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ICT, innovation and productivity: evidence based on Polish companies

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Abstract.*The main motivation behind this study is to evaluate the relationships among information and communication technologies (ICT), organisational practices, internationalization, innovation and human capital in a sample of Polish companies. To examine that we used the data from the Polish companies' survey conducted in 2015 for a representative sample of 805companies. Using ordinary least squares modeling, we examined determinants of labour productivity. Our study is one of the first empirical studies using this methodology for Polish companies.The principal finding that emerged from the study is that the presence of the ICT innovation was the main determinant of labour productivity. Moreover, other variables: operating on the international markets, education of the employees and executives and presence of the separate research and development department positively influence productivity. The results of the investigation bridge the gap in insufficient academic research about Central European countries and extend existing research on the company-level labour productivity determinants.*

Keywords:productivity, ICT, Polish companies

JEL Codes: L25, O33

1. Introduction

The widespread use of information and communication technologies (ICT) is one of the main distinguishing features of today's economic activity (Jovanovic and Rousseau 2005; Jorgenson and Vu 2007). The ICT have a positive influence on the productivity growth. Moreover, they contribute indirectly by the generation of complementary innovations that improve the economy's Total Factor Productivity (TFP) (Pilat 2006; Jorgenson et al. 2011; Ceccobelli et al. 2012). However, ICT do not give rise to generalised productivity improvements until companies and their workers have achieved the required technological, educational/training, strategic, organisational, labour and cultural competencies. In this context, the effects of ICT on company productivity are indirect. The link between innovation and ICT has been identified in literature as a set of internal knowledge externalities to explain company productivity (Venturini, 2015). Complementary relationships (co-innovation) are established with other components, in particular with human capital and workplace innovations. These spillovers are widely demonstrated in research using company data (Cardona et al., 2013; Díaz-Chao et al., 2015).

Although the transition of Poland from centrally planned economy to market-driven system occurred more than two decades ago, the country still faces considerable challenges in adapting economy to effectively compete in regional and global markets. The key issue is to find a way to increase productivity

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and adapt Polish economies' structure to global-knowledge competition, promote co-innovation and develop new goods and services that respond to the changing domestic and international demands. Thus, the impact of digital technological changes and their co-innovation processes on productivity is an important aspect in the Polish economic performance.

The main objective of the presented research is to provide one of the first evidence of the relation between information and communication technologies, co-innovation productivity factors and productivity in Polish companies. The following is the main question underpinning the research: Does the existence of new co-innovative productivity sources (the ICT investment, workplace organisation and human capital) affect the performance of Polish companies?

The remainder of this paper is organised as follows: The data section describes the dataset from the survey in Polish companies. The empirical results section reports the results of the ordinary least squares (OLS) model and the empirical findings. Finally, the conclusion provides a summary, main limitations and recommendations based on those findings.

2. Data

The empirical descriptive and econometric analysis presented in this paper is based on data collected using structured questionnaire interviews conducted in Polish companies. The data was collected within the framework of the research project titled "Impact of Information and Communication Technologies on productivity – macro and micro analysis", financed by the National Science Centre Poland at the Department of Economic Policy, University of Lodz, Poland. The survey was undertaken in 2015, covering 1007 Polish companies. The companies were chosen using the stratified random sampling and covered the companies form the whole country. The questionnaire was developed and tested in pilot surveys prior to its implementation in the field. The topic of the project underlined, that the main requirement of the field-research was to include only those companies, which use information and communication technologies. As a result, questionnaire interviews were conducted only in those companies that had computers and benefit from ICT in at least two of the nine business areas of management in: administration, accounting, human resources, production, supply, customer relationship, enterprise resource planning, computer aided design or manufacturing, control of machines and production lines. The questionnaire comprised of 55 questions organised by topic. Initially, questions were posed about the areas of the usage of the ICT in the company's activities. This was followed by sections on company management practices, organisation, innovation and research and development (R&D). Furthermore followed the questions about level of the education of employees and training activities. Last section covers characteristics of the company, among others as legal status, ownership and number of years in operation. The interviews were conducted face-to-face with interviewers using the Pencil and Paper Interview (PAPI) survey method. The interviews were conducted with managers, precisely owners, co-owners, directors, CEOs, board members of the companies. The companies operate in different industries among others agriculture, industry, construction and trade.

