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Productivity in southern European small firms: When and how work organization complements process innovation

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The aim of this paper is to analyse the effects of human capital, advanced manufacturing technologies (AMT), and new work organizational practices on firm productivity, while taking into account the synergies existing between them. This study expands current knowledge in this area in two ways. First, in contrast with previous works, we focus on AMT and not ICT (information and communication technologies). Second, we use a unique employer-employee data set for small firms in a particular area of southern Europe (Catalonia, Spain). Using a small firm data set, allows us to analyse the particular case of small and medium enterprises, since we cannot assume they have the same characteristics as large firms. The results provide evidence in favor of the complementarity hypothesis between human capital, advanced manufacturing technologies, and new work organization practices, although we show that the complementarity effects depend on what type of work organization practices are used by a firm. For small and medium Catalan firms, the only set of work organization practices that improve the benefits of human capital and technology investment are those practices which are more quality oriented, such as quality circles, problem-solving groups or total quality management.

I. Introduction

In the past years we have observed how the use of new technologies has spread among firms with the aim to improve productivity. Although the existing evidence show a positive relationship between new technologies and firm productivity, some recent studies point out that investment in new technologies is not enough to archive higher productivity levels, in addition to new technologies firms also needs to change their production process by implementing new work organizational practices, such as total quality circles, work teams, problem solving groups, or information sharing systems, in order for these new technologies to obtain higher productivity levels (Black and Lynch, 2004b; Osterman, 1994; Bresnahan et al. 2002).

At the same time, as Cozzarin and Percival (2010) point out, although firms invest in new technologies or implement new organizational practices, unless employees make efficient use of these elements the firm will not see high levels of returns on their investments. In these cases, the evidence suggests that only skilled workers can make better use of other production factors like new technologies or improve benefits to use new work organizational practices. The idea is that new technologies change the production systems, which has an impact on the internal organisation of firms. As Bayo-Moriones, et al. (2006) point out, investment in new technologies improves production process complexity, and hence problem-solving demands increase while generating greater information flows. In order to cope with these changes, firms need to decentralize the decision-making process and flatten their hierarchy levels, which would make organisational structures based on teamwork, quality circles, or problem solving groups more appropriate. It is in this new competitive context, where technological change and organizational change take place, that the requirements for more skilled workers increase. This is because more skilled workers have a greater ability to use new technologies, handle information, communicate and interact with other people, while tending to be more autonomous.

The difficulty to find data at firm level has lead to a smaller number of econometric studies that have examined the impact of human capital, new technologies, and new work organizational practices on firm performance, while taking into account the synergies existing between them. Among those studies that we do have, many contain the following aspects. First, they have focused on the effects of information and communication technologies (ITC), like office, computing and accounting machines, or communication equipment, and not on advanced manufacturing technologies (AMT), wich automate the manufacturing process with computer-controlled equipment. In contrast, in this paper we focus on the effects of AMT, such as computer-aided design (CAD), robotics, flexible manufacturing systems, and computer numerically controlled machines. Second, the empirical results about the complementarity between ICT, work organizational practices, and human capital are not clear. While Bresnahan et al. (2002) have found evidence in favour of the synergies between these three factors, Arvanitis (2005) only found evidence in favour of the synergies between ICT and human capital while Guri et al. (2008) found a negative impact of new organizational practices on the complementarity between new technologies and human capital.

In terms of AMT, we found evidence about the relationship between AMT and human capital improvements (Doms et al , 1997; Dunne et al. 2005; Snell et al., 1992 and Patterson et al., 2004), as well as AMT and the implementation of new work organizational practices (Siegel et al., 1997 and Patterson et al. 2004). Particularly, Bayo-Moriones et al. (2006) offer empirical evidence for the positive relationship among AMT, the implementation of new work organizational practices, and upskilling for Spanish manufacturing firms. None of these works, however, address the issue of the complementarity effects of these three factors on firm productivity, except for Cordero et al. (2009), who analyses 89 firms in the micro electro-mechanical systems industry. In this study, they found a positive and significant relationship between AMT, human capital, and work organizational practices on firm productivity, but when they combinate the interaction of these factors with the aim to analyse the complementarity effects, they did not find any significant effect, which does not satisfy the complementarity hypothesis.

Following these results, it seems there is no clear evidence regarding the existence of complementarity effects among these three factors on firm productivity. With the aim to shed some light on this topic, we divide our paper into two basic issues. The first one concerns the relationship among human capital, AMT, and new work organizational practices on firm productivity. The second analyses what type of work organizational practices can improve the productivity of human capital and AMT.

In order to achieve the goal of the paper, we use a unique employer-employee database[1] for Catalan SMEs. Previous research has mainly focused on large firms, but one can argue that the specificities of small and medium size firms call for a deeper understanding of the impact of these factors on firm productivity. This is especially relevant in southern European regions, where SMEs account for a very important share of the economy. In this sense, as Geroski (1998) points out, the firm dimension can affect its productivity in two different ways. First is direct effects, which shows that large firms are more efficient per se, second is indirect effects, which shows that firm dimension can determinate the efficiency of the production factors. Under the last assumption, it would be logical to find different behavior patterns of investment decisions among large and small firms. For example, large firms have more information to process and more workers to lead and coordinate, therefore the implementation of new work organizational practices that allow coordination of shared information among employees and the speeding up of decision making could improve firm productivity. In contrast, the implementation of these practices in small and medium firms with less workers and financial resources may result in higher costs and fewer benefits. It is possible, then that limited size may not call for formal new work organizational practices such as job rotation or teamwork. It is also possible that SMEs have greater difficulties in implementing and managing a cluster of co-inventions as opposed to with large firms. Therefore, simultaneous investments in new technologies, new work organizational practices, and skills could make SME firms less productive. In this sense Giuri, et al. (2008) did not find evidence for the complementarity among new technologies (ICT), new organizational practices, and human capital for small and medium Italian manufacturing firms. In fact, they found that new work organizational practices actually yielded negative effects on the complementarity between new technologies and human capital. Their results are consistent with the hypothesis that small firms experience a trade-off between new technologies and new work organizational practices.

[1] It is very difficult to find information at firm level. For this reason there is few evidence at micro level about the effects of human capital, new technologies, and new work organizational practices on firm productivity.

Finally, to test the hypothesis of complementarity among AMT, human capital, and new work organizational practices, we follow the supermodularity theory. The existing evidence analyses the synergies using a pair-wise test (testing only the complementarity effects between two practices), but this approach is problematic, since it ignores the impact of additional cross-terms. This approach examines only a partial expression for the cross derivate and is prone to an omitted variable bias that affects all coefficients. In order to solve this problem we use a test proposed by Locking et al. (2007), which is based on a multiple inequality restrictions framework corresponding to a definition of supermodularity theory[2].

The results of this test show a positive and direct impact of human capital and AMT on firm productivity. In the case of work organizational practices, they do not have a significant direct impact, except for those practices which are more oriented to a work team that, and in this case they have a significant negative effect. When we analyse the relationship among these factors, the results provide evidence in favor of the complementarity hypothesis between human capital, AMT and new work organization practices, however these complementarity effects depend on what type of practices are used by the firm. The conclusion is that, for small Catalan firms, the only set of work organizational practices that improve the benefits of human capital and new technology investments are those practices which are more oriented to quality production process, such as quality circles, problem-solving groups, and total quality management. A possible argument that justifies the negative effect of work teams and job rotation is that these practices are more difficult to implement than quality circles or problem-solving groups and for this reason the firm needs more time to see any benefit. These results are in line with those found by Giuri et al. (2008), although they focused on information and communication technologies.

The remainder of the paper is organized as follows. Section 2 discusses the determinants of firm productivity. Section 3 presents a methodological model that analyses the impact of human capital, new technologies, and new work organizational

[2] See Kodde and Palm (1986), Athey and Stern (1998), Leiponen (2002), Mohenen and Röller (2005) and Loskshin, Carree and Belberbos (2007).

practices on firm performances. Section 4 presents the data collection, variables and descriptive analysis. Section 5 shows the direct effects of these elements on firm productivity. Section 6 discusses the methodology used to analyse the complementarity effects and presents the principal results. Lastly, section 7 presents the concluding remarks.

II. Determinants of firm productivity

II.A. The impact of advanced manufacturing technologies

Since the end of the 1980s, we have witnessed how the use of AMT has spread among businesses, whatever sector they might operate in. The assumption is that investments in new digital based technology improve the efficiency of all stages of the production process by reducing setup times, run times, and inspection times. Using advanced systems such as computer-aided design (CAD) or computer numerically controlled (CNC) machines, provides a crucial advantage for businesses by allowing a quick and efficient answer to market shifts and better adaptation to shorter product life cycles. Additionally, these technologies allow the automatic detection of errors in the production process, which results in a reduction in inspection times and improvements in product quality (Bartel et al. 2007).

In general, new machines based on computer applications improve the process coordination, provide more efficient support for control and quality improvement, and achieve better performance by reducing time and production waste. Finally, the reduction in organization times makes possible the reduction in costs of change, and therefore, allows the firms to move from a large batch production to a small batch without any additional cost. In this sense, shift in process technology has facilitated increases in product variety, adjustment capacity, and allows for greater flexibility by the organization.

Much of the early empirical studies dealing with the relationship between new technology and productivity use country or sector level data. The early 1990s, however, analyses at the firm-level were beginning to find evidence that new technology had a positive effects ona a firm's productivity levels. The empirical evidence here is focuses most on the effects of ICT on firm productivity, but we can also find evidence about the positive relationship between the use of AMT and high productivity levels like in Cordero, et. al (2009), Bartel, et al., (2007), Brynjolfsson et al., (2003) and Doms, et al., (1997) for USA firm data, or in Matteucci, et al., (2005) for a comparative analysis among USA, UK, German and Italian firms.

II.B. The effects of new work organizational practice

In the literature on management, there is a broad discussion about the advantages and disadvantages of different work organization designs[3]. The most traditional work design is the work *organized in line* and based on Taylorist principles, which are characterized by *task cycles* of short duration, which are very specialized, well-defined, and standardized. In this framework, the workers have a low level of discretion, and the quality controls, routine maintenances and changes in the machines are designed by specialists. The aim of these work divisions is to reduce production cost and to take advantage of the economies of expertise. This organizational scheme is valid when a firm operate with large production lines and little variety of products, because the nature of highly specialized human resources and hardware allow the firm to take advantage of scale economies, but at the same time making the firm less flexible.

