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ICT, INNOVATION, WAGES AND LABOUR PRODUCTIVITY. NEW EVIDENCE FROM SMALL LOCAL FIRMS

TIC, INNOVACIÓN, SALARIOS Y PRODUCTIVIDAD DEL TRABAJO. NUEVA EVIDENCIA PARA EMPRESAS PEQUEÑAS Y LOCALES

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ABSTRACT

This article analyses new co-innovative sources (ICTs, human capital and training, and new forms of work organisation) of labour productivity in small firms producing for local markets. Using 2009 survey data for a representative sample of 464 firms based in Girona (a province in the north-east of Spain) and using Ordinary Least Square (OLS) econometric estimation techniques, two main findings have emerged from the study. First, that mean wage is the main determinant of labour productivity. And second, unlike the evidence available for larger firms, co-innovation does not have a total effect on explaining small local firm's labour productivity. Causal relationships between co-innovation and labour productivity have only been identified in the innovative small local firms, one quarter of the sample.

Key words: ICT, co-innovation, wages, labour productivity, small local firms, Spain. **JEL**: J24, L22, O31, O33.

RESUMEN

Este artículo analiza las nuevas fuentes co-innovadoras (TIC, formación y nuevas formas de organización del empleo) de la productividad del trabajo en empresas pequeñas que producen para los mercados locales. Utilizando datos de una muestra representativa para 464 empresas localizadas en Girona (un provincia del norte de España) durante 2009, y a través de técnicas de estimación econométrica por mínimos cuadrados ordinarios, la investigación ha obtenido dos resultados principales. En primer lugar, que el salario es el principal determinante de la productividad del trabajo. En segundo lugar, y en contraposición con la evidencia hallada para las grandes empresas, en las pequeñas empresas con mercados locales la co-innovación no ejerce un efecto total sobre la productividad del trabajo. Únicamente se ha obtenido relación de causalidad directa entre la co-innovación y la productividad en las pequeñas empresas locales innovadoras, una cuarta parte de la muestra total.

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Palabras claves: TIC, co-innovación, salarios, productividad del trabajo, empresas pequeñas y locales, España. **JEL**: J24, L22, O31, O33.

1. INTRODUCTION

The widespread use of Information and Communication Technologies (ICT) is one of the main distinguishing features of today's economic activity (Jovanovic and Rousseau, 2006; Jorgenson and Vu, 2007). The reason for this is twofold: first, their direct contribution to increased productivity and economic growth (Jorgenson, Ho and Stiroh, 2008), and second, their indirect contribution resulting from the generation of complementary innovations that improve an economy's Total Factor Productivity (TFP) (Pilat, 2006; Jorgenson, Ho and Samuelson, 2011; Ceccobelli, Gitto and Mancuso, 2012).

From the perspective of analysing the impact of ICT on firm productivity, empirical evidence shows that: 1) the rates of return on digital investment are relatively much higher than those on investment in other physical components; 2) the reason for this is that digital investment and use often go hand in hand with other endeavours, generally human capital improvement and organisational structure change (Bresnahan, Brynjolfsson and Hitt, 2002; Arvanitis, 2005). Indeed, the transformative impact of ICT investment and use on the results of business activity becomes more evident through co-innovation processes (Greenan, L'Horty and Mairesse, 2002; Brynjolfsson and Hitt, 2003; Torrent and Ficapal, 2010b; Cardona, Kretschmer and Strobel, 2013).

ICT investment and use do not give rise to generalised productivity improvements until firms and their workers achieve the required technological, educational/training, organisational, business, labour and cultural competencies. In other words, the role of ICT as a general purpose technology needs organisational and business process changes to fully exploit its growth opportunities (Ceccobelli, Gitto and Mancuso, 2012). For this reason and in this context, co-innovative sources of labour productivity in a sample of small local firms will be analysed below.

The availability of survey data for a representative sample of 464 small local firms in Girona (a province in north-eastern Spain) was especially useful for two reasons. First, because there is relatively little available evidence on co-innovative sources of productivity in small and medium enterprises (SMEs), especially small firms that produce primarily for local markets (Audretsch, 2002, 2006; Hall, Lotti and Mairesse, 2009; Wymenga et al., 2012). And second, despite evidence available for larger firms, a validated function on new co-innovativeness sources is a useful tool for evaluating small local firms' productivity, a task that is not without its difficulties in this dimension of business (Audretsch, 2002, 2006; Wymenga, Spanikova, Barker, Konings, & Canton, 2012).

The reminder of this paper is organised as follows. Section 2 presents a survey from the empirical literature about the relationships between ICT, innovation and firm productivity. Section 3 describes the data. Section 4 reports the model and the variables. Section 5 presents the results, and Section 6 provides conclusions and discussion based on those findings.

2. ICT, INNOVATION AND FIRMS LABOUR PRODUCTIVITY: A SURVEY FROM THE EMPIRICAL LITERATURE

The main results that the international empirical evidence has suggested in relation to the new co-innovative sources of firm productivity are presented in this section. The results are presented by country and date of publication, with special attention to the Spanish case.

In a baseline study on firms in the United States, Black and Lynch (2001, 2004) confirmed the decisive importance of ICT and innovation systems in the workplace in the explanation of firm productivity, particularly when co-innovation is introduced into establishments where there are trade unions to protect job security. Bresnahan, Brynjolfsson and Hitt (2002) found that firms with intensive ICT use and considerable implementation of innovation processes in the workplace (education, training, decision-making autonomy and decentralisation) have higher levels of labour productivity than firms that have innovated in such areas. In addition, the impact of labour on productivity is practically zero when there is a minimal presence of digital or organisational innovation in business activity. Brynjolfsson and Hitt (2003) identified a set of new organisational practices in firms (freedom of information and communication, decision-making rights, performance-related incentives, and investment in education and training) that, together with digital innovation, are determinants in the explanation of productivity growth. Atrostic and Nguyen (2005) found a positive impact on labour productivity in firms that intensively use telecommunications and computer networks.

