

# ICT uses, innovation and SMEs productivity: Modeling direct and indirect effects in small local firms

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## Table of contents

|                                                                                                  |    |
|--------------------------------------------------------------------------------------------------|----|
| Introduction .....                                                                               | 6  |
| 1 ICT, innovation and firms labour productivity: A review from the empirical<br>literature ..... | 7  |
| 2 Data description .....                                                                         | 12 |
| 3 Direct sources of small local firms productivity .....                                         | 13 |
| 4 Indirect sources of small local firms productivity .....                                       | 19 |
| 5 Concluding remarks and discussion .....                                                        | 27 |
| Acknowledgment .....                                                                             | 30 |
| Bibliographic references .....                                                                   | 30 |

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## **Abstract**

The working paper analyses new co-innovative sources of labour productivity (ICTs, human capital and training, and new forms of work organisation) 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) and Structural Equation Modelling (SEM) 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, in small local firms co-innovation has an indirect effect on labour productivity. Direct causal relationships between co-innovation and productivity have only been identified in the innovative small local firms. A causal relationship between co-innovation and all small local firms' productivity has been established indirectly, by the effect that the capacity to export to markets outside the European Union. Also, some new directions in public policy to improve the productivity in small local firms have been identified.

## **Keywords**

Information and Communication Technologies (ICT), Co-innovation, Firm productivity, Small local firms, Structural Equation Modelling (SEM).

## 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; Timmer et al., 2010; 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).

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.

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 direct effects of small local firms' productivity. Section 5 presents the results of the indirect effects analysis, and Section 6 provides conclusions and discussion based on those findings.

# 1. ICT, innovation and firms labour productivity: A review 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 and Ficapal (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 firms that produce mainly for local markets.

Table 1. International comparison of new co-innovative sources of firm productivity

| Country/research                          | ICT Investment and Use (ICT) | New Forms of Work Organisation (NORG) | Human Capital and Training (HCT) | Co-innovation                               |
|-------------------------------------------|------------------------------|---------------------------------------|----------------------------------|---------------------------------------------|
| <i>United States</i>                      |                              |                                       |                                  |                                             |
| Black & Lynch (2001; 2004)                | Positive                     | Positive                              | NS                               | NS                                          |
| Bresnahan et al. (2002)                   | Positive                     | Positive                              | Positive                         | NORG/ICT;<br>HCT/ICT                        |
| Brynjolfsson & Hitt (2003)                | Positive                     | NS                                    | NC                               | NORG/ICT                                    |
| <i>Australia</i>                          |                              |                                       |                                  |                                             |
| Gretton et al. (2004)                     | Positive                     | Positive                              | Positive                         | NORG/ICT;<br>HCT/ICT                        |
| <i>Germany</i>                            |                              |                                       |                                  |                                             |
| Hempell (2005)                            | Positive                     | NC                                    | NS                               | HCT/ICT                                     |
| Hempell & Zwick (2008)                    | Positive                     | Positive                              | Positive                         | HCT/ICT                                     |
| <i>United Kingdom</i>                     |                              |                                       |                                  |                                             |
| Bloom et al. (2005)                       | Positive                     | NC                                    | NC                               | NC                                          |
| Clayton et al. (2007)                     | Positive                     | NC                                    | Positive                         | HCT/ICT                                     |
| <i>Italy</i>                              |                              |                                       |                                  |                                             |
| Cristini et al. (2003)                    | NS                           | NS                                    | NS                               | HCT/ICT                                     |
| <i>Switzerland</i>                        |                              |                                       |                                  |                                             |
| Arvanitis (2005)                          | Positive                     | Positive                              | Positive                         | HCT/ICT                                     |
| <i>France and United Kingdom</i>          |                              |                                       |                                  |                                             |
| Caroli & Van Reenen (2001)                | NS                           | Positive                              | NS                               | NORG/HCT                                    |
| <i>Germany, France and United Kingdom</i> |                              |                                       |                                  |                                             |
| Matteucci et al. (2005)                   | Positive                     | NC                                    | NC                               | NC                                          |
| <i>Spain</i>                              |                              |                                       |                                  |                                             |
| Hernando & Núñez (2004)                   | Positive                     | NC                                    | NC                               | NC                                          |
| López-Sánchez et al. (2006)               | Positive                     | NC                                    | Positive                         | NC                                          |
| Badescu & Garcés (2009)                   | NS                           | NC                                    | NC                               | NC                                          |
| <i>Catalonia (a region of Spain)</i>      |                              |                                       |                                  |                                             |
| Torrent & Ficapal (2010)                  | Negative                     | Positive                              | NS                               | NORG/ICT (+)<br>NORG/HCT (-)<br>HCT/ICT (-) |

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

Source: Own elaboration

## 2. Data description

As noted in the introduction, ICT investment and use do not give rise to generalised productivity improvements until firms and their workers achieve the required technological, educational/training, organisational, labour and cultural competencies. For this reason and in this context, co-innovative sources of labour productivity in a sample of local firms will be analysed below. Unlike the studies reviewed, this study uses a two-pronged empirical method of analysis. First, co-innovative sources of firm productivity will be studied by taking a production-function modelling approach; a single equation with different elements explaining the dependent variable. In this modelling approach, regression analysis using the Ordinary Least Square (OLS) method will be used. And second, an additional analysis will be performed using Structural Equation Modelling (SEM) with measurement errors. This method allows for the analysis of relationships not only between the various factors considered explanatory of productivity, but also between such factors. Thus, the analysis completes the structural form through which firm productivity is explained.