Unfortunately, in the past years, the pressure on firms has been increasing as a consequence of the change of consumer demand and competence intensification. For this reason, firms are forced to offer more specialized and adjusted products to the particular needs of each customer. In this context, firms must be able to adjust their product portfolio more quickly and respond with greater speed to the new developments and ranges of models driven by the competitors[4]. To do that, a firm needs to increase the adaptation capacity and coordinate the various activities and production processes that appear. It is in this context that new work organizational practices become more

[3] See Appelbaum and Batt (1994).

[4] Invest in new technologies, like ICT or AMT, also contribute to the versatility and flexibility of the production system.

importanbecause, unlike traditional practices, they can improve the communication and response time of workers through the use of work teams, share information programs and quality circles.

The core of new work organizational practices is that work is organized to allow front-line workers to participate in decisions that alter organizational routines. Although in the literature there is no strict definition of what practices must be included in this new organizational design, we can identify common features. For example, these practices encourage employee participation, organize work around groups or teams, and involve a restructuring and redesign of tasks. Under this new work organizational design the labour tasks are broader, more versatile, and less specialized. For example, work teams are designed with the goal that employees take on more responsibilities for a set of tasks and make decisions about task assignments and work methods. In the case of quality circles, a firm tries to involve employees on a regular basis in various activities in order to identify and suggest improvements for work-related problems. In conclusion, the new organizational practices give the employee greater autonomy and flexibility, which in turn enable companies to adapt more quickly to changes or fluctuations in demand and become more productive.

Unfortunately, evidence for the relationship between firm productivity and new work organizational practices is not clear. We found evidence for the positive relationship between new work organizational practices and firm productivity in Huselid (1995), Ichniowsky, et al., (1997), Cappelli et al. (2001) and Black et al. (2001, 2004a, 2004b) for American firms; Wolf et al. (2002) for German firms; Addison (2005) for USA and German firms; Eriksson (2003) for Danish firms; Bryson, Forth et al. (2005) for British firms; Kato and Morishima (2002) for Japanese firms; and MacDuffie (1995) for the automobile industry in different countries. However, we also found evidence of negative effects of some work organizational practices on firm productivity. For example, Black et al. (2001, 2004b), and Bartel et al. (2007) found a negative impact of work teams on firm productivity. In this case, the decentralitzation caused by the introduction of some work organizational practices increased the risk of duplication of information, the probability of mistakes due to a lower level of control, and reduced returns to specialization, hence reducing worker efficiency and firm productivity. In order to solve this problem, the skill-bias organizational change theory predicts that investment in human capital reduces the cost of decentralitzation, since skilled workers have a greater ability to handle information, communicate, interact with other people, and trend to be more autonomous (Giuri et al. 2008).

II.C. Effects of Human Capita.

Traditionally, researchers have shown great interest in understanding the role of human capital on the production process. The existing research allows us to identify two basic mechanisms by which human capital can affect the firm productivity; direct and indirect mechanisms.

Direct mechanisms have been analysed most by the Theory of Human Capital. This mechanism deals with the direct impact of a worker's skills on their own productivity, and in turn, on firm productivity. For example, workers with higher skill levels perform their tasks more quickly and with fewer mistakes. They also have the ability to recognize and solve problems that may occur during the workday, thus they require less supervision and can reduce production and organizational times. At the same time, educated workers are more functional and versatile, and for this reason they are able to adapt themselves better to changes in production processes and produce more complex goods with higher quality.

In this case, researchers usually have been analyzing the effects of education on individual wages, under the assumption that wages reflex the worker marginal productivity. In the last years, however, new employee-employer data has appeared allowing one to investigate the direct effects of human capital on firm productivity. In this sense, we highlight works such as Hellerstein et al. (1999, 2007) that found, for an American case, a positive effect of education on firm productivity, and for a British case Haskel et al. (2005), and Galindo-Rueda et al. (2005) that also found positive effects. In contrast, Arvanitis (2005) highlights some research that does not show a positive effect of human capital on firm productivity for some American firms and concludes results unclear for firms in others countries.

The second mechanism coexists with those theories that analyse the relationship between human capital and new technologies (skill-bias technological change) or human capital and new work organizational practices (skill-bias organizational change). This mechanism, referred to as an indirect mechanism, is based on the assumption that highly skilled workers can improve firm productivity by making better use of other production factors such as new technologies (complementarity effects). In this way, firms with higher levels of human capital can improve the efficiency of their production processes and achieve higher returns from new technology investments. Additionally, higher capacity to recognize and solve problems and the greater ability to communicate that a skilled worker possesses, allows a firm to achieve better performance not only from technological change but also from organizational change. Therefore upskilling is expected in those firms that use new technologies and new work organizational practices. Evidence about skill-bias technological change can found in Acemoglu (1998), Autor, et al. (1998), and Machin et al. (1998), and for skill-bias organitzational change in Caroli et al. (2001).

II.D. Complementarity effects.

As previously stated, there is a large amount of research that analyses the relationship between new technologies and workers skills. From the existing evidence we can identify three principal reasons that explain why the adoption of new technologies require a more educated workforce (Doms et al.,1997; Dunne et al., 2005; Abowd et al., 2007; and Bartel et al., 2007).

The first reason suggests that the introduction of these technologies has increased the productivity of skilled workers, since now these workers are able to perform the same tasks more efficiently. The second reason is that new technologies are a substitute for the routine tasks that low-skilled workers do. Because of this, a firm demands less low-skilled workers and therefore the structure of firm skill mix could be modifier. The third reason is not only related to the implementation of new technologies, but is also linked to changes in the economic environment. As Bartel et al. (2007) noted, the intensification of the competence and the introduction of new technologies encourage greater diversification of production and increase the complexity of products, since the time and the amount of effort needed to produce this type of goods is increasing.

Because of this, the firm needs skilled workers who are responsible for carrying out such activities.

The first reason is related to the existence of complementarity effects between skilled workers and new technologies, and it highlights the importance of the indirect mechanism as an explanation of the human capital effects on firm productivity. By contrast, the other reasons are not based on these synergies, but in the substitution effect between a low-skilled workforce and new technologies that produce a change in the workforce composition.

In a recent paper, Autor et al. (2003) used a U.S. database to analyse the change in occupational characteristic over time, identifying shifts in the task composition. They found that over the past three decades, new technologies have replaced workers in manual, routine and repetitive task. In contrast, they have complemented workers engaged in tasks that are less routine and more related to problem solving and communication activities. The introduction of new technologies into a production processes is associated with a reduction in labor demand to perform routine tasks, but at the same time it produces an increase in labor demand for those who can perform more complex tasks. In the end, they found that the net result is an increase in demand for highly skilled workers who can more easily perform analytical and non-routine tasks.

In the works of Bresnahan et al. (2002), for U.S., Yasar et al. (2008) for Turkey, and Hempell (2003) for Germany, they, as well, analysed the relationship between new technology and human capital demand, but additionally they investigate the complementarity effects of these two factors on firm productivity. The results confirm the existence of synergies between human capital and new technologies (ICT) that result in higher productivity growth.

Although the evidence points out that technological change induces increments in skilled labor with the aim to improve firm productivity, new evidence shows that investment in organizational change is also required to achieve higher productivity from technological change. Milgrom and Roberts (1990) stated that a firm needs to invest not only in new technologies but also in other factors as an integrate system in the firm. In this sense, technological change must be accompanied by organizational changes[5].

The assumption is that the introduction of new technologies reduces production times, inspection times and organization times, but also enhances diversification of production and therefor increases the need to organize and coordinate production processes and different job tasks better. In this context of production diversification, organizational change allows production processes to become more efficient and reduces the downtime that exists between the manufacturing of products. This is only if these changes give a worker more decision power and autonomy.

In this case, Caroli (2001) observes that organizational changes help to increase productivity gains obtained by the adoption of new technologies. Black et al. (2001, 2004b), using data from 1994 and 1997 from a representative sample of U.S. manufacturing firms, have analysed the effect of changes in work organization on productivity and wages at the plant level. The practices considered in this resarch include work teams, wage incentives, and benefits associated with greater employee participation in decision-making. Although they found a weak relationship between the overall educational level and the productivity levels, they observe a significant and positive relationship between the proportion of non-managerial workers who use computers and high levels of productivity. They also found that the effect of technological change on the productivity level is more limited in those firms who have not invested in organizational change, although these results can not be extended to all new organizational practices since they observe that the use of autonomous teams reduces firm productivity.

Until now we have discussed the relationship between new technologies and human capital, as well as, new technologies and work organizational practices. Recently, however, some evidence about the relationship between work organizational practices and human capital also has appeared. The hypothesis is that new work organizational practices are associated with greater autonomy and discretion of workers, which involve the deployment of work teams, problem-solving groups or quality circles, suggestion

[5] Also see Brynjolfsson and Hitt (2000), and Cristini, Gaj and Leoni (2003).

programs for workers, worker information-sharing systems, rotation and redesign of the workplace, among other practices, have also increased the demand for skilled workers. Piva, et al. (2005) have made a review of the research about the impact of technological and organizational changes in the demand for skilled workers, concluding that these changes are complementary and have a positive influence on the demand for skilled labor. Caroli et al. (2001), using French and Britich establishment data, find evidence regarding the effects of organizational change on skill demand and a firm's productivity. First, they observe that establishments who introduce organizational changes are more likely to increase demand for skilled workers, and second they note that organizational change allows a faster growth of productivity in those human capital intensive firms than less intensive ones.

The review of the research shows the importance of human capital, new technologies, and new organizational practices on firm productivity by examining only the individual effects or the complementarity effects between two factors, but we know less about effects on firm productivity in cases that consider all three factors together. The lack of firm level databases has hindered the research in this area. Even so, we can highlight the pioneering work of Bresnahan et al. (2002) which uses a database of approximately 300 large manufacturing and service firms from the U.S. This research observes that new technologies (ICT) and new work organizational practices have a positive effect on the demand for skilled worker. They argue that the investment in human capital, new technologies and new organization are related for different reasons. The first reason is the substitution of new technology and low-skilled labor for those more repetitive tasks. But, more important, is the role human capital palys as a key factor in the adoption of new technologies and new organizational practices. According to these authors, there is a high correlation between changes in technological, organizational, and human capital levels, and the combinations of these three elements result in higher productivity gains. Another result is that high levels of human capital are associated with high levels of productivity only in those firm who also have high levels of technology and have adopted new work organizational practices.

