Skills, technology and organisational innovation in Spanish firms

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Abstract: The purpose of this research is to provide empirical evidence on the relationships among new technologies, innovative work practices and upskilling in the Spanish case. Using detailed plant-level data from a survey of Spanish manufacturing firms, we apply estimation methods, such as tobit and ordered probit models, to test the hypothesis that the use of ICT, AMT, and innovative work practices is positively related to upskilling. As available empirical evidence shows for other countries, we have found that AMT, ICT and innovative work practices are positively related to skills, although they have different effects on workforce composition and training. We have also found several significant effects of the interactive terms of the three technologies and work practices considered on the selected variables of upskilling. The main limitation is the lack of time series data. Cross-sectional data do not allow the use of lagged variables and make it impossible to analyse the evolution of the adoption of new technologies and work practices by firms and their dynamic effects on skills, or to study causalities among variables. In addition, the study relates only to manufacturing industries. Further research should consider expanding the analysis to the service sector and studying possible complementarities between technology and work practices, in terms of labor cost savings. This paper offers empirical evidence for Spain on the relationship between new technologies, innovative work practices and upskilling considered jointly. It analyses two different technologies: ICT and AMT. The paper also focuses on different dimensions of upskilling. [PUBLICATION ABSTRACT]

Links: Linking Service

Full Text: Introduction In the previous ten to 15 years, there have been substantial transformations in the way firms perform their activities. The extensive use of advanced manufacturing technologies (AMT) and information and communication technologies (ICT) has modified numerous functional areas and has changed the work environment at the firm level. Many authors have also come to realise that, along with the impact of new technologies, organisational changes such as the introduction of high-performance work practices also play an important role in the transformation of the firm ([37] Osterman, 1994; [7] Bresnahan et al., 2002). At the same time, in the last two decades OECD countries have registered changes in the skill composition of labour as well as a trend of upskilling ([33] Machin and Van Reenen, 1998). In recent years, much of the literature has been focused on demonstrating that this trend is related to the role of ICT - computers above all - and to a lesser extent to some AMT. Many researchers consider that upskilling is to a certain degree explained by the non-neutrality of technology which benefits skilled workers. It supports "the skill-biased technological change hypothesis" (SBTC). However, although the relationship between technology and skills seems obvious, there is no clear evidence regarding the extent to which other factors contribute to explain changes registered in skill structure and upskilling. Together with the SBTC hypothesis, some economists have become interested in the "skill-biased organisational change hypothesis" in order to explain that the new organisational practices adopted by firms lead to upskilling and changes in skill structure. However, there have been only a few studies analysing the impact of both new technologies and work practices on skills (see [10] Caroli and Van Reenen, 2001; [7] Bresnahan et al., 2002; [44] Piva et al., 2005)[1]. This paper aims to offer empirical evidence on the relationships among new technologies, new work practices and upskilling in the Spanish case. We investigate the hypothesis that the use of ICT, AMT, and innovative work practices is positively related to upskilling. While most studies examining the relationships between technology and skills focus mainly on computers or on AMT considered separately, this paper takes into account the differentiated nature of both categories. Moreover, we...
analyse the influence of ICT, AMT and innovative work practices on three different dimensions of upskilling: job skill requirements, workforce skill structure and training. In order to achieve the objective of the paper, we use detailed plant-level data from a survey of 281 Spanish manufacturing establishments conducted at the end of 2004. Unlike other relevant papers in the literature, the data allow us to capture each of the three new technologies and work systems under study, with extensive measures that include several aspects of them, which are measured by means of continuous variables and not just with single dummy variables. That reinforces the reliability of the measures and, as a consequence, the validity of our results. The paper is organised as follows. The next section contains a review of the main arguments and empirical findings in the literature regarding the relationships among new technologies (ICT and AMT), innovative work practices and skills. The third section focuses on methodological issues. There then follows an analysis of the empirical results obtained. The final section presents some issues for discussion and the major conclusions. Previous research ICT and skills ICT, computers in particular, can lead to changes in job skill and labour requirements for several reasons. As it happens with other new technologies, substitution of labour for capital due to ICT adoption can reduce the demand for low-skilled workers, especially in those manual and cognitive routine tasks ([49] Spitz-Oener, 2006). On the other hand, computerisation increases the demand for certain creative and complex tasks such as communication-related ones, which, in turn, requires the workforce to develop specific capabilities commonly exhibited by better educated workers ([49] Spitz-Oener, 2006). In addition, computers are often associated with a greater production of data, which requires workers to show analytical abilities in order to process and interpret the information produced ([7] Bresnahan et al., 2002). ICT favours codification of knowledge within the organisation, which increases the amount of knowledge available to employees. In order to obtain the maximum benefit from this codified knowledge, higher skilled workers are needed to assimilate, integrate and communicate it within the organisation in a more efficient way. In the last two decades, together with an increase in the rate of ICT adoption and use within firms, advanced economies have shown a trend of upskilling and a remarkable variation in the skilled/unskilled composition of labour ([33] Machin and Van Reenen, 1998; [49] Spitz-Oener, 2006). The relative share of white-collar workers has increased along with the upskilling of the workforce ([44] Piva et al., 2005). Much of the literature has been focused on demonstrating that this trend is related to technological change and, in recent years, to the role of ICT in the workplace, particularly computers. Regarding employment structure shifts in the USA, [5] Berman et al. (1994) provide evidence that the shift from production to non-production workers correlates with investment in computers for 450 US manufacturing industries in the 1980s. [2] Autor et al. (1998) also provide evidence for the USA of a correlation between the growth of the relative demand for more skilled workers from 1960 to 1990 and computer investment for both manufacturing and non-manufacturing sectors. [17] Dunne et al. (1997) also find that increases in the non-production labour share are positively related to the use of information technologies using plant-level data for US manufacturing for the 1970s and the 1980s. Evidence also confirms relationships between computers and skills for other developed countries[2]. In the UK, [28] Haskel and Heden (1999) offer evidence on the correlation between skill composition within establishments and computerisation, without finding significant differences in the results depending on types of computers. In Germany, [24] Falk (2005) finds that office and computing machinery in manufacturing and non-manufacturing industries increases the demand for both high-skilled and medium-skilled workers, while notably reducing the demand for unskilled workers in non-manufacturing industries. Also, [49] Spitz-Oener (2006) proves that, for a wide range of industries, IT use increases the demand for high-skilled workers by shifting the employees' activities towards analytical and interactive tasks. [19] Entorf and Kramarz (1998) argue that in France new technologies, computers included, are used by workers with higher skills who, in turn, increase their learning capacity and become steadily more productive, as they gain more experience in the use of ICT. As ICT tends to increase the level of required qualification, firms are also encouraged to invest in training. There is also extensive empirical evidence of the relationships between implementation of ICT and provision of training by firms (see among
AMT and skills