Based on research conducted on firms in the United States, another set of studies has also tried to test the causal relationships between co-innovation and business efficiency in other territories and in other business groups worldwide. Gretton, Gali and Parham (2004) found that a positive impact of ICT use for business, of new forms of organisation and of labour qualification on productivity in a sample of Australian firms. Grimes, Cleo and Stevens (2012) have confirmed a very significant transversal impact of broadband Internet use on firm productivity in New Zealand.

In a sample of British firms (Nickell and Van Reenen, 2000), and of British and French firms (Caroli and Van Reenen, 2001), the link between workplace innovation and firm productivity was found to be more apparent when labour relations systems developed joint practices for firms and workers to be involved in decision-making and problem-solving. Another set of studies conducted on British firms (Bloom *et al*., 2005; Clayton, Sadun and Farooqui, 2007) found that ICT investment and use have a significant impact on firm productivity, albeit to varying degrees. The most significant impacts occur in multinational firms and in industries that intensively use technology. In this respect, and in a sample of German, Italian and British firms, Matteucci *et al*. (2005) showed that ICT investment has a major impact on industrial productivity, whereas efficiency improvements in services are basically due to workers using computers.

In Italy, Leoni (2008) found that ICT investment and use would allow firms to implement changes in production processes, strategy, organisational structure and external relations; at the same time, such ICT investment and use would require changes in firm organisation to ensure their effective implementation. Cristini *et al*. (2003) concluded that: a) ICT and organisational change do not determine increases in added value if they are adopted independently; b) ICT determine a significant increase in firm labour productivity if, and only if, they are combined with the adoption of practices that encourage the delegation of responsibilities, greater worker autonomy and, more generally, practices that transform working methods; and c) there is a very significant complementary effect on labour productivity in firms where extended education, training and the introduction of ICT interact.

Becchetti, Londono and Paganetto (2003) analysed the impact of investment in ICT components (hardware, software and telecommunications) on productivity in small and medium-sized firms in Italy. Their results underscored the importance of investment in software, while investment in telecommunications would impact on the generation of product and process innovations.

In Switzerland, Arvanitis (2005) showed that positive effects are generated between some new organisational practices (work teams, delegation of competencies and contact with the client) and labour productivity. In addition, the building of a joint indicator of innovative practices in the workplace determines a positive effect on productivity, albeit considerably lower than the effect of the co-innovative indicator of ICT use and human capital. Finally, no relationship of complementarity has been found between the latter two components and work organisation. In a comparative study of Swiss and Greek firms, Arvanitis and Loukis (2009) confirmed the importance of investment in physical capital, human capital, technological and digital capital, and organisational capital in the explanation of productivity, although a greater impact was found on the efficiency of new co-innovative sources in Swiss companies.

In Germany, a set of studies based on several time samples of its industry's firms also confirmed the existence of relationships of dependence between labour productivity and digital technology and organisational innovation processes, though once again, evidence of relationships of complementarity was only found in the explanation of labour efficiency for co-innovation between ICT and human capital (Bauer and Bender, 2003; Hempell, 2005; Hempell and Zwick, 2008).

In Japan, Miyazaki, Idota and Miyoshi (2012) have classified ICT applications into four stages of sophistication (non-performing ICT assets, section-wide system applications, company-wide system applications and inter-corporate system applications) and found that the impact of ICT on firm productivity increases with a successive stage of ICT use sophistication. In Korea, Jung, Na and Yoon (2013) confirms the direct impact of ICT on industrial labor productivity and the indirect broadband network effect on industrial TFP.

More recently, Jiménez-Rodríguez (2012) has analysed the disaggregated effects or real ICT investment shocks on labour productivity in some EU-15 countries and the United States, distinguishing between ICT-intensive and less intensive industries. The response patterns to a real ICT investment shock on labour productivity are qualitatively similar for the two types of industries considered and in most of the countries. Also, the positive impact on labour productivity in the ICT-intensive industries was found to be greater after the mid-1990s, with the United States being the most positively affected country.

In Spain, Hernando and Núñez (2004) showed that: a) investment in ICT inputs had a significant positive impact in the explanation of output growth and firm productivity; and b) that such impact was greater after the mid-1990s. Other works (López-Sánchez *et al*., 2006) also suggest a positive and growing influence of the impact of ICT on firm productivity as the implementation of such ICT increases, especially when firms invest in the Internet and foster its use in the workplace. However, the low intensity of Internet use in the workplace suggests that much needs to be done to achieve efficiency improvements in Spanish firms. In fact, the weakness of the impact of ICT on firm productivity is clearly demonstrated when the firm- and time-specific effect is introduced. Badescu and Garcés-Ayerbe (2009) did not find a causal relationship between ICT investment and improvements in firm productivity in small and medium-sized firms, owing to the time lag between the digital enablement process and its returns in terms efficiency. In fact, the low intensity of ICT use by firms and the low presence of relationships of complementarity between digital innovation, organisational change and

occupational training have become a major limiting factor on firm productivity improvements in Spain (Torrent and Vilaseca, 2008).

From a regional perspective, and using survey data for a representative sample of firms in Catalonia (a region of Spain), Torrent & Ficapal 2 (2010a; 2010b) analysed new co-innovative sources of labour productivity (ICT use, skilled labour and new forms of work organisation). The results identified a competitive pattern marked by the decisive impact of physical productive capital and, to a lesser extent, by new forms of work organisation. In addition, a segmentation of the sample of firms suggested the existence of two distinct patterns of sources of productivity. In technology- and knowledge-intensive firms (about one fifth of the total) the sources of productivity were physical productive capital, new work organisation systems and relationships of complementarity between them and ICT use. For the remaining Catalan firms (80%, which neither used technology nor were knowledge intensive), no evidence was found to show any impact of new co-innovative sources on firm labour productivity. Likewise, Brasini and Freo (2012) have studied the extent of ICT implementation in manufacturing firms in an Italian region. There were two main findings: first, that a widespread implementation of ICT has not been exploited to its full potential, and second, that ICT adoption has produced higher growth in technical efficiency for adopter firms than for the non-adopter firms, but slower growth in productivity, thus supporting the productive paradox at firm level.