Arvanitis (2005) explores the case of manufacturing and service firms in Switzerland. He analyses the complementarity hypothesis between human capital, organizational practices, and new tecnologies (ICT), including the use of intranet and internet, on firm efficiency and performance. He obtains evidence only in favour of the synergy existing among human capital and new technologies, but not for the case of work organization[6]. In the same work, Arvanitis also reviews what little research there is that tries to analyse the relationship between these factors and firm productivity, but the results are unclear. Not all the studies show positive effects of new technologies, work organization and human capital on firm productivity, and the hypothesis of complementarity is not satisfied among all these factors. In European case studies, the results confirm complementarities between new technologies and human capital or new work organizational practice and human capital, but there is no evidence for the complementarity effects when we consider all three practices together[7]. In this respect, Giuri et al. (2008), that use a sample of Italian small manufacturing firms, found evidence of complementarity among human capital and work organizational practices, but not among human capital and new technologies (ICT). Moreover, they found that new organizational practices have a negative effect on the complementarity between new technologies and human capital.

III. Methodological framework of the impact of human capital, advanced manufacturing technologies, and new work organizational practices on firm productivity

In this section, we describe the methodology used to analyse the effects of human capital, new technologies, and new organizational practices on firm productivity.
We consider the basic Cobb-Douglas production function

$$y_{it} = a_{it} + \beta_k k_{it} + \beta_l l_{it}$$

(1)

where y is log of real value added, k is log of real capital input, l is log of labor input and β is the output elasticity with respect to inputs[8]. The term a can be interpreted as

[6] Particularly, he analyses the use of work teams.

[7] Berstschek and Kaiser (2004), Wolf and Zwich (2002), Hempell (2003) and Bauer (2003) for German firms.

[8] We use the Industrial Production Index to obtain the real value added, and the Industrial Price Index to obtain the real capital input, both are developed by the National Statistic Institute (INE). Our physical capital measure is the

the firm efficiency or total factor productivity, and can include other factors that will affect the firm output such as labor quality or human capital (KH), advance manufacturing technologies (AMT), or new work organizational practices (WO). Also included another firm characteristics which the econometrician cannot observe but the firm know (ω), and the idiosyncratic productivity shocks (u).

Therefore, the total factor productivity can be expressed as:

$$a_{it} = \beta_0 + \beta_{KH} KH_{it} + \beta_T ATM_{it} + \beta_{WO} WO_{it} + \omega_{it} + u_{it}$$

(2)

If we replace (2) in (1), we obtain the augmented Cobb-Douglas production function

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_{KH} KH_{it} + \beta_T ATM_{it} + \beta_{WO} WO_{it} + \omega_{it} + u_{it}$$

(3)

The most straightforward approach to estimate equation (3) is simply to run the ordinary last square (OLS) in the cross section, but this approach is problematic since it does not take into account the potential correlation between input levels and the unobserved firm-specific productivity shocks (ω) in the estimation of production function parameters. If those firms that have a large positive productivity shock respond by using more inputs, the OLS will yield biased parameter estimates.

Taking into account that our data is a cross-section, except for those economic variables for which we have three year information (2003-2005) such as labour and capital, we solve the simultaneity problem using the two-step estimator proposed by Black and Lynch (2001), and used by Bloom and Van Reenen (2007). Since our aim is to determine the effects of human capital, new technologies, and new work organizational practices on firm productivity, and the simultaneity problem may be most prevalent for inputs that adjust rapidly, such as labor or physical capital, we measure the (TFP) in stage one using the panel structure of the economic data. Then in stage two, using the cross section data, we estimate only the effects of our interest variables on TFP, where labor and physical capital are not included.

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firm book value following Black and Lynch (2001, 2004a), Bresnahan et al. (2002) and Brynjolfsson et al. (2003). Finally we measure the labor factor as the total number of employees.

Stage one

Among the methods that researches have used to measure TFP (stage one), the index number approach is the most popular. However, this method requires the imposition of a set of restrictive assumptions to get unbiased measurement of productivity and fails to address the simultaneity problem among inputs (Fariñas and Martín-Marcos, 2007) as well as measurement errors (Van Biesebroeck, 2007). Since we have economic panel data, we are able to use a production function approach to estimate the unbiased coefficients on capital and labor. With this information, we are then able to build our total factor productivity measure.

To archive this goal, we estimate equation 1 using the methodology proposed by Levinshon and Petrin, (2003). Black and Lynch (2001) is used within and GMM methods because they have a large six year panel data. Bloom and Van Reenen (2007), which has ten year information, is use within, GMM, and Olley and Pakes[9] estimators, and obtain the same conclusions independently from the estimation method. In our case, we only have a three years unbalanced panel data[10], and therefore the best estimator given the sample size is the Levinshon and Petrin estimator. This estimator may resolve the problem of simultaneity by using the information about a firm's material consumption as a proxy of unobserved firm-specific productivity shocks.

Therefore, the equation for the first stages is[11]

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \omega_{it} + u_{it}$$

(1b)

Next, we use the estimates of the efficient coefficients to build a measure went of firm productivity by subtracting the predicted output from its actual output at time t.

[9] Our economic data does not include investment information, it is for this reason that we use Levinshon and Petrin and no Olley and Pakes (1996) estimation. Even so, when firms make intermittent investments or when there are higher observations with zero-investment values, the investment decision fails. This is because the monotonicity condition does not hold for these observations.

[10] In our sample, more than 98% of the firms are observed over three years (2003, 2004, 2005). As a result, the results obtained in the first stage using a balanced or unbalanced panel data are the same.

[11] We estimate the first stage using a sample of 350 firms, because we did not limit the sample to information on human capital, new technologies, or work organizational practice. This fact allows us to include large a number of observations in the first stage, hence the precision of our estimates for capital and labor improve.

$$a_{it} = y_{it} - \beta_k k_{it} - \beta_l l_{it} = y_{it} - \hat{y}_{it}$$

(4)

We then average that value over the sample period 2003-2005 for each firm to get an estimate of the average TFP ($\overline{a}_i$).

Stage two

In the second stage, we regress the average of TFP on human capital, new technologies, new work organizational practices, and other sets of control variables (X_j).

$$\overline{a}_i = \beta_0 + \beta_{KH} KH_i + \beta_T ATM_i + \beta_{WO} WO_i + \sum_{j=1}^{J} \beta_j X_j + \varepsilon_i$$

(5)

Note that a two-stage method allows us to deal with the biases issue in the estimates of capital and labor, however biases can still arise in estimating the coefficients in the second stage. But, as we mentioned above, the simultaneity problem is more likely to appear for inputs that adjust rapidly, and is not the case for human capital, new technologies, and new work organizational practices. Nevertheless, there could be some omitted variable that may be correlated with our interest variables and consequently generate biases. It is for this reason that we introduce in the regression a large set of control variables[12].

IV. Data

To build our database, we merged information from different surveys. The first is the PIMEC-URV Survey (2006-2007). This survey provides information about employee-employer characteristics. The second survey is the *Iberian Balance Sheet Analysis System* (SABI), which is a source of business information from commercial registers,

[12] For an extensive discussion of the biased in the second stage, see Black and Lynch (2001).

and contains annual financial and account data on employment, sales, materials, capital, exports and imports, etc., for more than 1.2 million Spanish firms.

Due to the difficulty in finding data that contains information about human capital, new technologies, and new work practices, we believe it is necessary to explain how we designed our firm survey and how we collected the data.

III.A Firm Survey

To obtain the data required to conduct this kind of analysis, we collaborated with the small and medium firms association (PIMEC) to design, pre-test, and conduct a firm survey in 2006-2007[13]. The survey was designed following the Employer's Skill Survey (2001-2004) and the Work Skills in Britain Survey (1986-2002), although previously field research was carried out with the purpose of understanding and identifying reliable measures for our interest variables. Plant visits and interviews with industry experts allowed us to identify common features between firms and industries that help us to design and build our measurement of human capital, new technologies, and work organizational practices. For example, to identify a firm's technological level, we introduced in the survey a specific question with a set of technological elements. The respondents had to report which are used by the firm in the production process, but before this, we used the interviews of experts to verify that these technological elements are common in all industry production systems.

This survey was divided into two parts. The first one consists of a questionnaire, which consist of information about general characteristics, product and competitive strategy, and technology and work organizational practices that a firm uses. This part was answered by the general manager or the owner. The second part consists of three different questionnaires, one for the managers, one for the supervisors, and another for key production workers. In this second part, we find information about education, job satisfaction, training, wages, and other personal characteristics[14].

[13] This project was financed by the Catalan government.

[14] Initially, telephone contacts were made to gain participants. The surveys were sent by post to each firm, and with which were followed up by phone contacts. Finally, a courier picked up the completed surveys.

III.B Sample composition

Table 1 reports sample distribution according to the sector. Initially, the sample included 360 firms in the manufacturing sector, but after removing firms that had missing values in any of our interest variables, the sample was reduced to 224 small and medium firms[15]. In terms of occupation, the firms in the sample accumulate to a total of 7566 workers, 696 of which are managers, 688 are supervisor, 2820 are operators, and 3362 have other positions within the firm, such as clerical workers or unskilled production workers. Table 2 shows the distribution of the respondants for each occupational group.

To build our measurement of human capital, we use production workers' information. There are several reasons for this. The first reason is our interest in analysing the direct effects of the skills of production workers on firm productivity. The second reason is that work organizational practices and production technologies affect production workers' performance more than other non-production workers such as managers or clerical. Thus, it is reasonable to think that if any relationship exists between human capital, new work organizational practices, and AMT, this comes from the production workers' skills. Because of this assumption, our measure of human capital has been built using information from approximately 63% of the production workers in our sample[16].

III.C Variables

Although in literature there is no clear consensus on how to measure the skill of a workforce, we know that these measures must include those individual aspects related to productive skills. Traditionally, researchers have used education, training, or a worker's experience to approximate the level of a firm's human capital. Alternatively,

[15] The mean of inequality test confirms that there are no significant differences in terms of value added, total factor productivity, and firm size between the initial sample and the final sample.

[16] 9% of firms have information about only 1 or 2 operators, which represents 11% of the total firm operators. With the aim to count for possible measurement errors, we analyze the sensibility of the results by reducing the sample to those firms with more than 3 questioners by operators (represents as minimum 14% of total firm operators). In the reduced sample, the mean of operators respondent represents 70% of total operators in the firm, the sample being composed of 204 firms. The results are consistent with the results obtained with the large sample (224 firms).

some authors have also used wages as a proxy for the capacity of firm productivity, assuming that the remuneration of labor reflects their marginal productivity. The main problem of this approach is that wages depend on firm wage policies and the bargaining power of workers within the company[17]. For this reason, we use the educational level of the worker as a proxy of a firm's human capital. Particularly, our human capital variable is measured by the proportion of production workers with a college degree, according to Black et al. (2001, 2004a), Bresnahan et al. (2002) or Bloom et al. (2007).