AMT consists of computer-based technological advances leading to the automation of manufacturing processes. It comprises technologies such as computer-aided design (CAD), robotics, flexible manufacturing systems, automated materials handling systems and computer numerically controlled machines ([12] Das and Jayaram, 2003). As the literature on AMT posits, there are several consequences of the impact of AMT on skills. First, automation due to these technologies can reduce the need for low-skilled production workers to perform repetitive tasks ([46] Siegel et al., 1997). Second, in an AMT work environment, tasks are more sophisticated than those in traditional manufacturing. This requires workers to exhibit higher intellectual, technical and analytical abilities ([36] Mital and Pennathur, 2004). Third, AMT is integrative. This means that the production process is not divided into totally independent stages and, as a consequence, involves greater scope in the jobs and implies greater awareness of the facts in other parts of the plant ([14] Dean and Snell, 1991). To ensure that employees perform those wider tasks appropriately, it is necessary for them to acquire the required knowledge to be able to handle not only one but several stages of the manufacturing process. Finally, AMT demands higher commitment to learning to enable the acquisition of the knowledge required for the proper performance of manufacturing activities. As it happens with other new technologies, in order to obtain the maximum benefit from them, continuous improvement in the knowledge of the production processes is needed.[3] That involves investments in training and the hiring of better educated workers in order to achieve a higher skilled workforce ([48] Snell and Dean, 1992). Findings about the relationships between AMT and upskilling are still far from conclusive, given that the evidence is not widespread. [16] Doms et al. (1997) show that the use of some AMT in the USA (CAD, numerically controlled machines or robots) is associated with the presence of higher-skilled jobs. However, also in the USA, [18] Dunne and Troske (2005) find that the use of these technologies does not correlate with changes in the skill mix of the workers in the plant. On the other hand, [48] Snell and Dean (1992) find a positive association between the use of ATM and the training of employees in manufacturing firms in the USA. [41] Patterson et al. (2004) also find that AMT is positively associated with job skill requirements and the provision of training, using a sample of 80 British manufacturing firms. Innovative work practices and skills As it was mentioned above, changes in the skill structure of employment and upskilling within firms can be explained not only by technological change but also by the use of innovative work practices. These types of organisational innovation, also known as high-performance work practices, entail abandoning taylorist rigidities and shifting towards more flexible organisations ([37] Osterman, 1994). Jobs are enlarged, decentralisation in decision making and teamwork increase and, as a result, the responsibility of workers in the decision-making process is also enhanced ([26] Godard, 2004). Consequently, complexity of jobs in the workplace increases and demands a wider range of skills and a higher degree of technical competences in the various production areas ([51] Whitfield, 2000). New skills, such as data analysis capacity, reasoning and problem-solving abilities ([7] Bresnahan et al., 2002) as well as communication skills required to cope with the vast amount of information exchanges among workers, are examples of new competences usually found in those higher educated individuals ([10] Caroli and Van Reenen, 2001). Within this framework, training activities provided by companies play a key role as a means of developing the specific abilities mentioned above. This is supported by the empirical evidence that shows that a higher incidence of high-performance work practices leads to the increase of training within firms ([39] OECD, 1999; [51] Whitfield, 2000; [1] Arnal et al., 2001; [47] Smith et al., 2003). As a result of the effects of the new organisational practices on skilled labour requirements, and along with the SBTC hypothesis, in recent years some authors have undertaken studies to test the “skill-biased organisational change” hypothesis (SBOC), according to which innovative work practices favour the hiring of high-skilled workers over low-skilled ones (e.g. [27] Greenan and Guelllec, 1998; [10] Caroli and Van Reenen, 2001; [7] Bresnahan et al., 2002; [44] Piva et al., 2005). Empirical results show that a more flexible and decentralised organisation requires skilled workers. [44] Piva et al. (2005) demonstrate that the use of innovative work practices at the shopfloor level in Italian manufacturing firms implies redundancy of blue-collar workers, while it
slightly increases the demand for white-collar labour. [43] Piva and Vivarelli (2004) show a significant statistical impact of organisational change in the increase in the ratio of skilled/unskilled workers among Italian firms. [27] Greenan and Guellec (1998), using a 1987 French survey, find that new work practices are negatively correlated with the unskilled factory workers/total factory workers ratio. [39] OECD (1999) from a sample of establishments from ten European countries shows that those establishments using teamwork are less likely to have low skill requirements for their workforce. [10] Caroli and Van Reenen (2001) from a large database of French and British manufacturing firms find that the change in the number of skilled workers, measured through educational level, is significantly influenced by the decentralisation of authority. [7] Bresnahan et al. (2002) show that the use of innovative work practices is positively correlated with the educational level of skilled labour.

