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Econometric Modelling and Forecasting of the Polish ICT Sector Development with Regard to Macroeconomic Indicators

1. Introduction

The ICT sector is extremely important for socio-economic development. It has a strong linkage with other sectors, and its development results in an increase in benefits from other sectors of the economy. The achievements of the ICT sector are therefore the determinant of the direction of economic development. The values of ratios achieved by this sector are significantly related with the overall macroeconomic results of economic activity. The ICT sector is, therefore, referred to as a strategic sector.

The value of net sales of the ICT sector is becoming particularly important. These sales define the investment potential of innovative activity in the sector and enable an overall assessment of the development level of this sector. Therefore, the possibility of efficiency improvement of other economic sectors depends in this sense on the net sales of the ICT sector.

The aim of this study is the econometric analysis of the Polish ICT sector development in the period 2007–2014. As an indicator of the development of this sector, the level of achieved net sales was used. The estimated econometric models of revenue can be a source for the interpretation of the impact of significant explanatory variables on the dependent variable, and can also be fore-casting tools².

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² Verbeek, M. (2012). A Guide to Modern Econometrics. John Willey & Sons, Ltd, Chichester, 58–90; Hendry, D.F., Nielsen, B. (2007). Econometric Modeling: A Likelihood Approach. Princeton University Press, Princeton, 154–174; Jain, Ch. L., Malehorn, J. (2005). Simple Regression Models, in: Ch.L. Jain, J. Malehorn (ed.), Practical Guide to Business Forecasting. Graceway Publishing Company, Inc., New York, 371–383; Jain, Ch. L., Malehorn, J. (2005). Multiple Regression Models, in: Ch.L. Jain, J. Malehorn (ed.), Practical Guide to Business Forecasting. Graceway Publishing Company, Inc., New York, 385–401.

2. The Evolution of the Concept and Classification of the ICT Sector

In Poland until 2003 the classification of the ICT sector was defined according to the Polish Classification of Activities 1997 (PKD 1997). This classification corresponded to the Statistical Classification of Economic Activities in the European Community NACE Rev. 1 (Fr. Nomenclature statistique des Activités économiques dans la Communauté Européenne). In 2004-2008 the Polish ICT sector was classified according to PKD, which was adopted in 2004 and was constructed on the basis of the Statistical Classification of Economic Activities in the European Community NACE rev. 1.1, and a slightly different definition was in force. Thus, according to PKD 2004, the ICT sector was still ranging from the production of ICT to three types of ICT services (wholesale of ICT, telecommunications and IT services). However, according to the Polish ICT sector classification, which was valid in the period 2004-2008, wholesale ICT included: wholesale of computers, peripherals and software, and also wholesale of electronic components. According to the previous classification (PKD 1997 and NACE Rev. 1), wholesale of ICT included: the wholesale of household appliances and black goods, the wholesale of machines and office equipment for industry, trade and water transport. The change relating to the wholesale of ICT services in 2004 was the most significant difference between the analysed classifications. This change caused a decline in the recorded values of ratios in the field of ICT services in 2004 (e.g. the number of companies) in comparison to the preceding values of these ratios, and consequently a decline in the whole ICT sector³.

The current understanding of the ICT sector in Poland is based on PKD 2007, which corresponds to the Statistical Classification of Economic Activities in the European Community NACE Rev. 2. The definition, which was formulated in 2007 by WPIIS and was adopted in the OECD, is also based on NACE Rev. 2. According to this definition, the ICT sector comprises the following enterprises: producing goods enabling electronic data processing and communication including transmission and displaying, as well as service companies enabling electronic data processing and communication (applicable).

³ Społeczeństwo informacyjne w Polsce. Wyniki badań statystycznych z lat 2004–2006. Główny Urząd Statystyczny, Warszawa 2008, 7–14.

in 2004–2008) eliminated companies producing goods that enable the use of electronic processing to detect, measure and / or record physical phenomena.

According to PKD 2007, the ICT sector retained the existing overall structure, i.e. the division into the ICT production and ICT services, and also retained the classification of ICT services i.e. wholesale ICT, telecommunications and IT services. However, there were significant changes in the listed components⁴.

The PKD changes in 2004 were so significant that there is no possibility of comparing the ratios of the ICT sector in 2000–2003 with these from 2004–2006. What is more, the changes in the definition and classification which were made in 2007, caused the impossibility of comparing the values of both of these above-mentioned periods with the period 2007–2014. This fact was the reason that the ICT sector indicators from the period 2007–2014 were used in this publication. One definition and classification of this sector was valid, then.