The measure of technology we employ is similar to that used in Doms et al. (1997) and Gale et al. (2002), and is based on technological elements used in firm's production process, such as advanced manufacturing technologies. Instead, other studies that try to analyse the complementarity effects between human capital, new technologies, and work organizational practices, as in Bresnahan et al. (2002), Hempell (2003), Arvanitis (2005) or Guri et al. (2008), have used as a proxy of technology the investment in computers, softwares, hardware, or the use of internet or intranet. It is important to emphasize that our measure of technology are quite distinct from computer equipment, since the technologies that we use is directly employed in the production of manufactured goods, whereas computing equipment is often a main tool of managerial and clerical labor.

In the survey we asked the manager to indicate whether they used any of eight different AMT in the firm, which by their nature can be complementarity to each other, and used in any manufacturing industry. These technologies include such innovation as computer controlled machines, computer-aided design (CAD), automatic storage, flexible production systems, factory data network, automated sensors used on inputs and final product, and computer vision machines and automatic quality control systems.

Our measurement is built on the assumption that firms using a large number of technologies are more technologically advanced[18]. Taking into account this fact, we

[17] Some authors develop a new method consist in the use of personal fix effects as human capital measure. They regress a wage equation to obtain this personal fix effects controlling by firm specific effects. See Abowd, Kramarz and Margolis (1999).

[18] Although this technology measure doesn't take into account the intensity of use, Doms et al. (1997) realizes several exercises to check whether the number of technologies used is related to the intensity of use. They find that the counts act as a reasonable proxy for technological intensity.

consider that firms who use less than two elements are low technological firms, these that use between one or three elements are medium technological firms, and those that use more than three are advanced technological firms.

Finally, we use eight organizational practices questions asked in the survey to build our measurement of work organizational development. These practices are considered in the literature as new work practices that allow a firm to improve their flexibility and productivity levels. The purpose of these practices is to improve employee participation by implementing employee suggestion systems, information sharing manager-employees, job rotation, job redesign, problem solving groups, self-directed work groups or teams, quality circles, and total quality management (TQM)[19]. According to the complementarity hypothesis about work organizational practices[20], we built our index by adding the number of practices used by the firms[21]. Therefore, we consider that the most advanced firms in terms of work practices are those firms that use 5 or more practices, firms that use between two and four practices are in an intermediate situation, and the less advanced are those who use less than 2 practices.

Although this index will enable us to assess the impact of new work organizational practices on firm productivity while considering the synergies between them, we must take into account the fact that some organizational practices are more likely to be implemented together than others. In order to identify different sets of practices, we follow the work of Osterman (2006) and Laursen et al. (2003)[22] by using the principal component method. From the analysis we obtained three factors or sets of practices, the first one is composed of practices that are more related to the production process quality, such as employee suggestion systems, problem solving group, quality circles, and total quality management with the information sharing manager-employee included.

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[19] See in table 3 (annex) a brief definition of each practice.

[20] See Ichniowski et al. (1997), Laursen et al. (2003) and Black et al. (2001).

[21] This strategy has been used by Ichniowski et al. (1997), Bresnahan et al. (2002) and Gale et al. (2002). Osterman (2006) use both additive and principal component (1 factor) methods and he obtains the same results.

[22] Some authors point out the problems with using principal component methods with discrete variables. For this reason, we use the method proposed by Kolenikov and Angeles (2004) to calculate the principal component factors. This method uses the polychorical correlations to identify the factors. The results are consistent with those obtained using the traditional principal component method.

We will call this process quality practices, and the argument that justifies the introduction of information sharing in this bundles is based on the fact that these practises are related to the delegation of decision making and responsibilities to the workers. For this reason, it is essential to deploy new systems that allow information sharing between workers and management, thereby improving the decision-making process. The second bundle of practises is called team practices and is composed mainly of self-direct teams. The last bundle is called rotation practices and is composed of job redesign and job rotation.

In order to classified the firms in low, medium, and high levels of work organizational practices, we divide each factor into three equal parts. For example, in the case of process quality practices (factor 1) we classified the firms into three groups, the first belonging to the first tertile and representing those firms with a low level of process quality implementation, the second belonging to the middle tertile and representing those firms with a medium level of process quality implementation, and in the third group there are those firms in the top tertile, which represent those firms with high level of process quality implementation.

III. D Descriptive analysis

Table 4 presents summary statistics for our sample of firms. One of the characteristics of the sample is that it is composed mainly of small firms. The proportion of small to medium firms is 71% and 20% respectively, and only 9% are micro enterprises. The percentage of firms with a majority of foreign capital participation is only 4,4%, and the percentage of firms who participated in a business group is also very low, 10,7%. In respect to the export status of firms, we observe that the exporters are a high percentage of the total number of firms, approximately 64% of the firms report exporting products. However the proportion of total sales on foreign markets accounts for, on average, only 14.7% of the total sales of the firm, which means that exporters sell most of their output domestically.

In respect to our interest variables, table 4 also reveals that the proportion of production workers with a high educational level is only 9%, and firm investment in new technology and new work organizational practices is also low. On average the firms use between two and three production technologies, and the number of work practices implemented are approximately three. The most common technologies used by the firms in their production process are flexible production systems, factory data network, and computer-aided design (CAD). In the case of work practices, we observe that the employee suggestion systems, information sharing manager-employee, and job rotation are the most common extended.

In conclusion, the descriptive analysis shows low levels of human capital, new technologies, and new work organizational practices among Catalan manufacturing firms. Since these factors are determinants of firm productivity, the low endowment levels of these factors could explain the low level and growth of Catalan productivity[23].

V. Estimating the effects of human capital, advance manufacturing technology and new work organizational practices on TFP

In this section, we discuss the econometric results concerning the direct effects of human capital, AMT and new work organizational practices on firm productivity.

To measure TFP we estimate the production function (first stage) in a variety of ways. The fist way is OLS, but as we argued above, this measure will be biased by the simultaneity problem. For this reason we also use the Levinshon and Petrin (2003) method[24]. Next we calculated the average TFP for the period 2003-2005, and as a last step we regress this measure in respect to our interest variables (stage two) using OLS.

[23] During the period 2003-2005, the TFP growth is about 0,35% for the sample. This result is similar to the results obtained by Mas y Quesada (2005, 2007) for the Spanish economy during the period 2000-2002.

[24] Using OLS , the estimated elasticity of production with respect to physical capital is 0.123 and respect to labor 0.926, both are statistically significant, and the hypothesis of constant return to scale is rejected. Using LP, the estimated elasticity of physical capital and labour is 0.025 and 0.691 respectively. It should be noted that the capital coefficient is not statistically significant, and the hypothesis of constant return to scale is also rejected. The LP results are similar to the results obtained by Fariñas and Martín-Marcos (2007), using System GMM for a sample of Spanish manufacturing firms.

The results from the second stage estimation using OLS and LP to calculate the average TFP are reported in table 5 and 6. Although the results do not seem very sensitive to the estimation method, we observed high value for the coefficients obtained using LP method. The results confirm positive and significant effects of human capital and AMT on firm productivity after control for other firm characteristics. In contrast, we not can observe any significant direct effect of work organizational practices except in the case of those bundles of practices more related to self-direct teams. In this case, the coefficient of the variable takes a negative value, but at low significant level.

Since the results using OLS are biased, from now on we will focus on describing the results in table 6. In column 1, we only introduce the human capital *(HK)* as a determinant of TFP and other control variables. The results show that an increase of 1% in the percentage of graduate production worker is associated with an increase in productivity of 44%. In contrast, when we introduce new technologies and new work practices into the production function, this coefficient is a slightly smaller (column 4 and 5). This change can be explained by the synergies existing among these factors. If the firms who use more educated workers are those who also use a large number of new technologies and new work practices, then the human capital coefficient also reflects the effects of these others practices on productivity.

The effects of AMT on productivity are captured by two dummies that represents medium and advanced technological firms. We also find a significant and positive relationship, particularly in those firms that have implemented four or more technologies are 22,4% more productive than those firm who have implemented less than two practices. These results are consistent with Doms et al. (1997) and Bartel et al. (2007) results for a US manufacturing firms.

In column 3 and 4 we analyse the effects of new work practices on productivity. In the first case, we consider as a measurement of new work organizational practices the number of total practices implemented by the firm. In the second case we differentiated between different bundles of practices (principal component). When we consider the pull of practices, the effects on firm productivity are not statistically significant. Unfortunately, this result does not change when we analyse the effects of different sets of practices on firm productivity, except for those practices related to work teams. The results indicate that adopting self-direct teams has a negative and low significant impact on firm productivity. Particularly, those firms who adopt this set of practices are, on average, between 15.8% and 13.8% less productive[25]. This result may be due to the fact that these firms are small and medium in size and some of them can work as a team even if they are not conscious of that. Since this occurs, this result could be biased. Another reason could be that work teams are not easy to implement, and those firms who use this practice needs to invest in training of how to work in teams. For this reason, in a short period of time, this practice has had a negative impact on firm productivity.

At last, we comment about the effects of control variables on productivity. We use the age and the age square as a proxy of firm experience. The results show an inverted U-shaped relationship between experience and productivity. This means that experiences increase firm productivity, but productivity gains that have an extra year, are reduced over time. The results also reveal that size and worker experience have a positive and significant effect on firm productivity as well.

Another interesting result is the impact of exports on firm productivity. The results confirm a positive and significant effect of the percentage of foreign sales on productivity before controlling for human capital, new technology, and new work organizational practices. In contrast, this coefficient loses significance when we introduce these factors into the TFP. Theoretically there are two main arguments to explain why exporters are more efficient than non-exporters. The first reason is the self-selection hypothesis, which considers that firms self-select into the export market according to their productivity level. The second reason is the learning-by-exporting hypothesis, which, as an alternative, considers that those firms in the export market can take advantage of economies of scale or acquire knowledge and experience from a greater exposure to better practices. In the second case, the export firms are more productivity per se, but in contrast, in the firts case exporter firms are more productive because they invest more in those factors that increase firm productivity like human capital, new technologies, and new work organizational practices. Since our variable

[25] These results are in line with those found by Black et al. (2004a) and Bartel et al. 2007

lost significance after controlling for these factors, we conclude that our findings are consistent with self-selection hypothesis[26].

In conclusion, the evidence suggests that firm productivity depends directly on human capital and AMT, but not on new work organizational practices. If we take into account only these results, our conclusion will be that new work practices have a negative, if any, effects on firm performance, and it will be better for Catalan manufacturing firms to invest more in human capital and new technologies only. In reality this is not completely, because we do not take into account the synergies among these practices. For this reason, an important issue is analysed if there are some bundles of new work organizational practices that can improve the productivity of human capital and new technologies. In the next section, we attempt to analyse the complementarity effects between these factors.

VI. Complementarity effects

In this section we address the complementarity effects among human capital, AMT, and new work organizational practices on firm productivity.