Complementarities between ICT, AMT, work practices, and skills There is a theoretical and empirical debate on the existence of complementarities between new technologies (ICT and AMT use) and new work practices ([35] Milgrom and Roberts, 1990; [1] Arnal et al., 2001; [31] Hollenstein, 2004). On the one hand, like coordination technologies, ICT has a significant impact on the internal organisation of firms ([15] Dedrick et al., 2003), leading to changes in authority relationships, decentralisation of the decision-making process or flattening their level of hierarchy ([1] Arnal et al., 2001; [7] Bresnahan et al., 2002). On the other hand, innovative work practices are required for the effective use of ICT. For example, in the case of network technologies, ICT favours the creation of networks within firms, something that can be especially valuable and justified in the presence of team working. Regarding complementarities between work practices and AMT, it has been shown that AMT requires decentralisation in order to cope with problem-solving demands derived from greater operational uncertainties ([12] Das and Jayaram, 2003). AMT complexity involves greater flows of information, especially those known as horizontal flows ([27] Greenan and Guellec, 1998). In order to channel those lateral information flows throughout the firm, organisational structures based on teamwork, such as self-managing teams or employee involvement groups become appropriate. The empirical literature has studied complementarities in a twofold approach. On the one hand, it has investigated whether technological changes are associated with organisational changes. A positive relationship between them has been found in most cases. For instance, [30] Hitt and Brynjolfsson (1997) have found that IT is related to a higher degree of authority decentralisation, measured by the implementation of self-autonomous work teams and employee involvement groups. [1] Arnal et al. (2001) show that the improved flow of information between managers and workers, as a consequence of ICT adoption, demands the adoption of some innovative practices such as decentralisation of decision making or teamwork adoption. Similar results are shown by [31] Hollenstein (2004) and similar findings regarding AMT use and new work practices have been presented elsewhere ([46] Siegel et al., 1997; [3] Bayo-Moriones and Merino, 2004; [41] Patterson et al., 2004). Complementarities between ICT and organisational change have also been highlighted in the literature regarding the “productivity paradox”.