The study uses survey data for a representative sample of 464 firms operating in Girona (overall margin of error of  $\pm 4.6\%$  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  $\pm 5\%$ . 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.

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 (Lladós et al., 2003; Torrent et al., 2012; Díaz et al., 2013). Table 2 shows some of the main statistics describing the value generation process in the sample of Girona-based firms.

Table 2. Descriptive statistics of Girona-based firms

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

Source: Own elaboration.

### 3. Direct sources of small local firms productivity

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 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 ICT, 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 ICT, 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  $\alpha$ ,  $\gamma$  and  $\mu$  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 literature (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:

$$A_i = \exp (\delta_0 + \delta_1 \text{NORG}_i + \delta_2 \text{HCT}_i + \delta_3 \text{ICT}_i + \delta_4 \text{LABR}_i + \delta_5 \text{NORGICT}_i + \delta_6 \text{NORGHCT}_i + \delta_7 \text{ICTHCT}_i) \quad (2)$$

Where  $\text{NORG}_i$ ,  $\text{HCT}_i$  and  $\text{ICT}_i$  represent indicators of new forms of work organisation; human capital and training; and ICT investment and uses in firm  $i$ ;  $\text{LABR}_i$  represents individual variables for labour relations in firm  $i$ ; and  $\text{NORGICT}_i$ ,  $\text{NORGHCT}_i$ , and  $\text{ICTHCT}_i$  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,  $\delta_i$ , for  $i=0\dots7$ , represent the elasticities (coefficients) of the various explanatory components of the efficiency indicator.

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. The model of co-innovative determinants of labour productivity in Girona-based firms takes the following functional form:

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

Where,  $\beta_0$  (constant) incorporates the logarithmic difference of intermediate costs per worker and  $\beta_i$ , for  $i=0\dots 8$ , 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<sup>2</sup>.

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 labour 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 ICT in any value element; 2 = Low ICT use, when a firm uses ICT in one or two of the six defined value elements; 3 = Medium ICT use, when a firm uses ICT in three or four of the six value elements; and 4 = High ICT use, when a firm uses ICT 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  $\varepsilon_i$  represents the estimation error term. Coefficients  $\beta_i$ , for  $i=0\dots 11$ , represent the elasticities (coefficients) of the various explanatory components of firm labour productivity:

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

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.

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. 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.

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 ( $\beta=0.871$ ,  $p<0.001$ ), full-time jobs ( $\beta=0.148$ ,  $p<0.001$ ) and the workers' stock of training ( $\beta=0.061$ ,  $p<0.05$ ). 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 ( $\beta=1.200$ ,  $p<0.001$ ), training ( $\beta=0.382$ ,  $p<0.001$ ) and variable forms of worker remuneration ( $\beta=0.038$ ,  $p<0.01$ ). In addition, the mean wage squared ( $\beta=-0.298$ ,  $p<0.001$ ) and co-innovation between new forms of work organisation, and human capital and training ( $\beta=-0.336$ ,  $p<0.001$ ) 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 ( $\beta=1.289$ ,  $p<0.001$ ) and mean wage squared ( $\beta=-0.413$ ,  $p<0.001$ ) 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 ( $\beta=1.006$ ,  $p<0.001$ ), human capital and training ( $\beta=0.503$ ,  $p<0.001$ ), variable remuneration of workers ( $\beta=0.104$ ,  $p<0.001$ ) and full-time jobs ( $\beta=0.076$ ,  $p<0.01$ ) 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 ( $\beta=0.482$ ,  $p<0.001$ ), and ICT use, and human capital and training ( $\beta=0.150$ ,  $p<0.001$ ). 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.

Table 3. Sources of labour productivity in Girona-based firms\*

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Model 1     | Model 2     | Model 3     | Model 4     |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|
| <i>Standardised coefficients</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |             |             |             |             |
| Constant                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | (13.550)*** | (14.840)*** | (18.301)*** | (11.917)*** |
| Wage per full-time equivalent worker (WAGE)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0.871***    | 1.200***    | 1.289***    | 1.006***    |
| Wage squared per full-time equivalent worker (WAGE <sup>2</sup> )                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | -           | -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**     |
| <i>Statistics</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |             |             |             |             |
| N (observations)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 169         | 124         | 77          | 55          |
| Adjusted R <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 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       |
| <p>* Multiple linear regression analysis using OLS. Dependent variable: Logarithm of turnover divided by the number of full-time equivalent workers.</p> <p>Standardised coefficients. *** Significant at 99% confidence level; ** Significant at 95% confidence level; * Significant at 90% confidence level.</p> <p>Model 1: model without relationships of complementarity (co-innovation) for all Girona-based firms.</p> <p>Model 2: model with relationships of complementarity (co-innovation) for all Girona-based firms.</p> <p>Model 3: model with relationships of complementarity (co-innovation) for non-innovative Girona-based firms.</p> <p>Model 4: model with relationships of complementarity (co-innovation) for innovative Girona-based firms.</p> |             |             |             |             |

Source: Own elaboration.