3. Empirical results

In this research methodology is based on the Solow growth model (Solow 1957) and its subsequent elaboration by Jorgenson and Griliches (1967). This well-established traditional growth and productivity-accounting approach is used for the estimation of co-innovative sources of company productivity. As presented below, the efficiency component - Total Factor Productivity (TFP) incorporates the co-innovative productivity sources, which are the important growth factors complementing physical capital and labour. In

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the empirical analysis we use explanatory elements among others ICT investment, work organisation or human capital and they complete the analysis. Similar approach has been used in the company-level research in the United States (Bresnahan et al., 2002) or in the comparative study of Swiss and Greek companies (Arvanitis, Loukis, 2009).

The company production function of the Cobb-Douglas type takes the form:

$$Y_i = A_i f(K_i, L_i)$$

where, for any given company i, Y is the average gross salary of full-time employees in the company; A is the production efficiency (Total Factor Productivity); K is the input of physical capital; L is the input of labour.

The innovative sources of productivity are incorporated into the production efficiency indicator. This element shows the effects of company innovation that are not associated directly with factors of production. Thus, the indicator of efficiency A_i takes the following functional form:

$$A_i = \exp(\delta_0 INT + \delta_1 \mathrm{RD} + \delta_2 ORG + \delta_3 EDU + \delta_4 ICT)$$

Finally, the labour productivity function of the Polish companies, which would be estimated by the ordinary least squares (OLS) method, takes the following form:

$$\ln\mathrm{SALARY} = \beta_0 + \beta_1 \mathrm{INT} + \beta_2 \mathrm{RD} + \beta_3 \mathrm{ORG} + \beta_4 \mathrm{EDU} + \beta_5 \mathrm{ICT} + \beta_6 \ln\mathrm{SIZE} + \beta_7 \mathrm{SECTOR} + \varepsilon_i$$

where, β_0 (constant), β_i for i=1…7 represents the elasticities (coefficients) of the explanatory components of company productivity and εi is the estimation error.

The data collected through primary research is a rich source information on the Polish companies ICT usage, innovation activities and organization practices. However, the survey does not include the details of the financial situation in the companies. Despite ensured anonymity of the survey, the data on the balance sheet, profit and loss account, net turnover or the amount of the investment in the information and communication technologies were not collected. Usually the attempts to obtain such information result in the refusal to answer. Therefore, after the pilot survey it was decided not to incorporate in the questionnaire questions about the so-called 'sensitive data'. Despite of this limitation the microeconometric analysis has been performed. As a proxy of the productivity and the dependant variable we use the logarithm of average gross salary of full-time employees (SALARY). Salary is an approximation of the labour efficiency. In line with the neoclassical approach salary is a marginal productivity of labour. The salary used to determine the relationship from the salary structure to company productivity was used in the recent empirical evidence (Lallemand et al. 2009; Faggio et al. 2010; Mahy et al. 2011).

The information on the employee's salary was missing in 146 results of interviews and this companies were excluded from the analysis. Moreover, 55 companies had a missing values for the independent variables and were also excluded from the analysis. The final sample for the analysis counts 805 companies. The sample size is large enough to split the data on the subsets regarding the number of the employees of the company. The sample is split into four subsets: micro enterprises (less than 10 employees),

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small enterprises (10-49 employees), medium enterprises (50-249 employees) and large enterprises (more than 250 employees).

The labour input (L) from the Solow growth model is approximated by logarithm of number of full-time employees - variable SIZE. The set of independent variables is used to examine the hypothesis on the positive impact of those variables on productivity. We have included five independent variables: INT, RD, EDU, ORG and ICT. The estimated model includes also the control variable SECTOR, which is a industrial sector of the company.