Table 1 summarises the main results of the impact of new co-innovative sources on firm labour productivity for a broad set of studies. To begin with, it is important to underscore the preliminary nature of this comparative exercise, given that the diversity of not only the firms and sectors but also the study years and analysis models (cross-sectional and times-series) contemplated suggest that a degree of caution is required in the comparative interpretation (Draca, Sadun and Van Reenen, 2007; Torrent and Ficapal, 2010a; Cardona, Kretschmer and Strobel, 2013). Three conclusions can be drawn. First, most of the studies analysed found that ICT investment and use, and new organisational structures have a positive effect on firm productivity. Second and conversely, evidence on the impact of human capital quality on efficiency is mixed. And third, regarding relationships of complementarity (co-innovation), everything seems to indicate that there are two distinct patterns of influence. In studies for the United States and Australia, relationships of complementarity were found between organisational change and ICT, and between labour qualification and ICT. In contrast, in studies for European countries, most of the interactions found have their origins in relationships of complementarity between labour qualification and ICT, and between organisational change and labour qualification. In this respect, it should be noted that the impact of digital co-innovation processes on firm productivity in American and Australian firms is greater than in European firms.

Nevertheless, the international empirical evidence is particularly focused on large-scale firms. In this sense, the main purpose of the article is to advance the state of the art, and analyze the co-innovative sources of productivity in small companies that produce mainly for local markets.

TABLE 1. INTERNATIONAL COMPARISON OF NEW CO-INNOVATIVE SOURCES OF FIRM LABOUR PRODUCTIVITY

Country/research	ICT investment and use (ICT)	New forms of work organisation (NORG)	Human capital and training (HCT)	Co-innovation
United States				
Black and Lynch (2001; 2004)	Positive	Positive	NS	NS
Bresnahan et al. (2002)	Positive	Positive	Positive	NORG/ICT HCT/ICT
Brynjolfsson y Hitt (2003)	Positive	NS	NC	NORG/ICT
Australia				
Gretton *et al*. (2004)	Positive	Positive	Positive	ORG/TIC HCT/ICT
Germany				
Hempell (2005)	Positive	NC	NS	HCT/ICT
Hempell and Zwick (2008)	Positive	Positive	Positive	HCT/ICT
United Kingdom				
Bloom *et al*. (2005)	Positive	NC	NC	NC
Clayton *et al.* (2007)	Positive	NC	Positive	HCT/ICT
Italy				
Cristini *et al*. (2003)	NS	NS	NS	HCT/ICT
Switzerland				
Arvanitis (2005)	Positive	Positive	Positive	HCT/ICT
France and United Kingdom				
Caroli and Van Reenen (2001)	NS	Positive	NS	NORG/HCT
Germany, France and United Kingdom				
Matteucci *et al*. (2005)	Positive	NC	NC	NC
Spain				
Hernando and Núñez (2004)	Positive	NC	NC	NC
López-Sánchez *et al*. (2006)	Positive	NC	Positive	NC
Badescu y Garcés (2009)	NS	NC	NC	NC
Catalonia				
Torrent and Ficapal (2010)	Negative	Positive	NS	NORG/ICT (+) NORG/HCT (-) HCT/ICT (-)

NS: Not significant; NC: Not considered. The positive and negative values are statistically significant at a máximum 90% confidence level.

Source: Own elaboration

3. DATA DESCRIPTION

The study uses survey data for a representative sample of 464 firms operating in Girona (overall margin of error of +/- 4.6% in the case of maximum indetermination, p=q=50, for a confidence level of 95.5%). The research universe is made up of 66,682 firms that in 2009 developed its activity in the province of Girona. From this universe random sampling was performed in order to reach a margin of error of less than +/- 5%. The questionnaire used in the survey contained 47 questions against which a scoring value had to be assigned. It was subjected to an initial pilot stage (30 surveys) and was answered by businesspersons or directors with an overall view of the activities of their firms, in face-to-face interviews lasting

for one hour each. By gathering data on the value chain, the aim of the study was to analyse the sources of productivity in Girona-based firms. The fieldwork was carried out between June and October 2009. The research was conducted with support from the Girona Observatory on ICTs, the Girona Association of New Technology Firms and the Chamber of Commerce of Girona.

TABLE 2. DESCRIPTIVE STATISTICS OF GIRONA-BASED FIRMS

Indicators	Valid percentage (number of firms)
Business sector	
Manufacturing and construction	26.2
Wholesale and retail trade	20.4
Hotels, restaurants and tourism	21.6
Other market services	31.8
Firm size	
Fewer than 10 employees	95.4
From 11 to 49 employees	4.0
50 or more employees	0.6
Firm ownership	
Family firm	89.7
Business group	10.3
Worker training	
Untrained or primary education	32.8
Secondary education	47.3
University education	19.9
Extended training paid by the firm	8.1
Firm innovation	
R&D Department in firm	8.8
Innovation in last two years	26.5
Source of innovation: staff	86.0
Product innovation	50.4
ICT use in value chain	
No ICT use	21.1
Low ICT use	33.1
Medium ICT use	26.7
High ICT use	19.1
Average turnover (thousands of Euros)	
2008	183.5
2009	165.0
Destination of sales	
Girona and rest of Catalonia	94.7
Spain	2.5
European Union	2.5
Rest of the world	0.3

Source: Own elaboration

Girona is a province in the north-east of Spain where small local firms account for the bulk of economic activity. The sectors in which they are involved make low-intensity use of technology (food, metal and construction industries, trade and tourism). The firms have low levels of worker training, they could make better use of ICT and they have important productivity problems (Torrent *et al*., 2012). Table 2 shows some of the main statistics describing the value generation process in the sample of Girona-based firms.

4. MODEL AND VARIABLES

In the estimation of co-innovative sources of firm productivity, an extension of traditional models of growth accounting is normally used. On the basis of a labour productivity function, integrated by the accumulation of productive factors (capital per worker or intensification of capital) and by the efficiency with which they are combined (Total Factor Productivity, TFP), the literature incorporates co-innovative sources into the efficiency component of the mentioned productivity function.