## 4. Indirect sources of small local firms productivity

Having found a weak presence of relationships of complementarity (co-innovation) in the explanation of the level of productivity in Girona-based firms, the study will now go a step further and introduce the causal effects of interaction between the factors of productivity (indirect effects) into the analysis. Structural Equation Model (SEM) with measurement errors will be used for that purpose.

SEM are formal mathematical models, a set of linear equations that encompasses, as particular cases, various types of model, such as regression models, simultaneous equation systems, factor analysis and path analysis. The equation system's variables can be either directly observed and measurable variables or theoretical or latent variables representing concepts that are not directly observed. While latent variables must be continuous, observed dependent variables can be continuous, censored, binary, ordered, categorical (ordinals) or combinations of these variable types.

The general SEM model comprises two sub-models: a structural model that relates latent variables to each other, and a measurement model that relates each latent variable to the respective variables measuring it; these are generally called indicators. A causal structure between latent variables is usually assumed to exist.

SEM models have certain desirable distinctive features that: 1) allow for the explicit inclusion of the measurement error in the estimation process into as many variables as is seen fit; 2) allow for the simultaneous estimation of the parameters of a series of relationships of dependence, where a variable can act as dependent in some equations and independent in others; 3) are able show reciprocal causes, and recursive and non-recursive models; and 4) enable them, with new developments, to be used for exploratory analysis, albeit a confirmatory technique.

Following the most commonly used notation (Jöreskog and Sörbom 2004), it is possible to formalise SEM models by a system of linear structural equations whose matricial representation is:

$$\eta = \alpha + B \eta + \Gamma \xi + \zeta \quad (5)$$

Where:  $\eta$  ( $m \times 1$ ) and  $\xi$  ( $n \times 1$ ) are random vectors of latent dependent and independent variables;  $\alpha$  is a vector ( $m \times 1$ ) representing the intersections of axes;  $B$  ( $m \times m$ ) is the matrix of coefficients of latent endogenous variables representing the effects of variables  $\eta$  on other variables  $\eta$ ;  $\Gamma$  ( $m \times n$ ) is the matrix of coefficients of latent exogenous variables representing the direct effects of variables  $\xi$  on variables  $\eta$ ; and  $\zeta$  is a vector ( $m \times 1$ ) indicating the random perturbations in the equation. It is assumed that  $E(\eta)=0$ ,  $E(\xi)=0$  y  $E(\zeta)=0$ .

The observed (measurable) variables are represented by vectors  $y$  ( $p \times 1$ ), where  $p$  is the number of indicators of  $\eta$ ; and  $x$  ( $q \times 1$ ), where  $q$  is the number of indicators of  $\xi$ . Both formulations are related to the latent variables by the following equations:

$$y = \tau_y + \Lambda_y \eta + \varepsilon \quad (6)$$

$$x = \tau_x + \Lambda_x \xi + \delta \quad (7)$$

Where  $\varepsilon$  ( $p \times 1$ ) and  $\delta$  ( $q \times 1$ ) are the vectors of the error terms. It is assumed that  $\varepsilon$  is not correlated to  $\eta$ ,  $\xi$  or  $\delta$ ; and that  $\delta$  is not correlated to  $\eta$ ,  $\xi$  or  $\varepsilon$ .  $\Lambda_y$  ( $p \times m$ ) and  $\Lambda_x$  ( $q \times n$ ) are matrices containing the structural coefficients  $\lambda_{ij}$  that relate the latent and observed (measurable) variables, and  $\tau_y$  ( $p \times 1$ ) and  $\tau_x$  ( $q \times 1$ ) are the vectors of constant terms of intersection.

The fundamental hypothesis of structural equation systems is  $\Sigma = \Sigma(\theta)$ , where  $\Sigma$  is the population covariance matrix and  $\Sigma(\theta)$  is the model covariance matrix, written as a function of a parameter vector of  $\theta$ . The estimation of the parameters of  $\theta$  is obtained by minimising a function of adjustment:

$$F(\theta) = F[S, \Sigma(\theta)] \quad (8)$$

Once the model's parameters have been estimated, the resulting covariance matrix is compared with the data covariance matrix and, if the difference between the two matrices is statistically acceptable or zero, then the proposed SEM model is recognised as a plausible explanation of the reality.

The application of this method of analysis to sources of productivity in Girona-based firms will firstly allow a more complete explanatory model to be established by multiple equations. It will secondly allow specific measurement errors to be introduced for each variable. This will enable any potential problems due to specification errors to be eliminated and, consequently, the estimated parameters will be unbiased, consistent and of lower variance.

