0.167)*****</td>
</tr>
</tbody>
</table>

$R^2 = 0.24$

Wald test: $\chi^2(23) = 912.67$*****

*Significance level greater than 90%; **Significance level greater than 95%; ***Significance level greater than 99%. Robust standard errors in parentheses. Random effects panel data model. Number of firms: 547; number of observations: 1760. Control variables coefficients are omitted for sake of synthesis.