This is an important contribution because, in the analysis of the determinants of firm labour productivity, compound indicators of ICT use, new forms of work organisation or human capital and labour qualification can be used, as can their relationships of complementarity. This allows for the use of explanatory elements that go beyond pure investment, which contemplate the management and effective transformation of business activity. For example, in the case of ICTs, investment in such technologies is not an automatic determinant of efficiency improvements. For improvements to made, ICT goods and services must be used effectively by a firm's value elements, which entail the need to capture indicators of use.

In order to contrast co-innovative sources of firm productivity in Girona, an explanatory model has been used, which shows the effect on labour productivity of: a) physical productive capital; b) new forms of work organisation; c) human capital and labour qualification; d) ICT equipment and uses; e) relationships of co-innovation between ICTs, the new organisational structure and labour qualification; and f) labour relations. In order to specify this model, a firm production function has been taken as the basis; it satisfies the classic assumptions of concavity (increasing marginal products, diminishing marginal productivity, constant returns to scale and without factors there is not production) and is of a Cobb-Douglas type. That is:

$$Y_i = A_i \, PK_i^{\alpha} \, L_i^{\gamma} \, I_i^{\mu} \quad (1)$$

Where: Y_i is the level of turnover in firm i; A_i is the indicator of efficiency (TFP) in firm i; PK_i the endowment of physical productive capital in firm i; L_i is the endowment of labour in firm i; I_i is the endowment of intermediate production costs in firm i; and α, γ and μ represent the elasticities of physical productive capital, labour and intermediate costs over the level of turnover in firm i. Indeed, in keeping with the usual empirical literature (Bresnahan *et al*. 2002; Arvanitis, 2005; Clayton *et al*. 2007; Timmer *et al*. 2010), co-innovative sources of productivity are incorporated into the efficiency indicator. This element shows the effects — joint and complementary— of firm innovation that are not associated directly with factors of production. Thus, the indicator of efficiency A_i takes the following functional form:

$$A_i = \exp(\delta_0 + \delta_1 NORG_i + \delta_2 HCT_i + \delta_3 ICT_i + \delta_4 LABR_i + \delta_5 NORGICT_i + \delta_6 NORGHCT_i + \delta_7 ICTHCT_i) \quad (2)$$

Where $NORG_i$, HCT_i and ICT_i represent indicators of new forms of work organisation; human capital and training; and ICT investment and uses in firm i; $LABR_i$ represents individual variables for labour relations in firm i; and $NORGICT_i$, $NORGHCT_i$, and $ICTHCT_i$

represent combinations of indicators of organisation and ICT; organisation, and human capital and training; and ICT use, and human capital and training in firm i. Finally, δ_i, for i=0…7, represent the elasticities (coefficients) of the various explanatory components of the efficiency indicator.

From the establishment of the Cobb-Douglas production function and efficiency indicator, the functional form to contrast has been built. This functional form converts the production function with the innovation presence to a firm productivity function through the use of logarithmic transformation. Taking logarithms, expressing the equation (1) in terms of labour productivity, incorporating the specifications mentioned for the efficiency indicator and renaming the coefficients to be estimated, it is now possible to develop the basic equation to be tested. So, the model of co-innovative determinants of labour productivity in Girona-based firms takes the following functional form:

$$\text{Ln } Y_i - \text{Ln } L_i = \beta_0 + \beta_1 (\text{Ln } PK_i - \text{Ln } L_i) + \beta_2 \text{ NORG}_i + \beta_3 \text{ HCT}_i + \beta_4 \text{ ICT}_i + \beta_5 \text{ LABR}_i + \beta_6 \text{ NORGICT}_i + \beta_7 \text{ NORGHCT}_i + \beta_8 \text{ ICTHCT}_i \quad (3)$$

Where, β_0 (constant) incorporates the logarithmic difference of intermediate costs per worker and β_i, for i=0…8, represents the elasticities (coefficients) of the explanatory components of firm productivity.

Regarding the specific indicators and variables used in the estimation, the following comments need to be made. The dependent variable, firm labour productivity (LP), has been approximated by the logarithm of turnover divided by the number of full-time equivalent workers. The numerator of this ratio has been obtained from direct data on firm turnover. The denominator has been constructed by taking account of full-time and part-time jobs in the firms and expressing the number of workers as full-time equivalents.

Regarding the independent variables, the procedure described below has been followed. Firstly, it should be noted that the logarithmic difference between intermediate production costs and full-time equivalent workers, which is required for the conversion of the turnover indicator into added value, has been incorporated into the constant of the model to be estimated. Secondly, the effect of physical productive capital on firm productivity has been captured by two variables. The first is the logarithmic difference between the mean wage level and the number of full-time equivalent workers in the firms. The second is the expression of that variable squared. This second variable captures the existence of a wage maximum, from which the effect of wage on firm productivity diminishes (concave function). The two variables are continuous and have been called WAGE and WAGE^2. In line with recent evidence, these two variables allow us to capture the relationship between the wage structure and firm productivity (Lallemand *et al*. 2009; Faggio *et al*. 2010; Mahy *et al*. 2011). Regarding the use of wage as an indicator of productive physical capital in small local firms is important to make two points. First, note that in the context of small local firms analyzed the wage cost is configured as a very important component of productive physical capital. Within these contexts of analysis, wage is an indicator that partially captures the investment in human capital, in addition to the components attached to individuals in the process of small firm activity. Second, note that when dealing with small local firms, financial information on total productive investment is not always available. Given this limitation, it was considered appropriate the introduction of wage as an indicator of productive physical capital. Firstly, and as noted by economic theory, for its evident relationship to productivity and, secondly, being an indicator of capitalization available with our data.