The general analysis model establishes three hypotheses to be tested. As in OLS modelling, the dependent variable is labour productivity (LP) in Girona-based firms, approximated by the logarithm of turnover divided by the number full-time equivalent workers. The direct explanatory factors of labour productivity in Girona-based firms are considered to be the logarithm of wage per full-time equivalent worker (WAGE) and a the firms' export capacity (sales quota) to international markets outside the European Union, that is, exports to the rest of the world (XRW). Thus, two of the hypotheses identified in international empirical evidence would be satisfied in Girona-based firms: 1) the higher the wage per worker, the higher the productivity (*Hypothesis 1*); and 2) the higher the export intensity, measured as a firm's capacity to export goods and services to more distant overseas markets, the higher the productivity (*Hypothesis 2*). *Hypothesis 1* is related to a firm's capacity to increase turnover per worker through better paid and probably higher quality labour. *Hypothesis 2* is related to a firm's capacity to increase turnover per worker through economies of learning, scale, reach and scope, which can be achieved by growing export intensity.

After establishing the hypotheses related to direct factors of productivity, the analysis model also establishes a set of hypotheses related to indirect factors and their interrelationships. Specifically, the indirect causal relationship has been established for

the capacity of Girona-based firms to export to the rest of the world. It is postulated that the capacity of Girona-based firms to export to markets outside the European Union depends on variable forms of worker remuneration, VAREM, (*Hypothesis 3*) and ICT use, ICTU, (*Hypothesis 4*). The VAREM variable indicates the presence or absence of variable forms of remuneration by objective in a firm (0 = absent; 1 = present). The ICTU indicator indicates the intensity of ICT use in the value generation process 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 ICT in any value element; 2 = Low ICT use, when a firm uses ICT in one or two of the six defined value elements; 3 = Medium ICT use, when a firm uses ICT in three or four of the six value elements; and 4 = High ICT use, when a firm uses ICT in five or six of the defined value elements. Thus, *Hypothesis 3* postulates that the existence of incentives in worker remuneration will impact on a firm's capacity to export since it will probably have workers who are more motivated and committed to the value generation process. *Hypothesis 4* establishes a causal relationship between the intensity of ICT use and a greater capacity to export to more distant overseas markets. It is assumed that intensive ICT use makes a firm's value generation process more competitive, which improves its export capacity. The model also postulates that the intensity of ICT use impacts on a firm's capacity to implement variable forms of remuneration (*Hypothesis 5*). It is assumed that digital intensity is a lever of change for a firm, which also results in the development of new practices of variable remuneration by objective and new practices of human resources management.

Variable forms of remuneration are also explained by other components of the work organisation aspect. *Hypothesis 6* establishes dependence between human capital and training, and the presence of practices of variable remuneration of workers. 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. It is assumed that the higher the mean level of training of a firm's workers, the greater the presence of variable forms of remuneration. In keeping with the findings of empirical evidence, the presence of more highly qualified workers does not correspond to more traditional and less flexible organisational and worker remuneration practices.

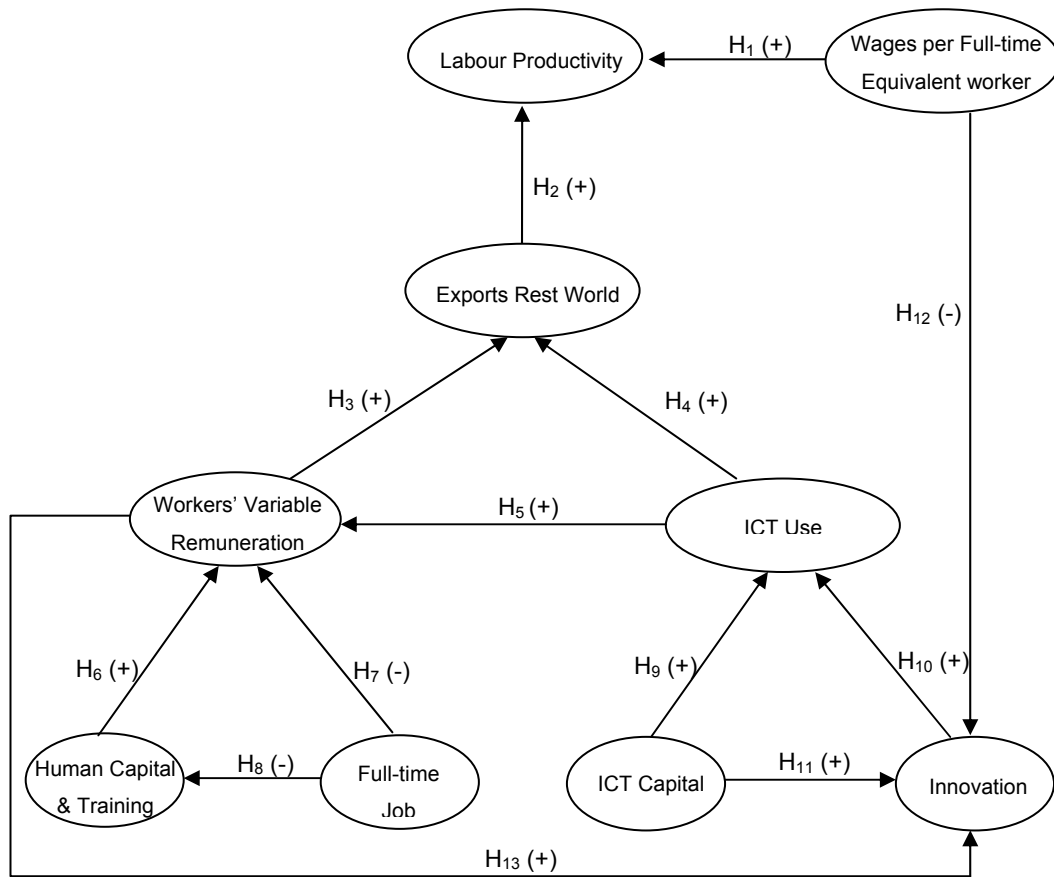
For a firm to improve its value generation process, it needs to have more highly qualified workers, to commit to and retain talent and human capital, and to develop new, more flexible forms of remuneration that better suit the needs of qualified workers. In contrast to the previous premise, *Hypothesis 7* establishes a negative causal relationship between a new and an old work organisation practice. The FTIMEJOB variable shows the presence of full time jobs in a firm (0 = absent; 1 =

