Anadolu Üniversitesi Sosyal Bilimler Dergisi | AÜSBD | Anadolu University Journal of Social Sciences

Internet Penetration and Productivity: A Panel Study

İnternet Kullanımının Yaygınlaşması ve Verimlilik: Panel Çalışma

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Abstract

Since the early 1990s, penetration of internet has accelerated significantly in the world. The impact of internet and ICT on labor productivity at firm and industry level has been studied by many authors. The purpose of this study is to look at the macro-level effects of the internet on various indicators of productivity. A dataset consisting of a panel of annual observations for 162 countries is used in the study. Another important point that distinguishes our paper form other contributions on ICT and productivity is that we employed the most comprehensive set of productivity indicators (13 productivity indicators) instead of using only one indicator. We identified a positive correlation between internet penetration and productivity. This finding is statistically significant and valid for thirteen different productivity indicators. Our results suggest that internet penetration increases productivity controlling for other factors that may contribute to productivity.

Keywords: *The Internet, ICT, Productivity, Panel Study*

Öz

1990'lı yılların başlarından beri, internetin penetratsyonu dünyada hızla artmıştır. İnternetin ve BİT'in firma ve endüstri düzeyinde emek verimliliği üzerindeki etkisi birçok yazar tarafından incelenmiştir. Bu çalışmanın amacı, internetin çeşitli verimlilik göstergelerine makro düzeyde etkilerini incelemektir. Çalışmada 162 ülkeye ait yıllık gözlemler kullanılmıştır. Çalışmayı BİT ve verimlilik üzerine yazılmış diğer çalışmalardan ayıran bir diğer önemli nokta da yalnızca bir gösterge kullanılması yerine en kapsamlı verimlilik göstergeleri setinin (13 verimlilik göstergesi) kullanılmasıdır. Çalışmada internet penetrasyonu ve verimlilik arasında pozitif bir ilişki olduğu tespit edilmiştir. Bu bulgu, on üç farklı verimlilik göstergesi için de istatistiksel olarak anlamlı ve geçerli bulunmuştur. Bulgularımız, verimlilik artışına etki eden diğer faktörlerin kontrol altında tutulması koşulları altında, internet penetrasyonunun verimliliği artırdığını göstermektedir.

Anahtar Kelimeler: *İnternet, BİT, Verimlilik, Panel Çalışma*

Introduction

Since the early 1990s, penetration of information and communication technologies (ICTs) has accelerated significantly in the world. Widespread expansion in the use of ICT has caused discussions on the impact of ICT on economic variables. Productivity affect of ICT usage is the most discussed impact of ICT usage in the literature.

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At the theoretical level, ICT penetration can improve the productivity of firms through several channels. First, ICT use can improve productivity of firms by reducing their transaction and productions costs. With ICT use, firms are able to communicate better, faster and at lower costs which reduce both internal and external transaction costs (Meijers, 2014, p. 139) and thus lowering production costs and enhancing productivity. Second, ICT usage can facilitate productivity of firms by allowing firms to conduct their business, marketing and pricing more efficiently. ICT enables firms to contact their customers directly by bypassing retailers, facilitates organizational capabilities such as customer relationship ability, reduces the amount of inventories, concludes their transactions and contracts faster, and reduces their time and efforts spent on international communication and marketing research (Choi, 2003; Bianchi and Mathews, 2016). Third, ICT can force firms to become more productive by intensifying market competition. ICT lowers entry barriers and costs and thus makes entry into several markets easier. Both lower transaction costs and lower entry barriers result in a greater market competition (intensified competition in the market) which leads to increase in the firm's productivity. (Salahuddin and Gow, 2016; Sanchez et al., 2006). Fourth, ICT usage can enhance productivity of firms by improving management and organizational efficiency of the firm. ICT penetration enhances the quality of decision-making and the efficiency of resource management of firms (Pradhan et al., 2014; Vu, 2011; Sanchez et al., 2006). Firms can take better decisions, make the most efficient use of resources in their operations and develop flexible and sensitive responses to changes of market conditions (Jung, Na and Yoon, 2013). Fifth, the use of ICTs in the private sector can increase productivity of firms by generating innovation and technology diffusion. ICT enables firms to access to new technologies, improves their products and services, develops new products, processes and business models, and collaborates for producing specialized inputs which in turn increases productivity of firms (Bertschek, Cerquera and Klein, 2013; Salahuddin and Gow, 2016). Efficient usage and exchange of knowledge among scientific institutions and business contributes into strengthening of innovative process which results in an increase in productivity (Czernich et al., 2011; Maciulyte-Sniukiene and Gaile-Sarkane, 2014, p. 1271). Lastly, the penetration of ICT use can enhance productivity by fostering improvement in labor skills, consumer sophistication and an increased level of broad-based education (Vu, 2011, p. 357).