Thirdly, a set of variables has been used for new forms of work organisation (NORG), human capital and training (HCT), innovation (INNOV) and ICT use (ICT). Regarding new forms of work organisation, and on the basis of five Likert-type discrete variables taking

values from 1 to 10, namely: 1) work supervision: 1 = hierarchical, 10 = by objective; 2) work time managed by workers: 1 = not at all, 10 = totally; 3) objectives proposed by workers: 1 = not at all, 10 = totally; 4) teamwork is fostered: 1 = not at all, 10 = totally; and 5) relevant information is shared: 1 = not at all, 10 = totally, a compound indicator has been generated (NORG) that takes two values: 0, when the five variables have values from 1 to 5; and 1, when the five variables have values from 6 to 10. Human capital and training in the firms have been captured by a variable that shows the workers' mean stock of training. The categorical variable HCT takes three values: 1, when the workers' mean stock of training falls into the category of untrained or primary education; 2, when the workers' mean stock of training falls into the category of secondary education; and 3 when the workers' mean stock of training falls into the category of university education. With the aim of showing a firms' innovatory dynamics, the categorical variable INNOV has been constructed, which takes two values: 0, when a firm has not implemented any innovation in the last two years; and 1, when a firm has implemented some type of innovation in the last two years. Finally, the categorical indicator ICT shows the intensity of ICT use in the firms. Having defined the following six value elements in the firms: 1) accounting, finance and taxation; 2) administration and human resources; 3) buying; 4) production; 5) turnover and distribution; and 6) management, the indicator ICT takes four values: 1 = No ICT use, when a firm does not use ICTs in any value element; 2 = Low ICT use, when a firm uses ICTs in one or two of the six defined value elements; 3 = Medium ICT use, when a firm uses ICTs in three or four of the six value elements; and 4 = High ICT use, when a firm uses ICTs in five or six of the defined value elements.

Fourthly, the labour relations dimension (LABR) in the firms is captured by two dichotomous variables. VAREM and FTIMEJOB respectively show the presence of forms of variable remuneration and of full-time jobs (0 = Absence; 1 = Presence) for the firms' workers. Fifth and lastly, and with the aim of showing relationships of complementarity (co-innovation) between the organisational, human capital and ICT use dimensions, the following three indicators have been generated. NORGICT is the indicator resulting from the multiplication of NORG by ICT; it shows the complementarity between new forms of work organisation and ICT use. NORGHCT is the indicator resulting from the multiplication of NORG by HCT; it shows the complementarity between new forms of work organisation, and human capital and training. And ICTHCT is the indicator resulting from the multiplication of ICT by HCT; it shows the complementarity between ICT use, and human capital and training.

Following the usual empirical method, a labour productivity (LP) function for Girona-based firms has been estimated by the Ordinary Least Square (OLS) method. This function takes a functional form like the one shown in Equation 4, which has its origin in expression 3 and where ε_i represents the estimation error term. Coefficients β_i, for i=0…11, represent the elasticities (coefficients) of the various explanatory components of firm labour productivity:

$$LP = \beta_0 + \beta_1 WAGE_i + \beta_2 WAGE^2_i + \beta_3 NORG_i + \beta_4 HCT_i + \beta_5 INNOV_i + \beta_6 ICT_i + \beta_7 VAREM_i + \beta_8 FTIMEJOB + \beta_9 NORGICT_i + \beta_{10} NORGHCT_i + \beta_{11} ICTHCT_i + \varepsilon_i \quad (4)$$

5. RESULTS

Before commencing the analysis of the coefficients obtained for the determinants of labour productivity, several comments need to be made. Firstly, it should be noted that the productivity function considered in Equation 4 has been tested in four different models. Model 1 is the model of determinants of labour productivity for the set of Girona-based firms, excluding relationships of complementarity (co-innovation). Model 2 is the model of determinants of labour productivity for the set of Girona-based firms, including relationships

of complementarity between ICT use, organisational change and human capital. Since relatively unsatisfactory results were anticipated in the light of international evidence, the sample of firms has been segmented using the control variable of innovation (INNOV). Model 3 represents the determinants of labour productivity, including co-innovation, for non-innovative Girona-based firms. And Model 4 represents the determinants of labour productivity, including co-innovation, for innovative Girona-based firms. The firm innovation has been captured through the categorical variable INNOV, which takes two values: 0, when a firm has not implemented any innovation in the last two years; and 1, when a firm has implemented some type of innovation in the last two years.

Secondly, it should be noted that the analysis of the matrix of correlations between dependent and independent variables (multicollinearity) suggests omitting the indicator of new forms of work organisation (NORG), due to it being highly correlated with other dependent indicators and variables. The correlation between the other explanatory variables is situated below 0.4 points. Third and lastly, it should be noted that the explanatory power of the four models developed is high (p=0.000), and that the level of adjustment (adjusted R^2) is no lower than 75% in any of the models. The four models developed are robust and explanatory of labour productivity in Girona-based firms.

TABLE 3. SOURCES OF LABOUR PRODUCTIVITY IN GIRONA-BASED FIRMS*

	Model 1	Model 2	Model 3	Model 4
Constant	(13.550)***	(14.840)***	(18.301)***	(11.917)***
Standardised coefficients				
Wage per full time equivalent worker (WAGE)	0.871***	1.200***	1.289***	1.006***
Wage squared per full time equivalent worker (WAGE2)	-	-0.298***	-0.413***	-0.022
New forms of work organisation (NORG)	-	-	-	-
Human capital and training (HCT)	0.061**	0.382***	0.203	0,503***
Innovation (INNOV)	0.016	0.006	-	-
ICT use (ICT)	-0.055	-	-	-
Variable remuneration of workers (VAREM)	0.023	0.038*	-0.011	0.104***
Full-time job (FTIMEJOB)	0.148***	0.012	0.004	0.076*
NORGICT (NORG*ICT)	-	0.021	-0.014	0.041
NORGHCT (NORG*HCT)	-	-0.336***	-0.111	0.482***
ICTHCT (ICT*HCT)	-	-0.073	-0.048	0.150**
Statistics				
Observations	169	124	77	55
R^2 adjusted	0.797	0.756	0.842	0.792
F	245.658	303.557	149.407	343.677
Significance	0.000	0.000	0.000	0.000

* Multiple linear regression analysis using OLS. Dependent variable: Logarithm of turnover divided by the number of full-time equivalent workers. Standardised coefficients: *** Significant at 99% confidence level;** Significant at 95% confidence level; * Significant at 90% confidence level.
Model 1: model without relationships of complementarity (co-innovation) for all Girona-based firms.
Model 2: model with relationships of complementarity (co-innovation) for all Girona-based firms.
Model 3: model with relationships of complementarity (co-innovation) for non-innovative Girona-based firms.
Model 4: model with relationships of complementarity (co-innovation) for innovative Girona-based firms.