present). It is assumed that there is a negative causal relationship between the presence of full-time jobs in a firm and variable forms of remuneration. Flexible remuneration practices, based on incentives, are presumably explained by variable forms of worker remuneration too, which full-time jobs do not establish. Finally, and in keeping with the above, *Hypothesis 8* establishes a negative causal relationship between full time jobs, and human capital and training. Once again, it is assumed that the presence of relatively inflexible forms of work, which full-time jobs presuppose, are not very conducive to capturing and retaining human capital in a firm.

Regarding the digital aspect, ICT use also establishes causal relationships with ICT capital endowment and the presence of innovative practices in a firm. The ICT capital variable ICTK shows the investment that a firm has made in buying ICT-related goods and services. The variable INNOV shows a firm's innovatory dynamics and 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. In this respect, *Hypothesis 9* establishes a causal relationship between ICT investment and use. It is assumed that a greater ICT investment leads to a higher intensity of ICT use. Likewise, *Hypothesis 10* establishes a causal relationship between a firm's innovatory dynamics and ICT use. It is assumed that, in firms with innovative practices, ICT-use needs increase. For this dimension, the model also established a causal relationship between ICT capital and innovative practices. *Hypothesis 11* shows the synergistic effects of digital investment beyond digital use. It is established that ICT investment also explains non-digital innovative practices.

Finally, and as a consequence of the specificity of the sample of firms analysed, the models establishes two final hypotheses outside the scope of new worker remuneration practices and of ICT. Both hypotheses refer to the explanation of innovation. The earlier review of the descriptive statistics shows that Girona-based firms are not very innovative. To be precise, only 26.5% of the firms are innovative. In addition, innovation is informal and not very collaborative. The basic source of innovation in Girona-based firms (86% of cases) is a firm's own workers, who are not explicitly working on research, development and innovation (RD&I) tasks. In this context, it is not odd to find that a negative causal relationship is established between wage per worker and innovation practices in a firm (*Hypothesis 12*). This hypothesis, which would show the informal nature of innovation, suggests that a firm's mean remuneration, given that it does not take account of the functions and tasks of innovative work, explains, negatively, the development of innovations in a firm. However, the establishment of practices of variable remuneration by objective — innovative work objectives among others— positively explains the development of innovation in a firm (*Hypothesis 13*). Figure 1 shows the model and the hypotheses postulated in this study.

Figure 1. Modelling the interaction between sources of firm productivity



Source: Own elaboration.

Formally, and simplifying the formulation considered earlier, the SEM model to be estimated, which shows direct and indirect factors that explain labour productivity in Girona-based firms, can be represented by the following system of equations with observed variables and measurement errors, as shown in expression 9. Equation 1, relating to the direct explanatory factors of labour productivity (LP), includes Hypotheses 1 and 2. Equation 2, relating to the indirect explanatory factors of the capacity to export to markets outside the European Union, includes Hypotheses 3 and 4. Equation 3, relating to the indirect explanatory factors of the presence of variable forms of worker remuneration by objective (VAREM), includes Hypotheses 5, 6 and 7. Equation 4, relating to the indirect explanatory factors of human capital and training (HCT), includes Hypothesis 8. Equation 5, relating to the indirect explanatory factors of ICT use (ICTU), includes Hypotheses 9 and 10. Finally, Equation 6, relating to the indirect explanatory factors of innovation, includes Hypotheses 11, 12 and 13.