3. The Importance of the ICT Sector for Socio-Economic Development

Currently, the impact of ICT on productivity and GDP is well-known. Accordingly, in the published literature the growth models include expenditure on this technology. The growth model, which assesses the impact of ICT, uses the Cobb-Douglas production function. Therefore, such explanatory variables as GDP (Y) and labour productivity (Y/L) are power functions of: capital expenditure on ICT, expenditures on the remaining capital (N_ICT), employment measured by the number of working hours (L). The only linear relationship is related to the general level of technology (A). The equations for GDP and productivity are as follows:

$$Y = AL^{\alpha}N_{I}CT^{\beta}ICT^{\gamma}$$
⁽¹⁾

$$Y / L = AL^{\alpha - 1}N _ ICT^{\beta}ICT^{\gamma}$$
⁽²⁾

Investments in ICT are, therefore, an important source of socio-economic development in the current wave of innovation. Spending on ICT stimulates the

⁴ Społeczeństwo informacyjne w Polsce. Wyniki badań statystycznych z lat 2007–2011. Główny Urząd Statystyczny, Warszawa 2012, 17–18.

economic growth in developed countries and in some newly industrialised countries, but high economic growth usually results in an increase of the investment activity in the field of ICT in less developed countries. There are still countries where the main sources of growth are physical capital (N_ICT) or traditional technologies, but investments in these resources (N_ICT) are the cause of a large part of the development gap⁵.

In the literature, there are descriptions of research results related to the estimation of Cobb-Douglas models, which have (among the independent variables) a variable representing the information sector. An analysis of the impact of the information sector on GDP was made by R. Hayes and H. Borko on the basis of the US economy. The explanatory variables, which were used by them, meant: capital, employment, spending on information (the information sector) and spending on raw materials and semi-finished products. Each variable contained observations from fifty-one branches of industrial production. An estimation of Cobb-Douglas models for the US data was also carried out by H. Engelbrecht. In turn, N. Karunaratne conducted similar analyses for the countries of the Pacific region. They took (as function arguments) only the size of the information sector and the size of the non-information sector. The results, which were obtained by all the above-mentioned authors confirmed the undeniable importance of the information sector in economic growth (obtained R square values were often even greater than 0.98)⁶.

There are also research results of the impact of the increase in broadband lines on economic growth. For example, L. Roller and L. Waverman confirmed in this regard a significant correlation (on the basis of the data from a period of over twenty years) for 21 OECD countries. According to their analysis, the impact of broadband growth on economic growth is significant only after reaching the critical mass by the telecommunications infrastructure. Similar results were obtained by A. Datta and S. Agarwal for 22 OECD countries. Then S. Koutroumpis based his research on 15 EU countries and showed that the growth of broadband in 2002–2007 resulted in economic growth, which accounted for 16.92% of the total growth in this period. In turn, S.P. Greenstein

⁵ Zielińska-Głębocka, A. (2012). *Współczesna gospodarka światowa. Przemiany, innowacje, kryzysy, rozwiązania regionalne*. Wolters Kluwer Polska, Warszawa, 48–49.

⁶ The mentioned analyses were described in: Dziuba, T. (2007). *Metody ekonomiki sektora informacyjnego*. Difin, Warszawa, 126–130.

and P. McDevitt showed that the deployment of broadband infrastructure creates approximately \$8.3-\$10.6 billion of new GDP in the US⁷.

The increasing use of information technologies in business processes has resulted in the fact that one of the most important indicators of national economic development is the level of income generated in the high technologies sector. Telecommunications services have the largest share in the net sales value in the Polish ICT sector. This fact is related to the dynamic development of the mobile telephony segment and the Internet segment⁸. The development mentioned is the result of the appropriate telecommunications policy, which assumed, inter alia: price reduction, stimulation of competition and ensuring an appropriate level of service quality⁹.

The appropriate level of the ICT sector development stimulates evolution in the direction of knowledge-based economies in developed countries, thus moving away from the economies based on the capital and labour. In this context, a statement may be made that the ICT sector development is a factor of knowledge-based economy development. The ICT sector development is also connected with the development of such concepts as electronic economy, digital economy, post-industrial economy, and information society¹⁰.