Source: Own elaboration.

Regarding the coefficients of the determinants of labour productivity in Girona-based firms, Table 3 shows the main results obtained. Firstly, it should be noted that the inclusion of intermediate production costs in the constant turns out to be appropriate, given the significance of this coefficient in the four models. The basic explanatory model (Model 1) of labour productivity in Girona-based firms is primary; it clearly manifests the growth model problems of the territory's business fabric. From highest to lowest relevance and significance of the standardised coefficient obtained, labour productivity in Girona-based firms is explained by mean wage (β=0.871, $p<0.001$), full-time jobs (β=0.148, $p<0.001$) and the workers' stock of training (β=0.061, $p<0.05$). While human capital and training, wage level and more stable forms of working day are significant and positive, neither innovation nor ICT use or variable forms of worker remuneration explain labour productivity in Girona-based firms.

The inclusion of relationships of complementarity (co-innovation) in the basic model, in other words, the generation of a compact model (Model 2) does not provide much positive news either. Again, from highest to lowest relevance and significance of the standardised coefficients obtained, labour productivity in Girona-based firms is explained by mean wage (β=1.200, $p<0.001$), training (β=0.382, $p<0.001$) and variable forms of worker remuneration (β=0.038, $p<0.01$). In addition, the mean wage squared (β=-0.298, $p<0.001$) and co-innovation between new forms of work organisation, and human capital and training (β=-0.336, $p<0.001$) explain, negatively, labour productivity in Girona-based firms. Regarding the coefficient of mean wage squared, the negative result was expected because it indicates that wage growth —the wage experience— reaches a maximum in the explanation of productivity. In this respect, the premise that unlimited wage increases always lead to improvements in productivity is not met. However, a much more worrying issue is the significant negative impact on productivity of the relationship of complementarity between new forms of work organisation, and human capital and training.

In short, while wage and its limited increase, human capital and training, and variable remuneration of workers explain labour productivity in Girona-based firms, the introduction of indicators of co-innovation give disappointing results. Firstly, because neither innovation nor full-time jobs are significant. And secondly, because the other two indicators of co-innovation —relationships of complementarity between ICT use and new forms of work organisation, and between ICT use and human capital and training— do not explain productivity in Girona-based firms either. Girona's business fabric displays a pattern of very basic primary efficiency, in which neither innovation nor co-innovation significantly and positively explains labour productivity.

The disappointing results obtained for the compact explanatory model (Model 2) suggest an additional segmentation of the sample of firms. By innovative practices, the sample of Girona-based firms has been divided according to whether they are non-innovative (Model 3) or innovative (Model 4). This segmentation seeks to find a set of firms in which co-innovation plays an important role in the explanation of productivity. A set of firms with an explanatory pattern of productivity is sought, one that is better suited to the new co-innovative conditions of competition identified in the international literature. As expected, the results from Model 3, the one for non-innovative Girona-based firms, confirm a pattern of very low-intensity primary productivity, without the presence of either the new determinants or of the co-innovative sources of firm labour productivity. In this majority set of Girona-based firms (nearly three quarters of the total), only mean wage (β=1.289, $p<0.001$) and mean wage squared (β=-0.413, $p<0.001$) explain labour productivity. Neither human capital and training

nor stable forms of working day, variable remuneration of workers or the three co-innovative sources explain labour productivity in this majority set of Girona-based firms.

In contrast, the results obtained for innovative Girona-based firms (nearly one quarter of the total) confirm the presence of new co-innovative sources of labour productivity in this smaller set. Innovative Girona-based firms (Model 4) display a more complete and intensive pattern of productivity that is more in keeping with the one identified in international empirical evidence. As is the case in the other models, mean wage (β=1.006, $p<0.001$), human capital and training (β=0.503, $p<0.001$), variable remuneration of workers (β=0.104, $p<0.001$) and full-time jobs (β=0.076, $p<0.01$) explain labour productivity. But, as a distinguishing element, the presence of significant positive coefficients of two indicators of co-innovation stands out: new forms of work organisation, and human capital and training (β=0.482, $p<0.001$), and ICT use, and human capital and training (β=0.150, $p<0.001$). So, innovative Girona-based firms channel new co-innovative sources of productivity through human capital and training, which establish relationships of complementarity with new forms of work organisation and with intensive ICT use. However, the link between new forms of work organisation and intensive ICT use does not turn out to be significant in the explanation of labour productivity in this minority set of firms.

6. CONCLUDING REMARKS AND DISCUSSION

In recent years, international empirical evidence has demonstrated the existence of new co-innovative sources of firm productivity based on the establishment of relationships of complementarity (co-innovation) between ICT investment and use, new forms of work organisation and labour relations, and human capital and training. Using 2009 survey data for a representative sample of the firms based in Girona (a province in the north-east of Spain), this article has analysed the determinants of firm labour productivity. The main aim of the study was to obtain new evidence on new co-innovative sources of productivity in a specific business fabric, a characteristic feature of which is the majority presence of small firms producing mostly for local markets. For that purpose, Ordinary Least Square (OLS) econometric technique has been used.

The results obtained from the estimation suggest that Girona-based firms have a primary, extensive grow th model with sources of productivity based on mean wage, human capital and training, and full-time jobs, without any presence of co-innovative determinants. In view of this bad news, which is inconsistent with international empirical evidence, we have obtained a segmentation of the sample of firms; innovative firms (26.5% of the total) that do present a model of intensive growth with strong co-innovative sources of productivity. In this minority segment of firms, labour productivity is explained by mean wage, human capital and training, full-time jobs and relationships of co-innovation between: 1) human capital and training, and ICT use; and 2) human capital and training, and organisational change.