The impact of ICT on labor productivity at firm and industry level has been studied by many authors: Brynjolfsson and Hitt (2003), Hu and Quan(2005), Stiroh (2002), Oliner and Sichel (2000) for the USA; Daveri (2002) for European Union (EU) economies; Sanchez, Rata, Duarte and Sandulli (2006) for Spain; Lehr and Lichtenberg (1999) for Canada; Oulton (2002), O'Mahony and Vecchi (2005) for UK, Fabiani, Schivardi, and Trento (2005), Atzeni and Carboni (2006) for Italy; Jalava and Pohjola (2002, 2008) for Finland, Grimes, Ren and Stevens (2012) for New Zealand, Jung, Na and Yoon (2013) for Korea; Vu (2013) for Singapore; Jorgenson and Motohashi (2005) for Japan. Firm level empirical studies support the theory and indicate that ICT has positive and significant effects on labor productivity.

However, firm-level productivity effects of ICT usage can differ depending on how information intensive the firm is (Kumar, Stauvermann and Samitas, 2015, p. 1) and how information technologies are used (Czernich et al., 2011, p. 508). ICT use and investments may lead to a rise of the total factor productivity at the macroeconomic level depending on the presence of complementary inputs such as skilled labor, experience, organizational structure and practices (Autor et al., 2003; Bloom et al., 2011; Czernich et al., 2011).

The purpose of this study is to look at the macro-level effects of the internet on various indicators of productivity. We used a dataset consisting of a panel of annual observations for 162 countries. Another important point that distinguishes our paper form other contributions on ICT and productivity is that we employed the most comprehensive set of productivity indicators (13 productivity indicators) instead of using only one indicator.

This article proceeds as follows. In the following section we introduce our data, model, and our empirical strategy. Estimation results are given in section 3. We offer concluding thoughts in the final section.

Empirical Framework

We investigated the impact of internet penetration on productivity by using 13 productivity indicators. The period under study is between 2000 and 2013. Our largest sample includes 162 countries.[1]

By using unbalanced panel data, we estimate the following one-way bivariate and multivariate fixed effect models (FEM);

$$PRD_{it} = \beta_{1i} + \beta_2 INTERNET_{it} + u_{it} \quad (1)$$

$$PRD_{it} = \beta_{1i} + \beta_2 INTERNET_{it} + \beta_3 GROSSCF_{it} + \beta_4 SCHOOLE_{it} + \beta_5 AWWH_{it} + \beta_6 AWWH\hat{}2_{it} + u_{it} \quad (2)$$

and the following one-way bivariate and multivariate random effect models (REM);

$$PRD_{it} = \beta_1 + \beta_2 INTERNET_{it} + \varepsilon_i + u_{it} \quad (3)$$

$$PRD_{it} = \beta_1 + \beta_2 INTERNET_{it} + \beta_3 GROSSCF_{it} + \beta_4 SCHOOLE_{it} + \beta_5 AWWH_{it} + \beta_6 AWWH\hat{}2_{it} + \varepsilon_i + u_{it} \quad (4)$$

where *it* subscript stands for the *i-th* country's observation value at time *t* for the particular variable. All variables are in logarithmic forms. β_{1i} represents country specific factors not considered in the regression, which may differ across countries but not within the country and is time invariant. ε_i is a stochastic term, which is constant through the time and characterizes the country specific factors not considered in the regression. u_{it} is error term of the regression.

Our dependent variable is productivity (PRD). Thirteen different productivity indicators are used in order to evaluate the sensitivity of our empirical results. Results may vary depending on which productivity indicator is used. If the results hold across different productivity indicators, it will be an indication of their robustness. The list of dependent variables, their definitions, and the data sources are given in Table 1 below.