The assumption is that firms choose between different levels of human capital, new technologies, and work practices in order to maximize their productivity. At the same time, productivity levels depend on the production process characteristics. For example, if the firm decides to implement a large-scale production of standardized goods, it could be possible that the mass production system allows the firm to achieve higher levels of productivity. In this case the optimal combination of factors that will be used is low skilled workers, specialized machinery, and traditional work organizational practices that avoid worker initiative. On the other hand, if the firm decides to produce a great variety of products with the aim to compete on the basis of quality and customization, they need a more flexible production process. Research suggests that higher skilled workers, new technologies, or new work practices allow the firm to increase their flexibility and productivity. Since these activities complement each other, the only way

[26] Delgado et al. (2002) and Fariñas et al. (2007), using a data set of Spanish manufacturing firms, find evidence favourable to the self-selection hypothesis.

to maximize firm productivity is to invest in all together, since because investing in any one of these activities increases the returns in the others. In this case, complementarities imply that firms investing in human capital and new technology will obtain a greater return from their investment in new work organizational practices than those firms that do not.

In the next sections, we describe the theoretical framework used in order to test the existence of complementarity among human capital, new technologies, and new work organizational practices. In conclusion, we present the results of our sample of firms.

VI.A. Theoretical framework for complementarity effects

In order to analyses complementarity effects among some production factors, we use a production function approach[27]. The idea is to analyse the effects of human capital, new technologies, and new work organizational practices on firm productivity, while taking into account these practices as an integrated system within a firm, as Milgrom and Roberts (1990) and Athey and Stern (1998) point out[28].

With the goal to analyse what is the optimal combination that maximizes a firm's productivity, we use level of factors endowment to identify different production systems[29]. Next we estimate the effects of each production system on firm productivity using a production function approach. Lastly, we use the test proposed by Lokshin et al. (2007) to analyse the complementarity hypothesis among human capital, new technologies and new work organizational practices.

Since the complementarity test uses the coefficients of each system on firm productivity, we need unbiased and consistent estimators. For this reason, we use the

[27] There is another approach, the correlation approach, which tests conditional correlation base on the residual of reduced form regressions of the practices of interest on all observable exogenous variables. Unfortunately, this test could be affected by omitted variables and measurement errors.

[28] Milgrom and Roberts (1990) argue that to be successful, firms typically need to adopt ICT as part of a system or cluster of mutually reinforcing organizational approaches.

[29] In the case that optimal combination includes higher level of all three factors the compementarity hypothesis holds.

two-stage estimator proposed by Black and Lynch (2001), and we regress the TFP respect of each production system.

We can model the expression of the PTF as

$$\overline{a}_i = \beta_0 + Z_i + \sum_{j=1}^{J} \beta_j X_j + + \varepsilon_i$$

where ($\overline{a}$) is the average TFP for the period 2003-2005, (*Z*) is a set of different production systems, and (*X*) is a set of control variables.

To classify our firms into each system, we take into account its relative position with respect to each factor. In order to do this, we consider two possible cases for each factor. For example, in the case of human capital, a firm is classified as an adopter firm if the percentage of graduate production workers is higher than the industry average, or not an adopted firm if the percentage is lower than the industry average. In the case of new technologies and new work organizational practices, a firm is considered as adopted if it belongs to the advanced level (see IIIC), and not an adopted firm in the other case.

We define a system as s(x,y,z) where x is the human capital dimension, y is the technology dimension, and z is the organizational dimension. Since we have three factors, we can identify eight different systems

Z= { s(1,1,1), s(1,1,0), s(1,0,1), s(0,1,1), s(0,0,0), s(0,1,0), s(1,0,0), s(0,0,0) }

where Z represents the set of all possible systems, and x, y and z each take a value of 1 if a firm adopts this factor, and 0 if it does not. For example, s(1,1,1) is the production system that uses a high level of human capital, high levels of new technologies and a high level of new work organizational practices.

To estimate the effects of each system on firm productivity we use different binary variables. Note that the adoption of a particular system also implies that a firm does not adopt another system. Next, we test the complementarity effects using the method proposed by Lokshin et al. and based on the Supermodularity theory. Following this theory, these factors are complements if this condition is satisfied

$$f(1,1,z) - f(0,1,z) \geq f(1,0,z) - f(0,0,z) \qquad z = 0,1$$

In our case, f represents firm productivity, and the existence of complementarities among these factors implies that the adoption of one factor produced more returns when the firm also used the other two factors. Next, we have to analyse the following multiple-restriction test

$$\begin{cases} \beta(1,1,0) + \beta(0,0,0) - \beta(1,0,0) - \beta(0,1,0) \geq 0 \\ \beta(1,1,1) + \beta(0,0,1) - \beta(1,0,1) - \beta(0,1,1) \geq 0 \end{cases}$$

VI.B. The complementarity effects estimatio

Table 8 shows the effects of the production system on Catalan manufacturing firms PTF. In column 1, we present the estimation results without controlling the possible effects of endogeneity, while in column 2 we show the results using the Levinshon Petrin method that allows us control of these problems.

The coefficient values are higher when we control the endogeneity problem, as well as in this case the goodness of fit are higher. The second column corroborates the results obtained when we analyse the determinants of firm productivity in the above section. In this sense, the firms that invest in human capital s(1,0,0) or in new technologies s(0,1,0) are more productive than those firms that do not invest in any of these factors s(0,0,0) or only invest in new work organizational practices s(0,0,1). However, the highest productivity level is obtained when the firm combines these factors and uses them as an integrate system. For example, those firms who implement together high levels of human capital, new technologies, and use new work organizational practices s(1,1,1) are 54% more productive than those firms that not invest in any of these inputs s(0,0,0), and 20% more productive than firms that only invest in human capital and new technologies s(1,1,0) .

Thus, although the results seem to support the hypothesis that those firms who opted for an integrate production system, based on workforce knowledge, advanced technologies, and more participatory work practices obtain higher productivity levels, we cannot identify if these productivity gains are because of individual effects (direct effects) or because of the existence of synergies between them that allow a firm to improve the productivity of the others factors beyond the direct effects (indirect effects). To identify if the combination of these three elements provides higher levels of productivity due to the indirect effects, we use the complementary test proposed by Lokshin et al. (2007). The results are clear and the complementarity hypothesis is satisfied independently of the estimation method. That is, firms that have a higher skilled workforce are more productive for two reasons. The first reason is that the direct effects of workers' qualifications on firm productivity, since they can do their tasks more quickly and with fewer mistakes improving their own productivity and in turn, the firm's productivity. The second reason is that the indirect effects of workers' qualification. In this sense, skilled workers can improve the productivity of new technologies and take advantage of the new work organizational practices that give more discretion to the worker. That is because they are more capable and efficient using these technologies and taking on more responsibilities.

The same thing happens with investment in new technologies, it produces both effects – direct and indirect- on firm productivity. In contrast those firms that decide to implement new work organitzational practices do not improve their productivity unless they also invest in human capital and new technologies. That means that work practices have only an indirect effect on firm productivity. This result can be explained under the assumption that new forms of work organizational practices make the production process more flexible, since they give to the employee great autonomy and responsibilities. In this context, the firm improves its productivity by the reduction of the time and cost of task organization, but that happens only when firm has qualified workers that can take over this responsibilities in an efficient way. At the same time, new organizational practices facilitate the diversification of the production by reducing the time it takes to change from one product to another (organizational time), but it is not enough to improve its efficiency. The firm needs to reduce production time if it wants to improve its productivity, for this reason a firm also needs to invest in new machines based on information and communication technologies in order to reduce the time of production, inspection and alignment between different batches of products.

In conclusion, the results show that only those firms that combine high levels of human capital and advanced technologies can improve productivity, but the highest efficiency is obtained only when the firm decides also to implement new work organizational practices. The last question that we have to answer is if any bundle of work organizational practices has the same effects on human capital and new technologies productivity for SME Catalan manufacturing firms. We analyse this issue in the next section.

VI.C. The estimation of complementarity effects for different bundles of work organizational practises

From the principal component analysis, we identified three bundles of work organizational practices. In this sense, we can observe a set of firms that decide to use those practices more related to a quality production process (first factor). There are another set of firms that prefer to use work teams practices (second factor), and the last set is composed by those firms that use more job rotation practices (third factor). The aim of this section is to analyse if any bundle of work organizational practices can improve the productivity of human capital or new technologies. In other words, we want to analyse the complementarity effects between skills, technologies, and work practices, taking into account the different types of work practices[30].

We estimate three different models. The first one analyses the complementarity effects between human capital, new technologies and those practices more oriented toward a quality production process. In this case, to determine the level of work organizational development (z), we use the distribution of the first factor. Thus, if s(x,y,z) represents the production system for each firm, we consider that z takes value 1 when the firm is in the third quartile of factor 1, and zero in the other case. For example, the dummy s(1,1,1) takes value 1 for those firms where human capital endowments are higher than the industry mean (x=1). In the same way, we use advanced technologies (y=1) and advanced quality oriented work practices (z=1)[31].

[30] Arvanitis (2005) uses a similar test, but he considers different types of information and communication technologies (internet and intranet) and human capital and team works. Another difference is that he uses a paid wise test. He only analyses the complementarity effects considering only two elements in each test.

[31] Table 9 shows a firm's distribution by each production system.

The second model analyses the complementarity among skills, new technologies, and those organizational practices more oriented toward works teams. Hence, z takes value 1 when the firm is in the third quartile of factor 2, and zero in other cases. The last model refers to the complementarity effects between skills, new technologies, and those practices more related to job rotation. In this case z takes value 1 when the firm is in the third quartile of factor 3, and zero in other cases.

The results are shown in table 10. Since the OLS estimation method presents an endogeneity problem, we focus on the coefficients obtained using Levishon and Petrin method.

In the fist place, we observe that, independently of the type of work organizational practice that a firm uses, the investment in human capital or new technologies has positive and significant effects on firm productivity in the case of Catalan manufacturing firms. Therefore, those firms that have a percentage of graduate operators that are higher than the industry mean, and have low levels of new technologies or work organizational development s(1,0,0), are between 13% and 19% more productive than those firms with low levels of endowment in all of these three production factors s(0,0,0). Those firms that decide to invest only in new technologies and use more than four new technological elements s(0,1,0) are between 19% and 25% more productive than the reference case s(0,0,0).

In respect to the complementarity effects, we observe that only those practices that relate mote to quality process improve the productivity effects on a combination of human capital and new technologies (model 1). In others cases, the results shows that if the firm wants to improve human capital and new technology productivity, it could be more suitable not to use those practices related to work teams or job rotation (models 2 and 3). In this sense, the combination of a high level of human capital, new technologies, and quality production process practices are related in that they improve approximately 50% of a firm's productivity. The complementarity test confirms that this improvement is caused partly by the direct effects, and partly by the synergies exiting between these three dimensions (indirect effects).