Empirical evidence shows how these complementarities often generate superadditive effects in terms of firm performance ([6] Black and Lynch, 2001; [7] Bresnahan et al., 2002; [31] Hollenstein, 2004). Similar results have been found when analysing the interactive effects of AMT and innovative work practices on firm results ([12] Das and Jayaram, 2003; [41] Patterson et al., 2004). Complementarities between technological and organisational changes raise the issue of to what extent their joint use impacts on skill requirements within the firm. These complementarities can be considered from two different perspectives. On the one hand, if both technological and organisational changes involve upskilling and if the type of skills required by them are similar to some extent, then the skill requirements resulting from both changes applied simultaneously could be expected to be inferior to the sum of the skill requirements derived from their separate implementation. Therefore, we should expect the interactive effects of both changes on skill requirements to be negative. From this point of view, the joint use of new technologies and new work practices would mean cost savings for the firm in terms of the higher wages associated with upskilling. Complementarities would then be explained by the fact that the company could take advantage of some overlapping skills to obtain better results from both
technological and organisational changes. Despite this reasoning, literature on this issue usually points out that
the existence of complementarities between new technologies and new work practices should lead to positive
interactive effects on upskilling ([44] Piva et al., 2005). Taking into account that one of firm goals regarding
human resources is having a better skilled workforce capable of increasing firm productivity, complementarities
exist when introducing one of the changes (organisational or technological), increases the effect of the other
one on upskilling. This should be considered as a result of complementarities between both changes. For
example, as literature has emphasised, computers use increases skills only when it comes together with
organisational changes ([7] Bresnahan et al., 2002). The impact of new technologies on skills is much higher
when it causes a change in the role played by workers within the firm. For this change to occur, it is necessary
to introduce organisational and technological changes simultaneously, given that, as it was above mentioned,
organisational changes call for higher skills requirements, more particularly interpersonal and analytical abilities.
These interactive effects of both types of changes on upskilling have been hardly investigated in the empirical
literature. [44] Piva et al. (2005) show that the joint presence of investments in R&D activity and organisational
changes has a positive influence on changes in the demand for white-collar workers and a negative one on the
demand for blue-collar workers. [25] Gale et al. (2002) find a negative interaction between AMT and innovative
work practices related to superior requirements in reading, problem solving and interpersonal and computer
skills.
Methodology Data The data used for the analysis come from a survey conducted in October and
November 2004. It includes 281 Spanish manufacturing establishments with 15 or more employees located in
Navarra, one of the most dynamic regions of Spain in terms of technological and economic development[4] .
Face-to-face interviews were conducted with plant managers or operations managers, depending on their
availability. Questions were asked about general features of the establishments, types of technology used, as
well as characteristics of the production workers, work organisation and human resources management (HRM)
practices applied to them. We followed the [37] Osterman (1994) approach in focusing on a specific group of
employees, in order to avoid aggregation problems ([30] Hitt and Brynjolfsson, 1997). These problems arise
because companies usually implement different types of human resources management practices for the
different occupational groups in the firm. Although focusing on a specific single group of employees could have
disadvantages as far as the generalisation of the results is concerned, this limitation is minimised in our case
since the majority of employees in the manufacturing sector are production workers. We chose the plant level
instead of the company level for our analysis because we considered that the person being interviewed would
show a better knowledge of the variables to be studied ([37] Osterman, 1994). The survey was limited to plants
with 15 or more employees because establishments with fewer employees usually show a less formal and more
variable work organisation. Often it is more difficult to obtain answers regarding their work practices ([9] Cappelli
and Neumark, 2001). The response rate was 39.77 per cent. In the case of Spain, due to the still limited
collaboration between the manufacturing sector and university research, this rate may be considered as rather
acceptable, since it is higher than that obtained in other studies related to Spanish firms (see [8] Camelo et al.,
2004) and similar to that of other key studies on HRM ([50] Wall and Wood, 2005). Measures Dependent
variables In order to measure skills in the workplace, we have considered the following dimensions of upskilling:
- job skill requirements; - workforce skill structure; and - training. As a measure of job skill requirements, the
respondent was required to assess on a 1 to 5 point scale the skill level required to perform production jobs in
the plant, with 1 meaning that the skill level required was very low, 2 corresponding to low, 3 to medium, 4 to
high and 5 to very high. A similar variable was used by [38] Osterman (1995) and [7] Bresnahan et al. (2002).
Workforce skill structure is measured by three different variables, commonly used to measure human capital in
of non-production workers at the plant level; percentage share of production workers with a university degree;
and percentage share of production workers with secondary education. Regarding firms’ effort devoted to
improving workers’ skills, we have considered two measures: percentage share of production workers having
received formal training funded by the firm in the last twelve months ([38] Osterman, 1995; [30] Hitt and Brynjolfsson, 1997); and training intensity, measured as the number of hours of training received by each production employee in the last year ([48] Snell and Dean, 1992). Independent variables ICT. The presence of ICT in the workplace is captured by an index defined as the mean value of three widely used variables ([7] Bresnahan et al., 2002): percentage share of production workers using computers; percentage share of production workers using intranet or extranet; and percentage share of production workers using the internet.