Due to the fact that the concept of post-industrial economy is used for the description of the current economic realities, contemporary enterprises are referred to as post-industrial enterprises. One of the features characterising a post-industrial company is that it utilises ICT for management and organisation of its activities. With the development of ICT, new management concepts have appeared which are based on these technologies. At the same time, departure

⁷ The results of the research are published in: Cambini, C., Jiang, Y. (2009). Broadband Investment and Regulation: A Literature Review. Telecommunications Policy. *The International Journal on Knowledge Infrastructure Development, Management and Regulation, 33*, 559–560.

⁸ Kaczmarczyk, P. (2015). Analizy statystyczne i techniki predykcyjne rynku telekomunikacyjnego. Wydawnictwo PWSZ w Płocku, Płock, 37–52; Kaczmarczyk, P. (2015). Analiza rozwoju rynku telefonii mobilnej w Polsce w latach 2002–2013. "Studia i Prace" Kwartalnik Kolegium Ekonomiczno-Społecznego SGH w Warszawie, 1(21), 77–92.

⁹ Kaczmarczyk, P. (2015). Ocena stopnia realizacji polityki telekomunikacyjnej w zakresie strategii regulacyjnej do roku 2015. *"Studia z Polityki Publicznej" Kolegium Ekonomiczno-Społeczne SGH w Warszawie*, 2(6), 79–94.

¹⁰ Korres, G.M. (2008). Technical Change and Economic Growth. Inside Knowledge Based Economy. MPG Books Ltd, Bodmin, 1–40, 149–258; Mutula, S.M. (2010). Digital Economies. SMEs and E-Readiness. Business Science Reference, Hershey, 1–26; Goliński M. (2011). Spoleczeństwo informacyjne – geneza koncepcji i problematyka pomiaru. Oficyna Wydawnicza SGH w Warszawie, Warszawa, 23–34.

from the existing forms of conducting business is noticed. Currently, there are even companies which are operationally entirely dependent on the Internet and networks linked to it.

4. Empirical Analysis of the Polish ICT Sector Development in the Period of 2007–2014 and the Forecasts' Construction

The analyses, which were described at this point of the article, were based on annual observations of twenty variables from the period 2007–2014. The publications of the Central Statistical Office of Poland were the data source. The used data related mainly to the Polish ICT sector, but also macroeconomic indicators relating to the Polish economy were used¹¹. Econometric models of the net sales in the ICT sector were the object of the research. The purpose of the research was the selection of the best fitted regression regardless of its type under the existing regression classifications.

Variable symbol	Variable name		
YEAR	Year number, Year = 1, 2,, 8		
A_ENT	Number of enterprises in the ICT sector		
A_ENT_P	Number of enterprises in production of the ICT sector		
A_ENT_S	Number of enterprises in services of the ICT sector		
A_EMP	Number of employees in the ICT sector		
A_EMP_P	Number of employees in production of the ICT sector		
A_EMP_S	Number of employees in services of the ICT sector		
SAL	Net sales in the ICT sector in millions PLN		
SAL_P	Net sales of the ICT sector production in millions PLN		
SAL_S	Net sales of the ICT sector services in millions PLN		
EXP	Net export sales in the ICT sector in millions PLN		
EXP_P	Net export sales of the ICT sector production in millions PLN		

Table 1. The Specification of the Applied Variables in the Research Study

¹¹ The data relating to the Polish ICT sector were juxtaposed on the basis: *Społeczeństwo informacyjne w Polsce. Wyniki badań statystycznych z lat*: 2004–2006. pp. 15–26; 2007–2011, pp. 19–27; 2011–2015, pp. 22–34, GUS, Warszawa. The macroeconomic indicators values were downloaded from the website: http://stat.gov.pl/wskazniki-makroekonomiczne/ (Accessed 14/05/2016).

Variable symbol	Variable name		
EXP_S	Net export sales of the ICT sector services in millions PLN		
S_EXP	Share of the net export sales in the ICT sector in the overall export in $\%$		
S_EXP_P	Share of the net export sales of the ICT sector production in production export in $\%$		
S_EXP_S	Share of the net export sales of the ICT sector services in services export in $\%$		
R_D	Expenditure on R&D in the ICT sector in millions PLN		
GDP	Gross Domestic Product (current prices) in millions PLN		
P_INDEX	Price index in % (2007 = 100)		
UNEMP	Number of the registered unemployed in thousands		

Source: The author's own elaboration.