With respect to those practices more related to work teams we observe that the decision to invest only in these practices and not in others production factors s(0,0,1) produce negative and low significant effects on firm productivity. But these results are not surprising, since the use of work teams exists to give more responsibilities and discretion to team members. For this reason, it is more necessary to use a high quality skill force that can deal with these challenges. This is not, however, enough to obtain productivity gains, since these practices are not easy to implement because workers need a certain period of time to adapt and feel confident with other team members. The distribution of roles and responsibilities among team members, as well as the need to coordinate differents task, could produce negative effects on work team performance if this distribution and coordination is wrong. This and the fact that a work team is a new practice for the Catalan firms could explain why the use of this practice has a negative effect on human capital and new technologies productivity (model 2).

Finally, from model 3 we observe that the implementation of job rotation practices neither have effects on firm productivity s(0,0,1), nor improve the productivity of human capital or new technologies s(1,1,1). A possible explanation is that the use of advanced technologies require that workers take time to learn about how to use it in an efficient way. In this sense, the decision to use the job rotation system can produce negative effects on human capital and new technology productivity in a short period of time. This is because workers are moved to another job place making it necessary for these workers to have to learn how to do new tasks and how to use the new technologies associated with this new place. In this sense, these workers were productive in the old job, but now they need time to become productive in the new one. For these reasons, it is not difficult to understand that the firm productivity could be lower in the early stages the implementation of these work practices.

In conclusion, the results show that only those work organizational practices that are more oriented to the process of quality production improve the productivity of human capital and new technologies. In contrast, work teams and job rotation practices have a negative effect on the productivity of the above-mentioned production factors. However, logical thinking makes us believe that these negative effects are produced partly because new work organizational practices for the Catalan manufacturing firms has only been implemented recently. Therefore, it will be interesting to analyse how the effects of these practices on firm productivity change over time.

VII. Conclusions

In the past years, some authors have tried to analyse why US firms are more productive than European firms. The first evidence shows the importance of new technology as a determinant of firm performance. Afterwards, some authors started to analyse the effects of human capital, and more recently some research papers tries to look for a relationship between work organizational practices and firm productivity. But as Milgrom and Roberts (1990) said, it is necessary to analyse these elements as a integrate system in the firm production process, taking into account the complementarity effect among these issues. Unfortunately, it is very difficult to find information at employer-employee level which contains data about human capital, new technologies, new work organizational practices, and firm performance. For this reason, there is little evidence that analyses the synergies existing among these production factors and its effects on firm productivity.

In this paper we use a unique employer-employee data set of SME firms in Catalonia (PIMEC-URV Survey 2006-2007) to shed light on the effects of human capital, new technologies (considering AMT) and new work organizational practices on firm productivity, taking into account the synergies existing among these issues. Additionally, we identify different bundles of work organizational practices with the aim to analyse what is the combination that maximizes the impact of human capital and new technologies.

The results confirm positive and significant direct effects of human capital and AMT on productivity, after control for others firms' characteristics. In contrast, we can not observe any significant direct effect of new work organizational practices, except in the case of those bundles of practices more related to self-direct teams, which take a negative value, but at a low significant level. If we only take into account direct effects, our conclusion will be that new organizational practices have a negative, if any, effects on firm performance, and it will be better for the Catalan firms to use the most traditional work organizational practices such as in a mass production context. But this is not technically true, since we need to analyse the indirect effects of those practices.

The complementarity test points out that the synergies among these factors are a true fact, but they depend on what type of bundles of work organitzational practices are considered in the analysis. In the case of catalan SMEs, there exists a set of practices that, although they do not produce any direct effect on firm productivity, improve the human capital and AMT productivity. This set of practices includes those practices more oriented to quality production process, such as quality circles, TQM and problem solving groups. In contrast, those practices more oriented to work teams and job rotation produce negative effects on human capital and new technology productivity.

A possible argument that justifies the negative effects of work teams and job rotation is that these practices are more difficult to implement than quality circles or problem-solving groups. For this reason, firms needs more time to witness any benefit from it. In this sense, it will be interesting to observe the evolution of the effects of these practices on firm productivity, but to do this we need a series of data over a long period of time that is difficult to obtain today.

In conclusion, the results show that those firms that invest and innovate in all dimensions of the production process obtain great levels of productivity. Unfortunately, in Catalan manufacturing firms, there is more tradition and routine than innovation[32]. This explains the low growth of firm productivity in the last years, far below that of the mean productivity growth for the European Union. The question is why some firms try to adapt to environmental change and invest in human capital, new technologies, and new work organizational practices, while others do not?. As García and Huerta (2004) point out as a possible explanation is financial constraints, the worsening corporate government, and the lower management capacity in the SMEs Spanish firms. If these

[32] Huerta et al. (2003) analyses the diffusion of new technologies and new human resource practices in the Spanish firms and he arrives to the same conclusion.

factors are really the problem, the challenge is to design and promote actions and public policies that allow SMEs easy financial access and consulting services to improve the managerial capabilities.

Finally, these findings need to be interpreted with caution because, since the data collected is cross-sectional, we cannot test the causal-effect of these factors on firm productivity, but only the correlation relationships.

References

Abowd, J.M., Kramarz, F. and Margolis, D. N. (1999): "High wage workers and high wage firms", Econometrica, Vol.67, pp. 251-333

Abowd, J., Haltiwanger, J., Lane, J., McKinney, K. and Sandusky, K. (2007): "Technology and the demand for skill: An analysis of within and between firm differences". NBER Working paper Nº13043.

Acemoglu, D. (1998): "Why do new technologies complement skills? Directed technical change and wage inequality". Quarterly Journal of Economics, Vol.113, pp.1055-1090.

Addison, J. (2005): "The determinants of firm performance: Unions, works councils, and employee involvement/high performance work practices". IZA Discussion paper series, Nº1620.

Appelbaum, E. and Batt, R. (1994): "The new American workplace". Ithaca, NY, ILR Press

Arvanitis, S. (2005): "Computerization, workplace organization, skilled labour and firm productivity: Evidence for the Swiss business sector". Economics of Innovation and New Technology, Vol 14, Nº 4, pp. 225-249

Athey, S. and Stern, S. (1998): "An empirical framework for testing theories about complementarity in organizational design", NBER Working Paper Nº6600, Cambridge, MA.

Autor D., Karz, F. and Krueger, A. (1998): "Computing inequality: Have computers changed the labor market?". Quarterly Journal of Economics, Vol. 113, pp. 1169-1213.

Autor, D., Levy, F. and Murnane, R. (2003): "The skill content of recent technological change: An empirical exploration". The Quarterly Journal of Economics, Vol. 118, pp. 1279-1333.

Bartel, A., Ichniowsky, C. and Shaw, K. (2007): "How does information technology affect productivity? Plant-level comparison of product innovation, process improvement, and worker skills". The Quarterly Journal of Economics, Vol.122 Nº4, pp.1721-1758.

Bauer, T.K. (2003): "Flexible workplace practices and labor productivity". IZA Discussion Papers, Nº700

Bayo-Moriones, A., Billón, M. and Lera-López, F. (2006): "Skills, technology and organizational innovation in Spanish firms". International Journal of Manpower. Vol. 29, Nº2, pp. 122-145.

Becker, B. and Huselid, M. (2006): "Strategic Human Resources Management: Where Do We Go From Here?". Journal of Management, Vol. 32, Nº6 , 898-925

Bertschek, I. and Kaiser, U. (2004): "Productivity effects of organizational change: Microeconometric evidence". Management Science. Vol. 50, Nº3, pp. 394-404.

Black, S. and Lynch, L. (2001): "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity". Review of Economics and Statistics. Vol. 83, Nº3, pp.434-445.

Black, S and Lynch, L (2004a): "What's Driving the New Economy?: The benefits of Workplace Innovation". Economic Journal, Vol.114 Nº493, pp.97-116

Black, S and Lynch, L. (2004b): "Workplace Practices and the New Economy". FRBSF Economic Letter. Nº 2004-10

Bloom, N. and Van Reenen, J. (2007): "Measuring and explaining management practices across firms and countires". The Quarterly Journal of Economics, Vol.122, Nº4 pp.1351-1408.

Bresnahan, T., Brynjolfsson, E. and Hitt, L. (2002): "Information technology, workplace organization, and the demand for skilled labor: firm-level evidence", The Quartely Journal of Economics, Vol. 117, Nº 1, pp. 339-376.

Brynjolfsson, E. and Hitt, L. (2000): "Beyond computation: Information technology, organizational transformation and business performance". Journal of Economics Perspectives, Vol.14, Nº4, pp.23-48

Brynjolfsson, E. and Hitt, L. (2003): "Computing productivity: Firm-level evidence". The Review of Economics and Statistics. Vol. 85, Nº4, pp. 793-808.

Bryson, A., Forth, J. and Kirby, S. (2005): "High-involvement management practices, trade union representation and workplace performance in Britain". Scottish Journal of Political Economy, Vol. 52, Nº3, pp. 451-491.

Capelli, P. and Neumark, D. (2001): "Do High Performance" Work Practices Improve Establishment-Level Outcomes?". Industrial and Labor Relations Review. Vol.54, Nº4, pp.737-775.

Caroli, E. (2001): "New technologies, organizational change and the skill bias: What do we know?". en Pascal Petit and Luc Soete eds Technology and the future of European employment (Cheltenam UK; Northhampton MA: Edward Elgar).

Caroli, E. and Van Reenen, J. (2001): "Skill-Biased organizational change? Evidence form a panel of British and French establishments". Quarterly Journal of Economics, Vol.116 pp.1449-1492.

Cordero, R., Walsh, S. and Kirchhoff, B. (2008): "Organization technologies, AMT and competent workers: Exploring relationship with manufacturing performance". Journal of Manufacturing Technology Management. Vol.20, Nº3, pp.298-313.

Cozzarin, B. and Percival, J. (2010): "IT, productivity and organizational practices: large sample, establishment-level evidence". Inf Technol Manag Nº11, pp. 61-76.

Cristini, A., Gaj, A., and Leoni, R. (2003): "The gains form investing in workplace organisation".Roma: 24th Conference of the International Working Party on Labour Market Segmentation.

Delgado, M.A., Fariñas, J. and Ruano, S. (2002): "Firm productivity and export markets: a non-parametric approach". Journal of International Economics. Vol57, pp. 397-422

Doms, M., Dunne, T. and Troske, K., (1997): "Workers, wages and technology", The Quarterly Journal of Economics, Vol. 112, Nº 1, pp. 253-290.