AMT. Implementation of AMT is captured by an index reflecting the average use of several technologies widely mentioned in the literature ([46] Siegel et al., 1997; [12] Das and Jayaram, 2003). The interviewed managers were required to assess on a ten-point scale the degree of utilisation of the following technologies at the plant level, where 0 meant "no use at all" in the plant and 10, "at its full potential": - computer-aided design/engineering/manufacturing (CAD/CAE/CAM); - computer numerically controlled machines; - automated materials handling systems, such as automated storage and retrieval systems (AS/AR) and automated guided vehicles systems (AGV); - flexible manufacturing systems (FMS); - robotics; and - computer integrated manufacturing (CIM). Work organisation. In order to capture work organisation systems for production workers, we have constructed an index from several practices shown in the literature ([37] Osterman, 1994; [32] MacDuffie, 1995; [9] Cappelli and Neumark, 2001; [7] Bresnahan et al., 2002; [26] Godard, 2004): percentage share of production workers in self-autonomous teams; percentage share of production workers in involvement groups, such as quality circles; the existence or not of a formal suggestion system for production workers; job breadth of production workers; autonomy of production workers to decide on work pace; autonomy of production workers to decide on work method; and autonomy of production workers to solve problems.

Practices (4) to (7) have been measured using a five-point scale. In the case of the variable regarding job breadth, the respondent had to assess subjectively the breadth of production jobs in the plant, defined as the variety of their tasks, where 1 corresponded to very low, 2 to low, 3 to medium, 4 to high and 5 to very high. Values for job autonomy variables also range from 1 (very low degree of autonomy) to 5 (very high degree of autonomy). Given that different scales are used for these measures, the index has been defined as the average of the standardised value of the measures, calculated by subtracting means and dividing by the standard errors, following [7] Bresnahan et al. (2002).