$$\begin{pmatrix} \text{LP} \\ \text{XRW} \\ \text{VAREM} \\ \text{HCT} \\ \text{ICTU} \\ \text{INNOV} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \\ \beta_{30} \\ \beta_{40} \\ \beta_{50} \\ \beta_{60} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \beta_{12} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \beta_{23} & \beta_{24} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \beta_{34} & \beta_{35} & \beta_{36} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \beta_{46} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \beta_{57} & \beta_{58} \\ \beta_{61} & 0 & \beta_{62} & 0 & 0 & 0 & \beta_{67} & 0 \end{pmatrix} * \begin{pmatrix} \text{WAGES} \\ \text{XRW} \\ \text{VAREM} \\ \text{ICTU} \\ \text{HCT} \\ \text{FTIMEJOB} \\ \text{ICTK} \\ \text{INNOV} \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{pmatrix} \quad (9)$$

The results of the SEM model (Equation 9) for the productivity of Girona-based firms are shown in Table 4. Firstly, it should be noted that the values obtained for the goodness-of-fit statistics (NIF=0.935; RFI=0.872; IFI=0.970; TLI=0.940; CFI=0.969) approach 1. In addition, the value of CMIN/DF=1.773, below 2, and the value of RMSEA=0.041, below 0.05, suggest the validity of the model developed.

Secondly, it is confirmed that all the standardised coefficients obtained are significant at a maximum 95% confidence level, and that their values are consistent with the hypotheses postulated. Third and lastly, it should be noted that, as was the case in the OLS estimation, the main direct determinant of labour productivity in Girona-based firms is mean wage (Hypothesis 1:  $\beta=0.916$ ,  $p=0.000$ ) followed at considerable distance by exports to international markets outside the European Union (Hypothesis 2:  $\beta=0.061$ ,  $p=0.024$ ).

Indeed, having found that there is a direct effect of export intensity on labour productivity in Girona-based firms, a set of indirect effects that complement the results obtained in the OLS model (Figure 2) can therefore be validated. In fact, a set of indirect determinants of labour productivity in Girona-based firms becomes manifest; such determinants could be grouped into two dimensions of co-innovation by the capacity to export to the rest of the world: 1) the organisational, labour and human capital dimension; and 2) the ICT and innovation dimension. Regarding the first dimension, the indirect impact on productivity is established by the effect of flexible remuneration practices on the capacity to export to the rest of the world (Hypothesis 3:  $\beta=0.154$ ,  $p=0.002$ ), which in turn are explained by ICT use (Hypothesis 5:  $\beta=0.256$ ,  $p=0.000$ ), human capital and training (Hypothesis 6:  $\beta=0.135$ ,  $p=0.006$ ) and, negatively, the presence of full-time jobs (Hypothesis 7:  $\beta=-0.103$ ,  $p=0.036$ ). This first organisational, labour and human capital dimension is completed by the negative indirect effect that full-time jobs has on human capital and training (Hypothesis 8:  $\beta=-0.116$ ,  $p=0.012$ ).

Regarding the second dimension, relating to ICT and innovation, the indirect impact on labour productivity is established by the effect of ICT use on the capacity to export to the rest of the world (Hypothesis 4:  $\beta=0.126$ ,  $p=0.006$ ), which in turn is explained by ICT capital (Hypothesis 9:  $\beta=0.433$ ,  $p=0.000$ ) and by innovation (Hypothesis 10:  $\beta=0.139$ ,  $p=0.002$ ). This second digital technology and innovation dimension is

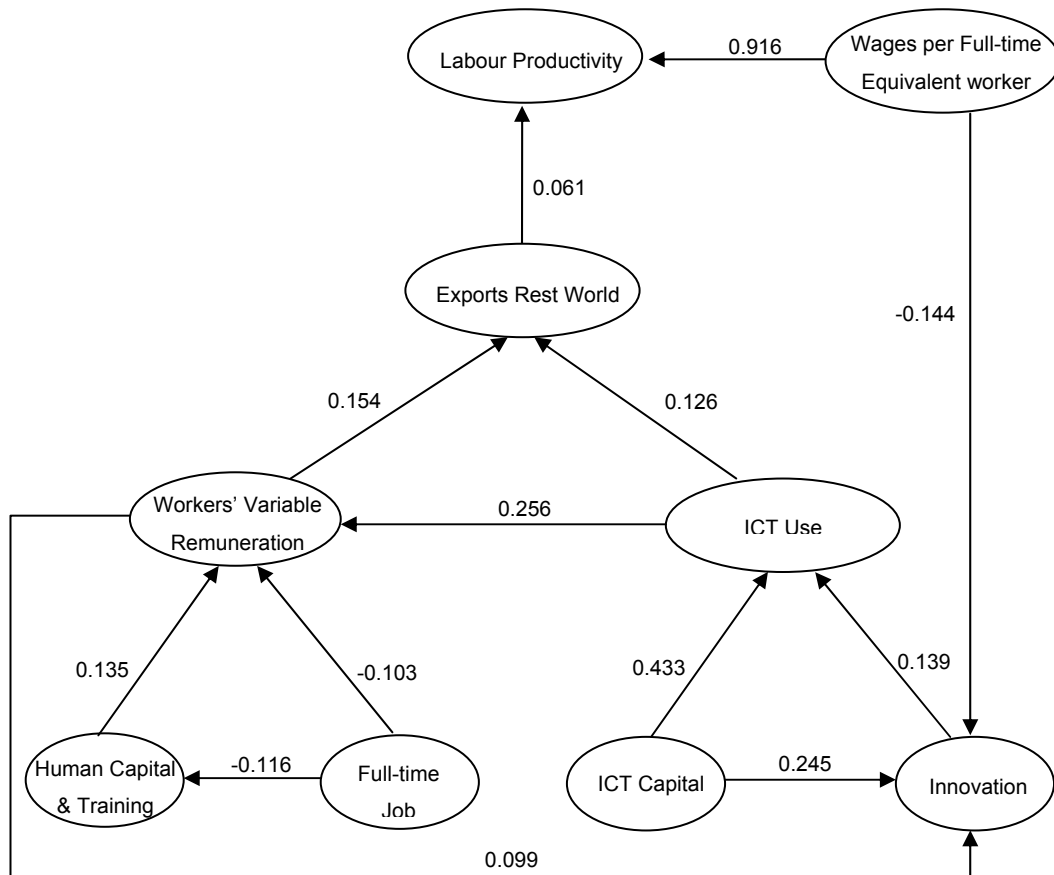
completed by the indirect effects that ICT capital (Hypothesis 11:  $\beta=0.245$ ,  $p=0.000$ ), mean wage (Hypothesis 12:  $\beta=-0.144$ ,  $p=0.045$ ) and the presence of flexible forms of worker remuneration (Hypothesis 13:  $\beta=0.099$ ,  $p=0.045$ ) have on innovation.