The analysis performed on a sample of small firms mostly producing for local markets has allowed three important conclusions to be drawn. First, for firms of this type, that mean wage is the main determinant of labour productivity. In this respect, it was found that productivity is basically associated with work intensity. Second, unlike the conclusions drawn by the majority of international evidence, which generally focuses on larger firms, co-innovation in small local firms does not have a total effect on labour productivity. In the estimation, causal relationships have only been established between co-innovation and productivity for a small segment of the firms in the sample; these are innovative firms, and they represent just over one quarter of the total number of firms. And third, the results obtained suggest new directions in public policy are required to improve the productivity of

small local firms. The incorporation of new determinants of productivity into their traditional growth models entails the fostering of innovation sources to explain their capacity to growth in the long run.

The study presented in this article has several limitations. Besides the variables and restrictions imposed on the analysis, perhaps the most significant is the unavailability of a time series. Additionally, the work presented should advance in the treatment of endogeneity of the data. The incorporation of new forms of econometric estimation, specially the estimation by instrumental variables, would give more consistency to the analysis and would endow greater robustness to the results.

However, the availability of survey data on a representative sample of small local firms has provided an excellent opportunity to analyse the determinants of their growth potential. In this respect, and bearing in mind the economic importance of the fabric of small local businesses, the availability of data for: a) other territories or business groups, and their possible comparison; b) a time series; c) better indicators; and d) new criteria for grouping firms would suggest that new approaches could be taken. Moreover, the analysis performed is susceptible to improvement, particularly with respect to the specification of the production function, better estimation techniques to solve the problem of data endogeneity, and to a more detailed study of the relationships of co-innovation between ICTs, organisation and labour qualification. Such major lines of improvement give this study a preliminary character and suggest that further research needs to be conducted on this issue.

7. REFERENCES

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.

Arvanitis, S., & Loukis, E.N. (2009): "Information and communication technologies, human capital, workplace organization and labour productivity: A comparative study based on firm-level data for Greece and Switzerland", *Information Economics and Policy,* vol. 21, nº 1, pp. 43-61.

Atrostic, B.K., & Nguyen, S.V. (2005): "IT and productivity in US manufacturing: Do computers networks matter?", *Economic Inquiry*, vol. 43, nº 3, pp. 493-506.

Audretsch, D.B. (2002): "The dynamic role of small firms: Evidence from the U.S", *Small Business Economics,* vol. 18, pp. 13-40.

Audretsch, D.B. (2006): *SMEs in the age of globalization*, Edward Elgar, Cheltenham and Northampton, MA.

Badescu, M., & Garcés-Ayerbe, C. (2009): "The impact of information technologies on firm productivity: Empirical evidence from Spain", *Technovation,* vol. 22, nº 2, pp. 122-129.

Bauer, T.K., & Bender, S. (2003): "Technological change, organizational change, and job turnover", *Labour Economics,* vol. 11, pp. 265-291.

Becchetti, L., Londono, D.A., & Paganetto, L. (2003): "ICT investment, productivity and efficiency: Evidence at firm level using stochastic frontier approach", *Journal of Productivity Analysis, vol. 20,* pp. 143-167.

Black, S.E., & Lynch, L.M. (2001): "How to compete: The impact of workplace practices and information technology on productivity", *Review of Economics and Statistics*, vol. 83, nº 3, pp. 434-445.

Black, S.E., & Lynch, L.M. (2004): "What's driving the new economy: The benefits of workplace innovation", *Economic Journal*, vol. 114, nº 493, pp. 97-116.

Bloom, N., Draca, M., Kretschmer, T., & Van Reenen, J. (2005): "IT productivity spillovers and investment: Evidence from a panel of UK firms", *Center for Economic Performance Discussion Paper*, nº 675.

Brasini, S., & Freo, S. (2012): "The impact of information and communication technologies: An insight at micro-level on one Italian region", *Economics of Innovation and New Technology*, vol. 21, nº 2, pp. 107-123.

Bresnahan, T.F., Brynjolfsson, E., & Hitt, L.M. (2002): "Information technology, workplace organization and the demand for skilled labor: A firm-level evidence", *Quarterly Journal of Economics*, vol. 117, nº 1, pp. 339-376.

Brynjolfsson, E., & Hitt, L.M. (2003): "Computing productivity: firm-level evidence", *Review of Economics and Statistics*, vol. 85, nº 4, pp. 793-808.

Cardona, M., Kretschmer, T., & Strobel, T. (2013): "ICT and productivity: conclusions from the empirical literature", *Information Economics and Policy*, vol. 25, pp. 109-125.

Caroli, E., & Van Reenen, J. (2001): "Skill biased organizational change? Evidence form a panel of British and French establishments", *Quarterly Journal of Economics*, vol. 116, nº 4, pp. 1449-1492.

Ceccobelli, M., Gitto, S., & Mancuso, P. (2012): "ICT capital and labour productivity growth: A non-parametric analysis of 14 OECD countries", *Telecommunications Policy*, vol. 36, pp. 282-292.

Clayton, T., Sadun, R., & Farooqui, S. (2007): "IT investment, ICT use and UK firm productivity", In Woulters, T. (Ed.), *Measuring the new economy. Statistics between Hard-Boiled indicators and intangible phenomena*, Statistics Netherlands and Elsevier, Amsterdam, pp. 103-126.

Cristini, A., Gaj, A., Labory, S., & Leoni, R. (2003): "Flat hierarchical structure, bundles of new work practices and firm performance", *Rivista Italiana degli Economisti*, vol. 2, pp. 313-330.

Draca, M., Sadun, R., & Van Reenen, J. (2007): "Productivity and ICT: A Review of the evidence". In Mansell, R., Avgerou, C., Quah, D., & Silverstone, R. (Eds.), *The Oxford handbook of information and communication technologies*, Oxford University Press, Oxford and New York, pp. 100-147.