Control variables As control variables we have included plant size, measured by the logarithm of the number of workers; plant age, measured by the logarithm of the number of years since the plant's foundation; the plant's membership of a foreign-owned multinational group of firms, measured by a dummy variable; and the existence or not of a collective agreement at the plant level, as indicative of the influence of unions in the plant. We have also considered the activity sector by distinguishing according to the type of goods produced in the plant: consumer goods, intermediate goods or capital goods (omitted category). Finally, we have considered the firm's strategy represented by a dummy variable which captures whether cost is more relevant than quality, flexibility, and time of delivery in the management of the plant. Table I [Figure omitted. See Article Image.] shows the definition of the variables, their mean and standard deviation. Estimation methods The estimation methods have been selected according to the characteristics of the dependent variables. Thus, we have used tobit models to explain variables representing workforce skill structure and training. In the case of the variable representing the skill level required to perform production jobs, we have estimated ordered probit models. For each of the dependent variables, four models have been estimated in a hierarchical way. The first model includes only ICT, AMT and innovative work practices, whereas the second one gathers the control variables. In the third model interactions between ICT and AMT, ICT and innovative work practices, and AMT and high-performance work practices have been added. Finally, in the fourth model we have included an interactive term measuring ICT, AMT and innovative work practices, taken together. To calculate the interactive terms, the three variables have been previously centred around the mean, in order to avoid multicollinearity problems ([11] Cohen et al., 2003). This method has been widely used to calculate interactive terms, since it reduces the measurement error without changing the structural relations.
among the variables involved (see, for example, [32] MacDuffie, 1995). Empirical results in Table II [Figure omitted. See Article Image.] we report the correlation matrix of the dependent and independent variables. If we observe the correlations between the independent variables, we may notice that ICT use is positively correlated with both AMT use and innovative work practices. The correlation between AMT use and incidence of new work practices is even higher. These results confirm previous empirical evidence on their joint use in firms (see among others, [7] Bresnahan et al., 2002, [44] Piva et al., 2005). In Tables III-VI [Figure omitted. See Article Image.] we detail the results obtained in the explicative models for the different variables on upskilling. In all cases, the significance of the ancillary parameters and the values of the log likelihood function show that the overall models are statistically significant at the .01 level. Table III [Figure omitted. See Article Image.] shows the results for job skill requirements, whereas Table IV [Figure omitted. See Article Image.] displays the marginal effects for the fourth model estimated. Out of the total control variables included, the only significant ones are those specific to the sector. This means that those firms that produce capital goods call for higher job skill requirements. In the four models the three variables associated with new technologies and new work practices (ICT, AMT and work organisation) register a positive and significant association with job skill requirements, in line with other empirical results found in the literature ([10] Caroli and Van Reenen, 2001; [41] Patterson et al., 2004). The coefficient of the interactive term AMT×work organisation is positive, but not statistically significant. However, the relationship detected between ICT×AMT and ICT×work organisation and job skill requirements is negative and significant. No influence for the triple interaction term is detected. Empirical results for the percentage share of non-production workers in the plant are shown in Table V [Figure omitted. See Article Image.]. Plant size is the only control variable which appears to be significant, showing a minus sign. Two of the variables representing new technologies and new work practices (AMT, and to a lesser extent, work organisation) are significant. AMT variable becomes significant once control variables are considered in the estimations. In both cases, the coefficient is positive. That means that the implementation of both of them in firms is related to a higher share of non-production workers in the plant workforce. Therefore, the evidence from this study agrees with the empirical results found by [44] Piva et al. (2005), [43] Piva and Vivarelli (2004) or [27] Greenan and Guelllec (1998). None of the three interactive effects in the third model is statistically significant. Nevertheless, in the fourth model, the joint effect of ICT, AMT and innovative work practices is positively related to the percentage share of non-production workers in the plant. This implies that, when taken together, AMT, ICT and innovative work practices have a higher effect on non-production workers share than when introduced separately. Hence, there is evidence of superadditive positive effects of new technologies and innovative work practices on the share of non-production workers ([7] Bresnahan et al., 2002), confirming the results obtained by [44] Piva et al. (2005). Table V [Figure omitted. See Article Image.] also shows the estimations of the explicative models of the percentage share of production workers with a university degree. The variable representing the plant's membership to a foreign-owned multinational group is the only control variable in the four models with a significant coefficient, showing a positive effect. Regarding core variables, results in the four models demonstrate that the use of both ICT and innovative work practices is related to a higher share of production workers who have completed university studies. It corroborates the findings of [10] Caroli and Van Reenen (2001), and [7] Bresnahan et al. (2002). However, this relationship is not found in the case of AMT. The only interactive term with a slightly but significant negative association with the percentage share of production workers with a university degree, is ICT×AMT. The rest of interactive terms considered do not show any coefficient significantly different from zero in any of the models in which they are included. Estimations related to the percentage share of production workers with secondary education are also shown in Table V [Figure omitted. See Article Image.]. Several control variables appear to be significant in the estimated models. For example, a negative effect for plant size and trade unions is registered. In addition, it is worth noting that those plants both pursuing a strategy of costs reduction and producing capital goods are those which present a higher percentage share of workers with secondary education. The significance of variables