Table 4. Interaction between sources of labour productivity in Girona-based firms\*

| Explained Variable                                         | Explanatory Variable | Coefficients | Standardised Coefficients | Standard Error | Critical Ratio | P-value |
|------------------------------------------------------------|----------------------|--------------|---------------------------|----------------|----------------|---------|
| LP                                                         | WAGES                | 0.001        | 0.916                     | 0.000          | 33.866         | 0.000   |
| LP                                                         | XRW                  | 0.822        | 0.061                     | 0.364          | 2.260          | 0.024   |
| XRM                                                        | VAREM                | 0.065        | 0.154                     | 0.021          | 3.162          | 0.002   |
| XRM                                                        | ICTU                 | 0.898        | 0.126                     | 0.325          | 2.765          | 0.006   |
| VAREM                                                      | ICTU                 | 41828.3      | 0.256                     | 11364.5        | 3.681          | 0.000   |
| VAREM                                                      | HCT                  | 3.013        | 0.135                     | 1.097          | 2.746          | 0.006   |
| VAREM                                                      | FTIMEJOB             | -0.062       | -0.103                    | 0.029          | -2.092         | 0.036   |
| HCT                                                        | FTIMEJOB             | -0.003       | -0.116                    | 0.001          | -2.516         | 0.012   |
| ICTU                                                       | ICTK                 | 0.467        | 0.433                     | 0.046          | 10.253         | 0.000   |
| ICTU                                                       | INNOV                | 0.126        | 0.139                     | 0.042          | 3.033          | 0.002   |
| INNOV                                                      | ICTK                 | 0.206        | 0.245                     | 0.039          | 5.310          | 0.000   |
| INNOV                                                      | WAGES                | 0.000        | -0.144                    | 0.000          | -2.007         | 0.045   |
| INNOV                                                      | VAREM                | 0.007        | 0.099                     | 0.003          | 2.003          | 0.045   |
| Statistics (Goodness of Fit)                               |                      |              |                           |                |                |         |
| NFI                                                        | 0.935                |              |                           |                |                |         |
| RFI                                                        | 0.872                |              |                           |                |                |         |
| IFI                                                        | 0.970                |              |                           |                |                |         |
| TLI                                                        | 0.940                |              |                           |                |                |         |
| CFI                                                        | 0.969                |              |                           |                |                |         |
| CMIN/DF                                                    | 1.773                |              |                           |                |                |         |
| RMSEA                                                      | 0.041                |              |                           |                |                |         |
| * SEM model with observed variables and measurement errors |                      |              |                           |                |                |         |

Source: Own elaboration.

Figure 2. Standardised estimated coefficients and path analysis.



Source: Own elaboration.

## 5. 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), the working paper 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, two econometric techniques were used: classic Ordinary Least Square

(OLS) analysis complemented by an SEM model with observed variables and measurement errors.

The results obtained from the OLS estimation suggest that Girona-based firms have a primary, extensive growth 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.

However, the results from the OLS estimation have not allowed any causal relationships to be established for the explanation of labour productivity in Girona-based firms. With the aim of adding to the available evidence on the direct and indirect determinants of labour productivity in a business fabric whose characteristic feature is the majority presence of small firms (95.4% with fewer than 10 workers) producing mostly for local markets (94.7% of turnover), an SEM model was developed and tested with observed variables and measurement errors. As was the case in the OLS model, the main direct cause of labour productivity in Girona-based firms is mean wage.