Pearson's correlation coefficients (p = 0.05) between potential explanatory variables and SAL variable (net sales value in the ICT sector) were juxtaposed in figure 1.



Figure 1. Pearson's Correlation Coefficients

Source: The author's own elaboration.

The highest significant value of the correlation coefficient was obtained for R_D variable. Between R_D variable and SAL variable there is a very strong linear correlation. This correlation is the strongest of all the analysed correlations



in this study. The Scatter plot with the linear regression of SAL on R_D was shown in figure 2.

Figure 2. Scatter Plot of Expenditure on R&D in the Polish ICT Sector vs. the Net Sales in This Sector

Source: The author's own elaboration.

The graph presents Neyman's confidence intervals (95 percent) as two confidence curves. The observations in 2010 and in 2011 are not unusual observations (influential observations and outliers). The calculated Cook's distances indicate a lack of influential observations and the obtained values of standardised residuals indicate a lack of outliers. The estimated regression model (R square = 0.9732; std. error of the estimate = 2932.3121; calculated F statistic = 218.0412 and p < 0.05) has statistically significant parameters, therefore, the theoretical (annual) increase in expenditure on R&D by 1,000,000 PLN causes the increase in the net sales in the ICT sector on average of 33,093,200 PLN.

Among the tested non-linear models of this relationship, the best results were obtained for the power regression model. The linear transform of this model was as follows:

$$\ln SAL = 10.3055 + 0.2019 \ln R_D.$$

The estimated linear regression model was characterised by an exceptionally good fit to the data (R square = 0.9908; calculated F statistic = 645.7772 and p < 0.05). The power model was as follows:

$$SAL = 29895.1040 \cdot R \quad D^{0.2019}$$

and was presented in figure 3.



Figure 3. Power Model of the Relationship between Expenditure on R&D in the Polish ICT Sector and the Net Sales in This Sector

Source: The author's own elaboration.

The model shows that with the increase in expenditure on R&D by 1 percent, the net sales in the ICT sector rise approximately by 0.2 percent.

A significant and very strong correlation (but slightly lower than the previously analysed correlation) was obtained for the Gross Domestic Product (GDP variable). Therefore, the analysis of the linear relationship between variables was extended to the estimation of the regression line (fig. 4).

Unusual observations were not identified. The analysed single regression model is also characterised by the very good fit to the empirical observations (R square = 0.9639; std. error of the estimate = 3405.7658; calculated F statistic = 160.0805 and p < 0.05). The statistical significance of the GDP variable was confirmed, therefore, the economic interpretation of the estimated structural parameter standing by this variable was justified. With the increase in the





Figure 4. Scatter Plot of the Polish Gross Domestic Product vs. the Net Sales in the Polish ICT Sector

Source: The author's own elaboration.

None of the tested non-linear models are characterised by a sufficiently satisfactory fit to the data. Accordingly, the description of the study of this relationship was limited to the linear regression analysis. The functional relationship between the development of the ICT sector and GDP growth, which was defined in the formula (1) and which distinguishes developed countries, was not found.

Then research relating to the estimation of the best possible linear model, which describes the formation of the net sales in the Polish ICT sector in the assumed period of time, was set. The forward stepwise regression method was used (F-to-enter statistic = 2 and F-to-remove statistic = 1). Three variables (i.e. R_D, EXP_S and S_EXP_S) of all the potential explanatory variables were initially selected for the model. But finally, (after the elimination of the phenomenon of collinearity) the single regression model with explanatory R_D variable was again received. This fact confirmed the highest approximation possibility of the model.

¹² The statistical significance of the structural parameters of the three presented models was also confirmed by using Student's t-test.

In all the described models, normal distributions of residuals were confirmed. For the second model and the third model grounds were not found to reject the null hypothesis of no autocorrelation in the residuals. In this analysis Durbin-Watson test was used. For the first model, the calculated DW statistic was in the range between lower (d_L) and upper (d_U) critical values, and the test was inconclusive. Finally, Pearson correlation coefficients between residuals values e_t and e_{t-1} (0.4302; p = 0.3353) proved to be statistically insignificant and the null hypothesis was also confirmed for the first model.