showing new technologies differs along the four models estimated to explain the percentage share of production workers with secondary education. For instance, although coefficients for AMT are significant in models 1 and 2, they become not significant when interactive terms are included. On the contrary, the ICT variable is significant with a positive sign in models 3 and 4. Finally, the coefficient of work organisation is significant and positive in all the models estimated. Therefore, focusing on the results obtained in the last model, as we have already explained regarding university education, it may also be found a positive influence of the use of ICT and advanced work practices on the percentage share of production workers with secondary studies. Out of the interactive terms included, ICT×work organisation is the only one with a significant impact, showing a negative coefficient. Table VI [Figure omitted. See Article Image.] shows the results of the analysis for training coverage and training intensity. Plant size, plant's membership to a foreign-owned multinational group, and production of consumer and intermediate goods, are the significant control variables and are positively connected with training coverage. In the four models, a positive relationship is also detected between ICT and the percentage share of production workers who have received training from the firm in the last year. Although they are less significant, the same results are obtained for the second model, in relation to the effect of innovative work practices, which corroborates the findings of [48] Snell and Dean (1992) and [41] Patterson et al. (2004). No relevant evidence for the effects of interactive terms is found. AMT×work organisation is slightly statistically significant in the third model, but it becomes insignificant in the last one. As it happens for training coverage, plant's membership to a foreign-owned multinational group has a positive effect on the number of training hours received by production workers. Likewise, it is noticeable that this number is even higher in those plants that produce consumer goods and in those where there is not collective bargaining between employer and employees. Table VI [Figure omitted. See Article Image.] also shows a positive relationship between ICT use and training intensity. The innovative work practices variable is only positively significant in the first two models, but only at a ten percent level. Therefore, the influence of work organisation on the number of hours of training is not as important as that of ICT. Unlike the training coverage variable, some interactive effects are statistically relevant. The joint use of ICT and AMT has a negative influence on training intensity. The same result, although less significant, is obtained for ICT×work organisation. However, the joint use of AMT and innovative work practices has a positive and statistically significant influence on training intensity. The triple interactive effect of the ICT, AMT and innovative work practices variables is not statistically significant. Discussion and conclusions In this paper we have tested the hypothesis that the use of ICT, AMT and innovative work practices is positively related to upskilling in the Spanish case. Unlike most previous studies, our analysis combines three different aspects related to skills: job skill requirements, workforce skill structure, and training provision by the firm. We have also considered the interactive effects of technology and flexible work practices on upskilling, effects about which there is hardly any empirical evidence. The main findings may be summarised as follows. As available empirical evidence shows for other countries, we have also found that AMT, ICT and innovative work practices are positively correlated with skills. These results are in line with others mentioned in studies testing the SBTC and the SBOC hypotheses. They also highlight the fact that the analysis of the determinants of upskilling must include a wide array of changes taking place in the firms. When considered independently, new technology - both ICT and AMT - has, by itself, a positive effect on skills in the plant. ICT and AMT enhance upskilling even without being accompanied by the use of organisational innovations. Although ICT and AMT are positively related to job skill requirements, they have different effects on workforce composition and therefore on skill structure. AMT use is more likely to be a substitute for labour, because it reduces production workers share in the total employment of the plant. However, with ICT use the percentage share of production workers in the plant remains the same. There are changes in the skill structure of production workers, with better educated employees being in greater demand. Firms using ICT in their production process tend to hire workers with a university degree or, at least, who have finished their secondary education. Consequently, we have found that the impacts of technology on production workers depend on the type of technology considered. AMT impacts
through substitution of labour for capital, whereas ICT enhances the hiring of better educated production workers. Although both technologies have impact on staff skill structure, ICT impacts on the distribution of production workforce, whereas AMT has effects on the distribution of workforce between blue collars and white collars. As a result, ICT appears to require higher formal skills than AMT. Though we have found that AMT use leads to greater skill requirements in the workplace, it seems to have no impact on the training provided by the firm, measured either by training coverage or by training intensity. Although these two results could appear contradictory, a possible explanation for their simultaneous occurrence could be that the type of training and knowledge AMT requires is not so easily transmittable by formal training methods. Skills required to use AMT properly are often acquired through informal on-the-job training, for example, through training received from a more experienced colleague while performing the tasks on the shopfloor. However, further research is needed in order to study the influence of AMT use on informal training. That would require the use of direct measures capturing the extent of on-the-job training on the shopfloor. These results confirm that the knowledge required to run AMT appropriately is usually less general than that required by ICT. In this sense, it should be noted that ICT is considered as general purpose technology ([13] de Koning and Gelderblom, 2006). These results about training are in line with those obtained regarding production workforce composition. ICT positively impacts the presence of workers with secondary education or a university degree, who have the sort of general knowledge that the educational system provides. Although we have found several significant effects of the interactive terms of the three new technologies and work practices considered on the selected variables of upskilling, in most cases the coefficients of the interactive effects are not statistically different from zero. In the case of triple interactions, their effect is significant only regarding the percentage share of non-production workers, showing a positive sign. Therefore, this result supports for this variable the hypothesis in the literature that there could be complementarities between technological and organisational factors implying the need for employees with relatively higher skills. The results obtained for the double interactive terms depend on the pair of variables considered. For example, the joint effect of AMT and new work practices is only significant with regard to the number of training hours received by production workers, with a positive sign. As a result, we have to dismiss any sort of complementarities between them when considering their impact on upskilling. For the joint effect of ICT×AMT and ICT×new work practices, the results are not so conclusive. Regarding these two interactive terms, their effect is not significant in three of the estimations, while it is significant and negative for the other three. Although it is not possible to reach a definitive conclusion, it is worth pointing out that the negative signs of some of the coefficients of these interactive terms could be explained by the similarities in the skill requirements derived from the combined use of ICT and high-performance work practices, and ICT and AMT, respectively. This issue raises new areas for further research. If the joint presence of new technologies and innovative work practices is confirmed to lead to negative effects in terms of skill requirements of the workforce, a reduction in the costs associated with having and obtaining a high skilled workforce can be expected as compared to the sum of