The capacity to export to international markets outside the European Union has a much lower direct impact on productivity. Indeed, having found a direct effect, it has enabled a set of indirect effects to be established that, by the intensity of exports to the rest of world, also explain labour productivity in Girona-based firms. This set of indirect effects can be grouped into two dimensions of co-innovation: 1) the organisational, labour, and human capital and training dimension; and 2) the ICT and innovation dimension. The first set of indirect effects is established by the effect of flexible remuneration practices on the capacity to export to the rest of the world. Such flexible, by-objective practices of worker remuneration are explained by ICT use, human capital and training and, negatively, the presence of full-time jobs. This first dimension is completed by the negative indirect effect that full-time jobs has on human capital and training. The second set of indirect effects on labour productivity in Girona-based firms is established by the effect of ICT use on the capacity to export to international markets outside the European Union. In turn, ICT use is explained by ICT capital and by innovation. This second dimension is completed by the indirect effects that ICT capital, mean wage and the presence of flexible forms of worker remuneration have on innovation.

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 wage is the main determinant of labour productivity. In this respect, it was found that productivity is basically associated with labour quality. Second, unlike the

conclusions drawn by the majority of international evidence, which generally focuses on larger firms, co-innovation in small local firms has an indirect effect on labour productivity. In the OLS estimation, direct 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. In the SEM estimation, the causal relationship between co-innovation and productivity has been established indirectly, by the effect that the capacity to export to markets outside the European Union has on labour productivity. 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 co-innovative sources to explain their capacity to export to more distant overseas markets.

The results obtained suggest new directions in public policy are required to improve the productivity in small local firms. First, it is important to emphasize the need to coordinate efforts in the joint promotion of ICT use, organizational change and training of employers and employees. For example, partial public policies to promote ICT use, without considering the other determinants of co-innovative productivity, may not produce the desired effects. And, second, point out the link between productivity and internationalization. In small firms that producing for local markets, promoting the internationalization of their products and services is a good instrument that public policy should address because international competition introduces efficiency enhancement mechanisms.

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. 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 and to a more detailed study of the relationships of co-innovation between ICT, 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.

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**Resumen**

*El documento de trabajo analiza las nuevas fuentes co-innovadoras (uso TIC, capital humano y aprendizaje, y nuevas formas de organización del trabajo) de la productividad del trabajo en las pequeñas empresas que producen para los mercados locales. Utilizando datos de una encuesta para una muestra representativa de 464 empresas localizadas en Girona (una provincia del noreste de España) en 2009, y empleando dos técnicas de estimación econométrica: mínimos cuadrados ordinarios y modelos de ecuaciones estructurales, la investigación obtiene dos principales resultados. En primer lugar, el salario es el principal determinante de la productividad del trabajo. En segundo lugar, y en contraposición con la evidencia disponible para las grandes empresas, en las pequeñas empresas locales la co-innovación ejerce un efecto indirecto sobre la productividad del trabajo. Las relaciones causales directas entre la co-innovación y la productividad sólo se han identificado en las pequeñas empresas locales innovadoras. En este sentido, las relaciones de causalidad entre la co-innovación y la productividad de todas las pequeñas empresas locales se establece indirectamente, a través de su capacidad para exportar a los mercados de fuera de la Unión Europea. Finalmente, el documento de trabajo identifica nuevas direcciones en la política pública para mejorar la productividad de las pequeñas empresas locales.*

**Palabras clave**

*Tecnologías de la Información y la Comunicación (TIC), Co-innovación, Productividad de las empresas, Pequeñas empresas locales, Modelos de ecuaciones estructurales (SEM)*

**Resum**

*El document de treball analitza les noves fonts co-innovadores (ús TIC, capital humà i aprenentatge, i noves formes d'organització del treball) de la productivitat del treball a les petites empreses que produeixen per als mercats locals. Utilitzant dades d'una enquesta per a una mostra representativa de 464 empreses localitzades a Girona (una província del nord-est d'Espanya) el 2009, i usant dues tècniques d'estimació economètrica: mínims quadrats ordinaris i sistemes d'equacions estructurals, la investigació obté dos resultats principals. En primer lloc, el salari és el principal determinant de la productivitat del treball. En segon lloc, i en contraposició amb l'evidència disponibles per a les grans empreses, a les petites empreses locals la co-innovació exerceix un efecte indirecte sobre la productivitat del treball. Les relacions causals directes entre la co-innovació i la productivitat només s'ha identificat a les petites empreses locals innovadores. En aquest sentit, les relacions de causalitat entre la co-innovació i la productivitat de totes les petites empreses locals s'estableix indirectament, a través de la seva capacitat per a exportar als mercats de fora de la Unió Europea. Finalment, el document de treball identifica noves direccions de la política pública per a millorar la productivitat de les petites empreses locals.*

**Paraules clau:**

*Tecnologies de la informació i la comunicació (TIC), Co-innovació, Productivitat de les empreses, Petites empreses locals, Models d'equacions estructurals (SEM)*

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