We used four labor productivity indicators, two total factor productivity indicators, six value added productivity indicators, and GDP per person employed. Two total factor productivity indicators of Penn World Table are used in our empirical investigation: total factor productivity level at current PPPs and welfare-relevant total factor productivity levels at current PPPs. We used four labor productivity measures of The Conference Board. Total Economy Database of The Conference Board reports four labor productivity indicators, namely, Labor productivity per person employed in 1990 US$, Labor productivity per person employed in 2014 US$, Labor productivity per hour worked in 1990 US$, and Labor productivity per hour worked in 2014 US$. We also used total and sectoral value added productivity indicators obtained from World Bank. Finally, we used GDP per person employed.

Definition and data source of explanatory variables are given in Table 2 below. Our explanatory variables were chosen in the light of previous studies found in the literature and our main hypothesis (Djankov and Murrell 2002; Estrin et al., 2009; Belorgey et al.,

1 The sample includes the following countries: Afghanistan, Albania, Algeria, Andorra, Antigua and Barbuda, Argentina, Armenia, Aruba, Australia, Austria, Azerbaijan, Bahamas, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Central African Rep., Chad, Chile, Colombia, Congo, Costa Rica, Croatia, Cuba, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Faroe Islands, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Korea Republic, Kuwait, Kyrgyzstan, Lao P.D.R., Latvia, Lebanon, Lesotho, Liechtenstein, Lithuania, Luxembourg, Macao, Macedonia, Madagascar, Malawi, Maldives, Mali, Malta, Mauritania, Mauritius, Mexico, Micronesia, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Rwanda, Saint Lucia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, South Africa, Spain, Sri Lanka, Sudan Republic, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Tajikistan, Tanzania, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela, Yemen, Zambia, Zimbabwe.

Table 1. List of Dependent Variables

Variable	Definition	Data Source
CTFP	Total Factor Productivity Level at Current PPPs	Penn World Table
CWTFP	Welfare-relevant Total Factor Productivity Levels at Current PPPs	Penn World Table
LPROD1	Labor productivity per person employed in 1990 US$ (converted at Geary Khamis PPPs)	The Conference Board
LPROD2	Labor productivity per person employed in 2014 US$ (converted to 2014 price level with updated 2011 PPPs)	The Conference Board
LPROD3	Labor productivity per hour worked in 1990 US$ (converted at Geary Khamis PPPs)	The Conference Board
LPROD4	Labor productivity per hour worked in 2014 US$ (converted to 2014 price level with updated 2011 PPPs)	The Conference Board
PCV	{Gross value added at factor cost (current US$)}/ {Total Population}	WDI WDI
MAN	{Manufacturing, value added (current US$)}/ {Employment in Manufacturing (thousand of persons)x1,000}	WDI ILO
AGR	{Agriculture, value added (current US$)}/ {(Employment in agriculture (% of total employment)/100)x (Persons employed (in thousands of persons)x1,000)}	WDI WDI The Conference Board
IND	{Industry, value added (current US$)}/ {(Employment in industry (% of total employment)/100)x (Persons employed (in thousands of persons)x1,000)}	WDI WDI The Conference Board
SERV	{Services, etc., value added (current US$)}/ {(Employment in services (% of total employment)/100)x (Persons employed (in thousands of persons)x1,000)}	WDI WDI The Conference Board
PLV	{Gross value added at factor cost (current US$)}/ { Persons employed (in thousands of persons)x1,000}	WDI The Conference Board
GDPPEREMP	GDP per person employed (constant 1990 PPP $)	WDI

Table 2. Explanatory Variables

Variable	Definition	Data Source
Internet	Percentage of individuals using the Internet	World Telecommunication/ICT Indicators Database of UN
Gross Capital Formation	Gross capital formation (% of GDP)	WDI
School Enrollment	School enrollment, tertiary (% gross)	WDI
Hours Worked	Annual hours worked per worker	The Conference Board

2006).

Our main explanatory variable is INTERNET which is the percentage of individuals using the internet. The data regarding the Internet are obtained from World Telecommunication/ICT Indicators Database of UN.

We also introduced three more determinants of productivity into our analysis to see how robust our finding is:

GROSSCF is gross capital formation (% of GDP). The data come from World Development Indicators of the World Bank. The coefficient on the GROSSCF is expected to have a positive sign as improvements in labor productivity and total factor productivity can arise from greater investment in fixed capital.

SCHOOLE refers to gross tertiary school enrolment percentage. The data come from World Development Indicators of the World Bank. The coefficient of the School Enrollment is expected to be positive in our model since investment in human capital may improve productivity.