Faggio, G., Salvanes, K. G., & Van Reenen, J. (2010): "The evolution of inequality in productivity and wages: panel data evidence", *Industrial and Corporate Change*, vol. 19, nº 6, pp. 1919-1951.

Greenan, N., L'Horty, Y., & Mairesse, J. (2002): *Productivity, inequality, and the digital economy. A transatlantic perspective,* MIT Press, Cambridge, MA.

Gretton, P., Gali, J., & Parham, D. (2004). "The effects of ICT and complementary innovations on Australia productivity growth", In OECD (Ed.), *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, Paris, pp. 105-130.

Grimes, A., Cleo, R., & Stevens, P. (2012): "The need for speed: impacts on internet connectivity on firm productivity", *Journal of Productivity Analysis*, vol. 37, nº 2, pp. 187-201.

Hall, B.H., Lotti, F., & Mairesse, J. (2009): "Innovation and productivity in SMEs: Empirical evidence for Italy", *Small Business Economics*, vol. 33, pp. 13–33.

Hempell, T. (2005): "Does experience matter? Innovations and the productivity of information and communication technologies in German services", *Economics of Innovation and New Technology*, vol. 14, nº 4, pp. 277-303.

Hempell, T., & Zwick, T. (2008): "New technology, work organization, and innovation", *Economics of Innovation and New Technology*, vol. 17, nº 4, pp. 331-354.

Hernando, I., & Núñez, S. (2004): "The contribution of ICT to economic activity: A growth accounting exercise with Spanish firm-level data", *Investigaciones Económicas*, vol. 28, nº 2, pp. 315-348.

Jiménez-Rodríguez, S. (2012): "Evaluating the effects of investment in information and communication technology", *Economics of Innovation and New Technology*, vol. 21, nº 2, pp. 203-221.

Jorgenson, D.W., & Vu, K. (2007): "Information technology and the World growth resurgence", *German Economic Review*, vol. 8, nº 2, pp. 122-145.

Jorgenson, D.W., Ho, M.S., & Stiroh, K.J. (2008): "A retrospective look at the US productivity growth resurgence", *Journal of Economics Perspectives*, vol. 22, nº 1, pp. 3-24.

Jorgenson, D.W., Ho, M.S., & Samuels, J.D. (2011): "Information technology and U.S. productivity growth: evidence from a prototype industry production account", *Journal of Productivity Analysis*, vol. 36, pp. 159-175.

Jovanovic, B., & Rousseau, P.L. (2006): "General Purpose Technologies", In Aghion, P. & Durlauf, S.N. (Eds.), *Handbook of Economic Growth*, Elsevier North Holland, Amsterdam, pp. 1182-1226.

Jung, H-J., Na, K-Y., & Yoon, C-Y. (2013): "The role of ICT in Korea's economic growth: Productivity changes across industries since the 1990s", *Telecomunications Policy*, vol. 37, pp. 292-310.

Lallemand, T., Plasman, R., & Rycx, F. (2009): "Wage structure and firm productivity in Belgium", In *The Structure of Wages: An International Comparison*, University of Chicago Press, Chicago, pp. 179-215.

Leoni, R. (2008): *Economia dell'innovazione. Disegni organizzativi, pratiche lavorative e performance d'impresa,* Edizione FrancoAngeli, Roma.

López-Sánchez J.I., Minguela, B., Rodríguez, A., & Santulli, F. (2006): "Is the internet productive? A firm-level analysis", *Technovation*, vol. 26, nº 7, pp. 821-826.

Matteucci, N., O'Mahoney, M., Robinson, C., & Zwick, T. (2005): "Productivity workplace performance and ICT: Evidence from Europe and the US", *Scottish Journal of Political Economy*, vol 52, nº 3, pp. 359-386.

Mahy, B., Rycx, F., & Volral, M. (2011). "Wage dispersion and firm productivity in different working environments", *British Journal of Industrial Relations*, vol. 49, nº 3, pp. 460-485.

Miyazaki, S., Idota, H., & Miyoshi, H. (2012): "Corporate productivity and the stages of ICT development", *Information Technology and Management*, vol. 13, nº 1, pp. 17-26.

Nickell, S.J., & Van Reenen, J. (2000): "Technological innovation and economic performance in the United Kingdom", *London School of Economics Working Papers*, nº 51.

Pilat, D. (2006): "The impacts of ICT on productivity growth: Perspectives from the aggregate, industry and firm level", In Mas, M. & Schreyer, P. (Eds.), *Growth, capital and new technologies*, Fundación BBVA, Bilbao, pp. 113-147.

Timmer, M.P., Inklaar, R., O'Mahoney, M., & Van Ark, B. (2010): *Economic growth in Europe. A comparative industry perspective*, Cambridge University Press, Cambridge, MA.

Torrent, J., Díaz, A., Ficapal, P., Jiménez, A.I., Curòs, P., Soler, I., & Viñas, C. (2012): *L'empresa gironina a l'economia del coneixement. Noves fonts de productivitat i competitivitat?*, Edicions de la Universitat de Girona, Girona.

Torrent, J., & Ficapal, P. (2010a): "TIC, co-innovación y productividad empresarial: Evidencia empírica para Cataluña y comparación internacional de resultados", *Revista de Economía Mundial*, vol. 26, pp. 203-233.

Torrent, J., & Ficapal, P. (2010b): "¿Nuevas fuentes co-innovadoras de la productividad empresarial?", *Innovar*, vol. *20*, *nº* 38, pp. 111-124.

Torrent, J., & Vilaseca, J. (2008): *La empresa red. Tecnologías de la información y la comunicación, productividad y competitividad*, Ariel, Barcelona.

Wymenga, P., Spanikova, V., Barker, A., Konings, J., & Canton, E. (2012): *EU SMEs in 2012: at the crossroads. Annual report on small and medium-sized enterprises in the EU, 2011/12*, European Union, Brussels.