Dunne, T. and Troske, K., (2005): "Technology adoption and the skill mix of US manufacturing plants", Scottish Journal of Political Economy, Vol. 52, Nº 3

Eriksson, T. (2003): "The effects of new practices: evidence form employer-employee data". en Kata, T. y Pliskin, J. eds. Advances in the Economics Analysis of Participatory and Labor-Managed Firms, Vol. 7 .

Fariñas, J. and Martín-Marcos, A. (2007): "Exporting and economic performance: Firm-level evidence of Spanish manufacturing". The World Economy. Vol. 30 Nº4, pp. 368-646.

Gale, H.F., Wojan, T. and Olmsted, J. (2002): "Skills, flexible manufacturing technology, and work organization". Industrial Relations, Vol. 41, Nº1

Galindo-Rueda, F. and Haskel, J. (2005): "Skills, workforce characteristics and firm-level productivity: Evidence from the matched ABI/Employer skills survey. IZA discussion paper series, Nº1542

Geroski, P. (1998): "An applied econometrician's view of large company performance". Review of Industrial Organization, Vol.13, pp.271-293.

Giuri, P., Torrisi, S. and Zinovyeva, N. (2008): "ICT, skills, and organisational change: Evidence form a panel of Italian manufacturing firms". Industrial and Corporate Change, volume 17, number 1, pp.29-64.

Gretton, P., Gali, J. and Parham, D. (2002): "Uptake and impacts of ICT in the Australian Economy: Evidence from aggregate, sectorial and firm level". Paper presented in The OECD Workshop on ICT and Business performance, Paris, Diciembre 2002.

Haskel, J., Hawkes, D. and Pereira, S. (2005): "Skills, human capital and the plant productivity gap: UK evidence from matched plant, worker and workforce data". CEPR Discussion Paper Nº 5334

Hellerstein, J, Neumark, D. and Troske, K.(1999): "Wages, productivity, and worker characteristics: Evidence from plant-level production functions and wage equation", Journal of Labor Economics, 1999, vol.1, nº3.

Hellerstein, J and Neumark, D.(2007): "Production function and wage equation estimation with heterogeneous labor: Evidence from a new matched employer-employee dataset". En Ernst R. Berndt y Charles M. Hulten, eds. Hard to Measure goods and services: Essays in Honor of Zvi Griliches (University of Chicago Press).

Hempell, T.: (2003): "Do computers call for training? Firm-level evidence on complementarities between ICT and Human Capital Investments". Discussion Paper Nº 03-20. Centre for European Economic Research

Huerta, E. (ed), Bayo, J.A., García Olaverri, C. and Merino, J. (2003): "Los desafíos de la competitividad. La innovación organizativa y tecnológica en la empresa española". Fundación BBVA.

Huselid, M. (1995): "The impact of human resource management practices on turnover, productivity, and corporate financial performance". Academy of Management Journal. Vol.38, Nº 3, pp. 635-872.

Ichniowski, C., Shaw, Kathryn. and Prennushi, G. (1997): The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines. The American Economic Review, Vol. 87, Nº 3, pp 21-313

Kato, T. and Morishima, M. (2002): "The productivity effects of participatory employment practices: evidence from new Japanese panel Data". Industrial Relations, Vol.41, Nº4, pp.487-520.

Kolenikov, S. and Angeles, G. (2004): "The use of discrete data in PCA: Theory, simulatins, and applications to socioeconimc índices. University of North Carolina, mimeo.

Kodde, D and Palm, F. (1986): "Wald Criteria for jointly testing equality and inequality restrictions". Econometrica, Vol.54, Nº5, pp. 1243-1248

Laursen, K. and Foss, N. (2003): "New Human Resources Management Practices, Complementarities, and the Impact on Innovation Performance". Cambridge Journal of Economics. Vol. 27, Nº2

Lawler, E. (1986): "High involvement management", San Francisco, CA, Jossey-Bass.

Leiponen, A. (2002): "Exploring the sources of skill-biased technical change: a firm performance perspective". Cornell University, Working paper 2002-11

Levinsohn, J. and Petrin, A. (2003): "Estimating production functions using inputs to control for unobservables", Review of Economic Studies, Vol. 70, pp. 371-341.

Lokshin, B., Carree, M. and Belderbos, R. (2007): "Testing for complementarity and substitutability in the case of multiple practices". Maastricht University, mimeo.

MacDuffie, J. (1995): "Human resource bundles and manufacturing performance: Organizational logic and flexible production systems in the world auto industry". Vol.48, Nº2, pp.197-221.

Machin, S. and Van Reenen, J. (1998): "Technology and changes in skills structure: Evidence from seven OECD countries". The Quarterly Journal of Economics, Vol. 113, pp.1215-1244.

Mas, M. and Quesada, J. (2005): "ICT and economic growth: A quantification of productivity growth in Spain 1985-2002", OECD Statistics Working Paper, Nº4

Mas, M. and Quesada, J. (2007): "Spain: A success story shadowed only by a poor productivity performance", National Institute Economic Review, Nº200, Abril 2007.

Matteucci, N., O'Mahony, M., Robinson, C. and Zwich, T. (2005): "Productivity, workplace performance and ICT: Industry and firm-level evidence for Europe and the US". Scottish Journal of Political Economy, Vol.52, N.3 pp.359-386.

Milgrom, P. and Roberts, J. (1990): "The economics of modern manufacturing: Technology, strategy and organization". American Economic Review, Vol.80, pp.511-528.

Mohnen, P. and Röller, L.H (2005): "Complementarities in innovation policy". European Economic Review. Vol.49, pp.1431-1450.

Olley, S., and Pakes, A. (1996): "The dinamics of productivity in the telecommunications equipment industry", Econometrica, Vol.64, Nº 6, 163-1298.

Osterman, P. (1994): "How common is workplace transformation and who adopts it? "Industrial and Labor Relations Review, Vol.47 Nº2

Osterman, P. (2006): "The wage effects of high performance work organizations in manufacturing". Industrial and Labor Relations Review, Vol.59 Nº2, pp. 187-204.

Patterson, M.G., West, M.A. and Wall, T.D. (2004): "Integrated manufacturing, empowerment and company performance". Journal of Organizational Behavior. Vol.25, Nº5, pp. 641-665.

Piva, M., Santarelli, E. and Vivarelli, M. (2005): “The skill bias effect of technological and organisational change: Evidence and policy implications”. Research Policy, Vol. 31, Nº2, pp. 141-57.

Siegel, D.S., Waldman, D.A. and Youngdahl, W.E. (1997): “The adoption of advanced manufacturing technologies: human resource management implications”. IEEE Transactions on Engineering Management. Vol. 44, Nº3, pp. 288-298.

Snell, S.A. and Dean, J.W. (1992): “Integrated manufacturing and human resource management: a human capital perspective”. Academy of Management Journal. Vol. 35, Nº3, pp. 467-504.

Yasar, M. and Morrison Paul, C. (2008): “Capital-skill complementarity, productivity and wages: evidence form plant-level data for a developin country”. Labour Economics, Vol.15 pp. 1-17

Van Biesebbroech, J. (2007): “Robustness of productivity estimates”. The Journal of Industrial Economics. Vol. 55, Nº3 pp. 529-569

Wolf, E. and Zwick, T. (2002): “Reassessing the Impact of High Performance Workplace”. ZEW Discussion Paper Nº02-07

Annex

Table 1: Firm distribution by sectors

Sector	CNAE Code	% Firms
Food and Beverages	15	16,07
Office, accounting and computing machinery	31-33	13,84
Rubber and plastics	25	8,93
Fabricated metal products, except machinery	28	29,91
Machinery and Equipment	29	24,55
Furniture	36	6,7

Table 2: Survey distribution by occupational group

Occupational groups	Total workers	Workers respondents	% responders
Managers	696	323	46,4%
Supervisors	688	346	50,3%
Operators	2820	1780	63,1%
Others workers	3362	-----	
Total	7566	2449	
Total firms	224	224	

Table 3: Principal Component Analysis (results using polychoricas correlations).

	Factor 1 (process quality)	Factor 2 (work teams)	Factor 3 (job rotation)
Employee suggestion systems	**0,3127**	0,0055	-0,2400
Information sharing manager-employees	**0,1642**	0,1121	-0,0982
Job Rotation	0,1291	-0,2296	**0,5044**
Job Redesign	0,2938	0,213	**0,4432**
Problem solving group	**0,3300**	-0,0019	-0,0886

Self-directed work group/team	0,2741	**0,7293**	0,1466
Quality circle	**0,3467**	-0,2255	-0,1093
Total Quality Management	**0,4650**	-0,4950	-0,1176
KMO	0,7664		

Nota:KMO, Kaiser, Meyer and Olkin test to assess the appropriateness of using factor analysis on data. It takes value 0 to 1. A KMO higher than 0.5 indicates the correlation matrix is suitable for factor analysis. We retain only those factors with eigenvalues upper 1, three factors, which account for 73% of the variation.

Work organizational practices description

Employee suggestion systems

Is a systems to solicit and utilize input form the firm employees in order to archive cost saving, improve product quality, workplace efficiency, customer service, or working conditions. One mechanism consist in placing suggestion boxes in common areas or implementing formal programs with committees to review ideas and propose new ones.

Information sharing manager-employees

It is refers to vertical communication which occurs up and down the organizational structure. Information sharing manager-employees should incorporate both upward communication from the employees to the management and downward communication from the management to the workforce.

Job Rotation

It is a way of extending or enlarging the tasks carried out by employees. Employees are moved form one job to another in a planner manner. Job rotation can often lead to increased job satisfaction and worker skills because expose the employee to different experiences and different tasks.

Job Redesign

Consist in redesign the parameters of an existing job to incorporate additional or different required tasks. Job redesign allows enlarging and enriching jobs that increase employee satisfaction and motivation.

Problem solving groups

It is a group of workers from the same area that meet regularly in order to identify and suggest solutions to different problems that appear. Basically, this group is responsible to identify and clarify the problem, generate potential solutions, evaluate potential solutions, select a solution, implement it and evaluate the outcomes.

Self-directed work group/team

It can be likened to a cell-structure form of production, where the employees themselves decide how the work will be allocated, in what order, what the overall objective are, recruit ana hire they members and decide about remuneration.

Quality cicle

It is a discussion group which meets on a regular basis to identify quality problems, investigate solutions and make recommendations as to the most suitable solution. The members are employees with specific skills or expertise.

Total quality management (TQM)

It is a set of management practices focused on process measurement and controls as means of continuous quality improvements. Total quality management takes into account all quality measures taken at all levels on involving all firm employees.