The dummy variable INT indicator of institutional conditions, takes value 1 when the company is operating in the international market and 0 if otherwise. To show a company's innovatory dynamics, we used variable RD: innovation which takes value 1 when the company has separated R&D department and 0 if otherwise.

For the needs of the econometric modelling we created two indices ORG i EDU. ORG is a indicator of the work organisation. The create this index we used answers on questions: 1) if the implementation of the information and telecommunication technologies brought the changes in the business functions of the company (ORG1); 2) if employees can manage their own time independently (ORG2); if employees can participate in initiating or making changes in the company (ORG3).

To take into account the different scaling across organisation practices and questions regarding education. To calculate indices we followed the procedure used by Bloom et al. (2012). The scores were converted to z-scores by normalising each practice (i.e. each question) to the mean of zero and the standard deviation of one:

$$z_{p_i} = \frac{p_{i-\overline{p_i}}}{\sigma_{p_i}}$$

where: z_{pi} is a z-score for a question pi for a company *i*, p_i is an unweighted average for a question p_i for all the companies, and σ_{pi} is a standard deviation for a question pi for all the companies.

Furthermore, z-scores for each company are added:

$$M_i = z_{p_1} + z_{p_2} + z_{p_3}$$

In the last step the sum if the results is normalised by subtraction of the average for each observation and then division of the difference by the standard deviation:

$$z_i = \frac{M_i - \overline{M_i}}{\sigma_i}$$

As a result of this transformation the average for ORG indices is equal to zero. The negative values mean worse organisational practices in the company and positive values - better performance than average for all companies in the analysis.

The same method was used to create EDU variable. The index is composed by the answers on three questions regarding education level of executives (EDU1), education level of employees (EDU2) and assessment of the skill level of the employees by executives (EDU3). The negative deviation of the index from zero means lower level of the human capital, while the positive deviation means the higher level of the human capital.

Lastly, the variable ICT; has a value 1 when the company has invested in the information and communication technologies during last 24 months before the interview and 0 if otherwise.

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Table 1: Variables and indicators used for the model estimation

Variable	Definition	Indicator	Values
SALARY	Average gross salary of full-time employees in the company	Productivity	Natural logarithm
SIZE	Number of employees employed on a full-time	Labour	Natural logarithm
SECTOR	Industry sector	Control variable	1. Agriculture 2. Industry 3. Construction 4. Trade 5. Other services 6. Production and commercial 7. Other
INT	Operating in the international market	Institutional conditions	1. Yes 0. No
RD	Presence of separated R&D department	Innovation	1. Yes 0. No
ORG1	Presence of changes in company's business functions with the implementation of ICT	Organisation	1. Yes 0. No
ORG2	Employees can manage their own time independently	Organisation	6. Always 5. Very often 4. Often 3. Rarely 2. Very rarely 1. Never
ORG3	Employees can participate in initiating or making changes in the company	Organisation	6. Always 5. Very often 4. Often 3. Rarely 2. Very rarely 1. Never
EDU1	Education level of executives	Education	3. Higher education 2. Secondary education 1. Below secondary education
EDU2	Education level of employees	Education	3. Higher education 2. Secondary education 1. Below secondary education
EDU3	Assessment of the skill level of the employees by executives	Education	1. Employeesperform well all commissioned work 0. Other
ICT	Presence of the ICT investment in the last 24 months	Information and communication technologies	1. Yes 0. No

Source: Own elaboration

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The results of the ordinary least squares estimation of the productivity of Polish companies are presented in Table 2. We estimated the model for all the companies and sample divisions for according to the size: micro, small, medium and large. The models include sector-fixed effects as the additional control that will affect productivity. All the models estimated are significant (p-value<0.000) and the level of adjustment (adjusted R^2) is satisfactory and varies from 20% to 36%.The set of diagnostic tests was performed to test the assumptions of the classical linear regression model: general form specification test, variance homoscedasticity, autocorrelation and normality of the distribution of the residual. The results of most of the tests confirmed that the models are valid for the interpretation.