The prognostic value of the net sales in the Polish ICT sector for 2015, 2016, and 2017 was formulated on the basis of the estimated models. In the process of formulating the forecasts the passive forecasting approach was assumed. The forecasts of explanatory variables were made by using linear trend models. Pearson correlation coefficients between the YEAR (time variable) and respective variables: B_R and GDP (which are the explanatory variables in the three previously analysed models) showed a very strong correlation and amounted to: 0.9870 and 0.9898, respectively. The values of the forecasts and their errors are juxtaposed in the table below.

Regression model	Forecast in millions PLN	Absolute error of <i>ex ante</i> forecast in millions PLN	Relative error of <i>ex ante</i> forecast in %			
2015						
SAL = 84925.6452 + 33.0932R_D	141804.1177	3702.9160	2.61			
$SAL = 29895.1040 \cdot R_D^{0.2019}$	134491.0169	2469.7018	1.84			
SAL = -12915.4646 + 0.0845GDP	141746.8193	4304.4645	3.04			
2016						
SAL = 84925.6452 + 33.0932R_D	148398.2456	3963.0571	2.67			
$SAL = 29895.1040 \cdot R_D^{0.2019}$	137502.2663	2576.5571	1.87			
SAL = -12915.4646 + 0.0845GDP	148328.2152	4608.0610	3.11			
2017						
SAL = 84925.6452 + 33.0932R_D	154992.3734	4254.2805	2.74			
$SAL = 29895.1040 \cdot R_D^{0.2019}$	140273.3245	2679.7699	1.91			
SAL = -12915.4646 + 0.0845GDP	154909.6112	4947.8480	3.19			

Table 2. Results of the Forecasting Process

Source: The author's own elaboration.

All the computed forecasts are characterised by low relative errors. If a forecaster sets the acceptability threshold of forecasts error at 2% in this study, the forecasts for 2015, 2016, and 2017 computed only according to the power model would be considered as acceptable. Therefore, it may be expected that the net sales in the Polish ICT sector in 2015, 2016, and 2017 shall amount to 134,491,016,900 PLN, 137,502,266,300 PLN and 140,273,324,500 PLN, respectively. Certainly, if a forecaster assumes a slightly higher acceptability threshold of the forecast error (e.g. 3.3%), it will mean that all the forecasts should be considered as acceptable.

5. Conclusion

The three analysed regression models of the net sales in the Polish ICT sector are characterised by the very good fit to the empirical data and the low forecast errors. However, the first and the second model, in which R_D (expenditure on R&D in the Polish ICT sector) is an explanatory variable, are characterised with the highest opportunities of approximation and prediction.

The first and second model are the most useful in the economic interpretation of the development of the Polish ICT sector, due to the best fit to the data. In the context of use in forecasting, the second model provides the best results (the lowest relative errors of ex ante forecasts) in comparison to the first and the third tested model. Furthermore, the simple regression model is a relatively simple forecasting tool, owing to only one explanatory variable. Due to the fact that the R_D variable is very strongly linearly correlated with the time variable, the future value of the R_D variable may be obtained by using the estimated linear trend model.

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- http://stat.gov.pl/wskazniki-makroekonomiczne/ (Accessed 14/05/2016).

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Ekonometryczne modelowanie i prognozowanie rozwoju polskiego sektora ICT z uwzględnieniem wskaźników makroekonomicznych

Streszczenie

Celem artykułu jest analiza rozwoju polskiego sektora ICT w latach 2007–2014. W części teoretycznej zaprezentowano dotychczasową ewolucję obowiązującego pojęcia i stosowanej klasyfikacji sektora ICT według NACE w UE oraz PKD w Polsce. Opisano również znaczenie sektora ICT dla kształtowania gospodarki opartej na wiedzy i rozwoju społeczno-gospodarczego. W części empirycznej przedstawiono ekonometryczną analizę przychodów netto ze sprzedaży w polskim sektorze ICT w latach 2007–2014. Wykorzystano dane roczne, które są dostępne w publikacjach GUS. Zdefiniowano 19 potencjalnych zmiennych objaśniających. Spośród testowanych modeli ostatecznie wybrano te, które były najlepiej dopasowane do danych i które umożliwiły również uzyskanie najniższych błędów *ex ante* dotyczących prognoz przychodów netto ze sprzedaży w sektorze ICT do 2017 r.

Słowa kluczowe: sektor ICT, gospodarka oparta na wiedzy, analiza ekonometryczna, prognozowanie