the upskilling costs of introducing separately new technologies and new work practices. For example, there should be a reduction in the costs from training activities or a reduction in the payroll costs derived from having a better educated, and therefore better-paid, workforce. The empirical literature so far has paid attention to the complementarities of technological and organisational changes in their impact on productivity, but our results point to the need to analyse complementarities in costs, and more specifically, in labour costs derived from a more skilled workforce. Considering the framework of Spanish economy, where the majority of firms are SMEs and investment in innovation and technology remains one of the challenges to achieve long-term growth, some tentative policy implications can be drawn in view of the results obtained in this research. At a firm level, results show that the greater the degree of implementation of new technologies and innovative work practices, the higher the need for new skills. In this context, companies should be able to develop strategies to adapt themselves to a changing environment of more demanding job skill requirements, more specialised workforce structure and new training needs. Planning future changes in skills and training
needs in advance as well as coordinating the development of new skills provided by the firm, would increase firms’ flexibility to face workforce adaptation and reorganisation. In this sense, we would like to highlight the need of actions oriented to increase middle managers’ awareness of the key role played by training as a means to encourage training schemes at other levels within the firm. This should be implemented taking into account the different effects of the various types of technologies and organisational practices on upskilling as well as considering the different sorts of knowledge and skills that each of these changes demand. From a public policy viewpoint, several remarks may also be pointed out. It is necessary to carry out more studies in order to analyse the relationship of causality between technology and innovative work practices at a firm level, because, depending on the direction of the relationship, the policy implications which can be drawn might be different. Thus, if organisational change drives technological change, the role of educational policy becomes even more important, since organisational change can be more dependent on human capital than certain types of technological change. In addition, the skill bias introduced by both technological and organisational changes on workforce structure should also consider the effects of the globalisation process, particularly, but not limited to, labour globalisation. It will allow companies to access to a global labour supply of skilled workers. The increasing international mobility of high-tech labour and the boom of high-tech jobs which is already taking place in other developed countries should encourage changes in the educational policy at a national level. The development of new strategies in the educational and training policy should strengthen the base of a national education system which allows workers to quickly adapt themselves to the current and future skills needs. In this sense, it is worth noting the disappointing position of Spain in terms of educational results, compared to those obtained by other advanced economies. This is surely related to the low ICT use found for Spain at a global level[5]. Greater efforts should be devoted to increase investment in education and training as well as to improve the educational results. The educational policy should consider new ways to encourage the acquisition of different types of knowledge and skills to provide a lifelong learning approach. In this sense, the European Higher Education Space seems to be oriented to achieve this aim as well as to promote mobility within Europe. However, it is necessary more time in order to asses the results of this new approach. In short, the impact of new technologies and innovative work practices on upskilling calls, in the Spanish case, for different strategies both at firms and at a national level in order to guarantee the acquisition of the skills needed to meet successfully the new requirements and to face the challenges within a context of an increasing process of globalisation. Finally, the limitations of the present study are related to the data and the variables considered. The main limitation has been the lack of time series data. Cross-sectional data do not allow the use of lagged variables, which makes it impossible to analyse the evolution of the adoption of new technologies and work practices and by firms, their dynamic effects on skills, or to study causalities among variables. In addition, the survey used in this paper is related to manufacturing establishments and production workers. Given its importance in our economies, it would be of special interest to study service firms, since they have been underrepresented in the research on the determinants of upskilling, and it would help to identify any differences with regard to manufacturing firms. Knowledge, Work Organisations and Economic Growth News Release, 63/2006 Do Computers Call for Training? Firm-Level Evidence on Complementarities Between ICT and Human Capital Investments Alberto Bayo-Moriones and Fernando Lera-López wish to acknowledge the financial support from the Government of Navarra in respect of the call for research projects. The first author would also like to thank the Spanish Ministry of Science and Technology for the funding received for the project SEC 2004-07530. Footnote 1. Although the empirical evidence is not conclusive ([42] Piva and Vivarelli, 2002), some studies suggest that skill upgrading could be explained by other factors related to the globalisation process, such as trade ([34] Manasse et al., 2004) and FDI ([45] Slaughter, 2000). According to [42] Piva and Vivarelli (2002), while technological and organisational changes explain skill-biased reallocation of firms within industries, globalisation plays a key role to justify the reallocation between different industries, at an international level.
2. The SBTC hypothesis has also been positively tested in middle-income countries, suggesting that SBTC could be a global phenomenon. However, there is not much evidence on this issue regarding low-income countries ([4] Berman and Machin, 2004).

3. Further discussion on this point can be found in the section devoted to complementarities between technological and organisational changes and skills.

4. According to [21] Eurostat (2006a), Navarra is the second region in Spain and the forty first (out of 266) in Europe-25, in terms of GDP per inhabitant in 2003. Regarding technological innovation, Navarra is the second region in Spain in terms of total R&D personnel as percentage share of total employment and is above the EU-15 and EU-average in this ratio ([22] Eurostat, 2006b).

5. Spain is lagging behind the majority of OECD countries in terms of ICT adoption at the firm level (see [20] European Commission, 2005 for detailed data). Regarding education, out of the total students, 30 per cent do not finish secondary education, which is one of the highest rates in Europe. At the same time, less than 10 per cent of workers attend training courses (non-formal job-related education and training during a 12 month period) ([40] OECD, 2006).

References

Appendix

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Illustration
Table I: Definition and descriptive statistics
Table II: Correlation matrix
Table III: Ordered probit estimations for job skill requirements
Table IV: Marginal effects for ordered probit estimation of job skill requirements (Model 4 in Table III)
Table V: Tobit estimations for workforce skill structure variables
Table VI: Tobit estimations for training variables

Subject: Studies; Innovations; Information technology; Manufacturing; Skills; Organization development

Location: Spain