The results of estimation confirmed that investment in the information and communication technologies is significant variable for the whole sample ($\beta = 0{,}145$, $p < 0{,}001$) and for the other subsamples, but medium companies. In line with the stated hypothesis in all subsamples, but small companies, presence of separate R&D department leads to higher levels of the labour productivity. The causal relationship between education and productivity approximated by the index EDU is statistically significant and as expected has a positive direction. This relationship is not present in the large companies subsample. However, the hypothesis regarding the positive influence of the organisational practices has been not confirmed by the model. This variable is only significant for the medium companies ($\beta = 0{,}069$, $p < 0{,}05$). The international presence of the company positively influence the productivity levels in the all companies sample ($\beta = 0{,}054$, $p < 0{,}05$) and for the small companies ($\beta = 0{,}137$, $p < 0{,}05$).

Table 2:Influence of ICT and complementarities on labour productivity

Variable	All	Micro	Small	Medium	Large
(Intercept)	7,515***	7,358***	7,702***	7,355***	7,751***
	(0,173)	(0,275)	(0,379)	(0,366)	(0,239)
INT	0,054*	0,055	0,137*	–0,004	0,038
	(0,026)	(0,044)	(0,068)	(0,053)	(0,066)
RD	0,121***	0,179**	0,063	0,122*	0,140*
	(0,029)	(0,059)	(0,093)	(0,053)	(0,064)
ORG	0,025	0,010	–0,026	0,069*	0,068
	(0,015)	(0,023)	(0,041)	(0,032)	(0,038)
EDU	0,066***	0,053*	0,086*	0,081*	0,057
	(0,015)	(0,022)	(0,040)	(0,034)	(0,041)
ICT	0,145***	0,146***	0,223***	0,084	0,140*
	(0,023)	(0,032)	(0,061)	(0,050)	(0,066)
SIZE	0,025***	0,091**	-0,044	0,071	–0,004
	(0,007)	(0,028)	(0,060)	(0,046)	(0,037)
SECTOR	Yes	Yes	Yes	Yes	Yes
R^2	0,277	0,246	0,204	0,325	0,261
Adj. R^2	0,266	0,219	0,139	0,280	0,200
P-value	0,000	0,000	0,000	0,000	0,000
Num. obs.	805	348	146	178	133

Note: *** $p < 0{,}001$, ** $p < 0{,}01$, * $p < 0{,}05$; the standard error in brackets.
Source: Own elaboration.

4. Conclusions

The relationship between productivity and co-innovative sources of company productivity has been widely investigated, but mainly in the high developed countries. This paper provides new empirical evidence from Poland, post communist country. We use the new data collected by survey in the representative sample of Polish companies in 2015.

We verified the hypothesis about the positive influence of indices of innovation, internationalization, management practices, education and ICT investment on the productivity of the companies. The results of the ordinary least squares model were presented for the total sample and subsamples divided by the size of companies. The results differs between the samples. The ICT investment and presence of separate R&D department and human capital are the main factors influencing company's productivity. The management practices and internationalization to the lesser extend, or appeared to be insignificant. All in all, the ICT investment should go hand in hand with other determinants of productivity. Policy makers should have in mind the presence and importance of the joint promotion of co-innovation productivity factors to boost company's productivity.

The main limitation of this study is a missing financial data, which would be a better approximation for the company's labour productivity. Moreover, all variables are derived from the questionnaire based on the scaled data. Usage of the discrete variables instead continuous variables causes more issues in obtaining stable econometric model and may cause bias in the estimates. Moreover, we have in mind existing disparities in labour productivity caused by company heterogeneity across industries and with different size. This topic is of great importance and more country data should be collected covering especially small and medium enterprises, to identify the problems which are faced by companies.

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