Table 4: Descriptive statistics

Variables	*Mean*	*Estand. Desv.*
% graduate workers	0,090	0,167
Automatic sensors used on inputs and outputs	0,182	0,387
Automatic storage	0,227	0,420
Flexible manufacturing systems	0,400	0,491
Computer vision machines	0,102	0,304
Automatic quality control systems	0,213	0,411
CAD-controled machine	0,276	0,448
Factory network.	0,653	0,477
Computer-aided design (CAD)	0,418	0,494
Total new technologies number	2,471	1,742
Employee suggestion systems	0,427	0,496
Information sharing manager-employees.	0,689	0,464
Job Rotation.	0,516	0,501
Job Redesign.	0,373	0,485
Problem solving group.	0,329	0,471
Self-directed work group/team.	0,253	0,436
Quality circle.	0,391	0,489
Total Quality Management.	0,209	0,407
Total work organizational practices number	3,187	2,153
age	29,133	24,700
Exporter firms	0,640	0,481
% external sales	0,147	0,195
% managers	0,135	0,121
% supervisor	0,111	0,082
% operators	0,416	0,228
Operators experience (age mean in the same job)	9,122	5,853
Firms with foreign capital	0,044	0,207
Firm part of a business group	0,107	0,309
Micro firms (less 10 workers)	0,094	0,292
Small firms (10 -49 workers)	0,710	0,455
Medium firms (50-249 workers)	0,196	0,398
Total observations	**224**	

Table 5: Determinants TFP mean to the period 2003-2005. (OLS method)

	(1)		(2)		(3)		(4)		(5)		(6)	
	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.
HK	0,310*	0,165							0,307*	0,165	0,295*	0,159
AMT												
medium			-0,003	0,056					0,001	0,057	0,010	0,057
high			0,117*	0,066					0,139*	0,071	0,134*	0,073
WO												
medium					-0,026	0,052			-0,050	0,054		
high					-0,036	0,072			-0,085	0,077		
WO quality												
medium							-0,030	0,063			-0,052	0,065
high							-0,016	0,060			-0,058	0,066
WO team												
medium							-0,009	0,066			0,002	0,066
high							-0,093	0,080			-0,080	0,079
WO rotation												
medium							0,018	0,061			0,004	0,059
high							-0,052	0,065			-0,050	0,064
age	0,005*	0,003	0,004	0,003	0,004	0,003	0,004	0,003	0,005**	0,003	0,006**	0,003
age2	-2,63E-05**	1,31-05	-1,64E-05	1,26E-05	-1,68E-05	1,26E-05	-1,9E-05	1,26E-05	-2,95E-05**	1.39E-05	3,08E-05**	1.39E-05
Exporter	-0,027	0,070	-0,029	0,070	-0,019	0,071	-0,013	0,069	-0,039	0,070	-0,037	0,069
% exports	0,214	0,198	0,215	0,203	0,226	0,200	0,190	0,193	0,196	0,205	0,170	0,199
Worker experience	0,008	0,005	0,006	0,005	0,007	0,005	0,007	0,005	0,007	0,005	0,007	0,005
Family	0,088	0,145	0,122	0,133	0,109	0,141	0,077	0,151	0,080	0,141	0,054	0,149
Group	0,068	0,087	0,061	0,082	0,074	0,084	0,087	0,100	0,068	0,084	0,083	0,099
Size												
Small	0,281***	0,105	0,252**	0,102	0,267***	0,100	0,284***	0,106	0,273**	0,107	0,289**	0,112
medium	0,191	0,144	0,147	0,146	0,183	0,139	0,223	0,144	0,176	0,146	0,212	0,153
N	224		224		224		224		224		224	
Rsquare	0,3361		0,3391		0,3265		0,3401		0,354		0,365	

Note: *Robust OLS estimation. Industrial and regional controls are included in all estimations. ***, **, * represents statistical signification al 1%, 5% and 10% respectively.*

Table 6: Determinants TFP mean to the period 2003-2005. (LP method)

	(1)		(2)		(3)		(4)		(5)		(6)	
	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.	Coef.	Err. Est.
HK	0,443**	0,197							0,417**	0,186	0,412**	0,188
AMT												
medium			0,037	0,060					0,043	0,061	0,040	0,062
high			0,224***	0,068					0,241***	0,075	0,223***	0,075
WO												
medium					-0,041	0,057			-0,084	0,058		
high					0,042	0,075			-0,037	0,076		
WO quality												
medium							-0,009	0,065			-0,049	0,067
high							0,040	0,063			-0,029	0,067
WO team												
medium							-0,069	0,071			-0,054	0,069
high							-0,158**	0,077			-0,138*	0,074
WO rotation												
medium							-0,005	0,069			-0,025	0,065
high							-0,049	0,065			-0,047	0,062
age	0,005*	0,003	0,004	0,003	0,003	0,003	0,004	0,003	0,005*	0,003	0,006**	0,003
age2	-3,39E-05**	1,37E-05	-1,85E-05	1,34E-05	-1,79E-05	1,31E-05	-2,02E-05	1,34E-05	-3,43E-05**	1.41E-05	-3,6E-05**	0,000
Exporter	0,042	0,072	0,036	0,073	0,054	0,074	0,067	0,073	0,023	0,073	0,031	0,072
% exports	0,361*	0,204	0,348*	0,209	0,383*	0,208	0,338*	0,201	0,330	0,210	0,301	0,203
Worker experience	0,016***	0,005	0,013***	0,005	0,014***	0,005	0,014***	0,005	0,014***	0,005	0,014***	0,005
Family	0,061	0,154	0,112	0,137	0,115	0,141	0,055	0,153	0,077	0,143	0,025	0,152
Group	0,139	0,094	0,122	0,089	0,145	0,090	0,181*	0,104	0,133	0,090	0,172*	0,102
Size												
Small	0,375***	0,109	0,316***	0,102	0,354***	0,106	0,359***	0,107	0,346***	0,108	0,356***	0,110
medium	0,633***	0,135	0,547***	0,132	0,609***	0,130	0,633***	0,131	0,580***	0,135	0,604***	0,138
N	224		224		224		224		224		224	
Rsquare	0,4541		0,463		0,4416		0,4553		0,488		0,496	

Note: *Robust OLS estimation. Industrial and regional controls are included in all estimations. ***, **, * represents statistical signification al 1%, 5% and 10% respectively.*

Table 7: Firm distribution by productive systems

Productive systems	% Firms
S111 Production systems intensive in human capital, new process technologies and new work organizational practices	1,79%
S110 Production systems intensive in human capital and new process technologies	5,36%
S101 Production systems intensive in human capital and new work organizational practices	2,68%
S011 Production systems intensive in new process technologies and new work organizational practices	6,25%
S001 Production systems intensive in work organizational practices	6,70%
S010 Production systems intensive in new process technologies	10,71%
S100 Production systems intensive in human capital	20,98%
S000 Traditional production systems (low levels of human capital, new process technologies and new work organizational practices)	45,54%

Table 8: Effects of each production system on TFP median to the period 2003-2005

	Model 1 (OLS)		Modelo1 (LP)	
	Coef.	Std. Err.	Coef.	Std. Err.
S111	0,289	0,214	0,536***	0,142
S110	0,232*	0,135	0,335***	0,123
S101	0,091	0,114	0,267	0,173
S011	-0,019	0,094	0,171	0,112
S001	0,028	0,134	0,004	0,107
S010	0,200***	0,071	0,226***	0,081
S100	0,111	0,071	0,162**	0,077
N	224		224	
R squared	0,363		0,493	
Complementarity test	Satisfied		Satisfied	

*Nota: Age, age squared, external market competition, belong a group, family firm, worker experience, size, occupational structure, industrial and regional controls variables are included in all estimations. ***, **, * represents statistical signification al 1%, 5% and 10% respectively.*

Table 9: Firm distribution by each production system and each bundle of practices.

Production systems	Organizational practices oriented to quality production process (factor1)	Organizational practices oriented to work teams (factor2)	Organizational practices oriented to job rotation (factor3)
	% Firms	% Firms	% Firms
S111	3,13%	2,23%	1,79%
S110	4,02%	4,91%	5,36%
S101	4,02%	4,46%	9,38%
S011	10,71%	4,02%	5,80%
S001	12,95%	15,63%	16,96%
S010	6,25%	12,95%	11,16%
S100	19,64%	19,20%	14,29%
S000	39,29%	36,61%	35,27%

Nota: *s(x,y,z)where x is the human capital dimension, y is the technology dimension, and z is the organizational dimension. In column 1 z represents those practices more related to quality production process, in column 2 z represents those practices more related to work teams, and in column 3 z represents those practices more related to job rotation.*

Table 9: Effects of each production system on TFP median to the period 2003-2005 (by bundles of work organizational practices)

OLS

	Modelo1 (quality process)[a]		Model 2 (work teams)[b]		Model 3 (job rotation)[c]	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
S111	0,320**	0,151	0,258	0,190	-0,218	0,165
S110	0,164	0,164	0,210	0,153	0,442***	0,119
S101	0,111	0,101	0,108	0,111	0,073	0,076
S011	0,042	0,077	-0,016	0,144	0,023	0,090
S001	-0,046	0,090	-0,127*	0,076	0,064	0,071
S010	0,191**	0,087	0,124*	0,068	0,222***	0,080
S100	0,098	0,072	0,068	0,072	0,143	0,089
N	224		224		224	
R square	0,3714		0,3752		0,4044	
Complementarity Test	Satisfied		Not satisfied		Not satisfied	

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	Modelo1 (quality process)[a]		Model 2 (work teams)[b]		Model 3 (job rotation)[c]	
	Coef.	Std. Err.	Coef.	Coef.	Std. Err.	Coef.
S111	0,533***	0,126	0,257*	0,156	-0,064	0,165
S110	0,233	0,142	0,393***	0,143	0,540***	0,102
S101	0,290**	0,137	0,127	0,129	0,170*	0,096
S011	0,152*	0,089	0,022	0,153	0,136	0,106
S001	-0,072	0,081	-0,119*	0,070	0,058	0,071
S010	0,222**	0,090	0,197**	0,078	0,252***	0,088
S100	0,133*	0,077	0,155*	0,079	0,191**	0,093
N	224		224		224	
R square	0,512		0,503		0,520	
Complementarity Test	Satisfied		Not satisfied		Not satisfied	

*Nota: Age, age squared, external market competition, belong a group, family firm, worker experience, size, occupational structure, industrial and regional controls variables are included in all estimations. ***, **, * represents statistical signification al 1%, 5% and 10% respectively. a) work teams and job rotation factors are included as control variables, b) quality production process and job rotation factors are included as control variables, c) quality production process and work teams factors are included as control variables.*