AWWH refers to annual hours worked in the relevant country. The data are from The Conference Board Total Economy Database. Theoretically, an increase in the average weekly working hours increases the productivity of a worker; however, it decreases the productivity of a worker after a threshold level. Thus, we employed AWWH and square term of AWWH (AWWH^2)

to test the above hypothesis. Thus, the coefficient on AWWH is expected to be positive while the coefficient on AWWH^2 is expected to be negative.

Estimation Results

Estimation results are reported in Table 3 and 4 for bivariate and multivariate models, respectively. Tables also report the Hausman test statistics for choosing between FEM and REM models. At the 5% significance level, the Hausman test statistics results select FEM model for all models except the multivariate model where INDVLADPLCUR is dependent variable.

As shown by bivariate results in Table 3, the estimated coefficient of INTERNET variable has the expected positive sign and is statistically significant at 1% level in all models. The strongly significant explanatory power of INTERNET is not affected by the inclusion of the other additional covariates as seen in Table 4. Thus, this finding suggests a positive relation between the internet penetration and productivity in all forms and implies that countries that have greater internet penetration will have higher productivity levels.

In regard to the other explanatory variables, the estimated coefficient on Gross Capital Formation is positive and significant at least at 10% significance level in all models except one model. Similarly, the estimated coefficient on School Enrollment is positive and significant at least at 1% significance level in all models except one model. The coefficients on AWWH and AWWH^2 take the anticipated signs and are significant at least at the 5% significance level in all models but two models.

Overall for our purpose, the finding of a positive re-

Table 3. Bivariate Model Estimation Results

	AGR	CTFP	CWTFP	GDPMP	IND	LPROD1
Constant	**8.0360**	**-0.7305**	**-0.8196**	**9.3095**	**8.9303**	**9.3521**
Standard Error	0.0467	0.0107	0.0098	0.0068	0.0335	0.0065
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
INTERNET	**0.3099**	**0.0699**	**0.0816**	**0.0982**	**0.3618**	**0.0977**
Standard Error	0.0151	0.0040	0.0037	0.0026	0.0108	0.0024
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number of Observations	998	1307	1307	1546	1002	1666
Number of Countries	108	110	110	120	108	120
R-squared	0.9441	0.9625	0.9587	0.9911	0.9551	0.9908
Estimated Model	FEM	FEM	FEM	FEM	FEM	FEM
Hausman-statistics	114.34	88.769	90.661	273.36	33.310	285.75

Table 3. Bivariate Model Estimation Results (Continue)

	LPROD2	LPROD3	LPROD4	MAN	PCV	PLV	SERV
Constant	**10.0103**	**2.1902**	**2.8342**	**8.7599**	**7.4135**	**8.4465**	**8.7300**
Standard Error	0.0065	0.0148	0.0148	0.0436	0.0132	0.0172	0.0289
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
INTERNET	**0.0979**	**0.1365**	**0.1364**	**0.3911**	**0.3432**	**0.3341**	**0.3578**
Standard Error	0.0024	0.0042	0.0042	0.0144	0.0052	0.0062	0.0093
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number of Observations	1676	880	875	584	2112	1424	1001
Number of Countries	121	64	63	76	162	107	108
R-squared	0.9926	0.9891	0.9890	0.9646	0.9819	0.9794	0.9684
Estimated Model	FEM	FEM	FEM	FEM	FEM	FEM	FEM
Hausman-statistics	246.81	159.38	144.60	17.854	301.76	214.62	78.918

Table 4. Multivariate Model Estimation Results

	AGR	CTFP	CWTFP	GDPEMP	INDV	LPROD1	LPROD2
Constant	**-365.843**	**-169.298**	**-148.941**	**-179.7410**	**-15.1959**	**-193.46**	**-192.83**
Standard Error	133.1300	32.5136	30.2005	20.3269	66.3336	20.129	20.129
P-value	0.0062	0.0000	0.0000	0.0000	0.8189	0.0000	0.0000
INTERNET	**0.2693**	**0.0472**	**0.0451**	**0.1118**	**0.4466**	**0.1176**	**0.1176**
Standard Error	0.0438	0.0097	0.0090	0.0065	0.0222	0.0064	0.0064
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GROSSCF	**-0.0607**	**0.1338**	**0.2830**	**0.0634**	**0.1974**	**0.0317**	**0.0317**
Standard Error	0.1134	0.0259	0.0241	0.0189	0.0605	0.0185	0.0185
P-value	0.5925	0.0000	0.0000	0.0009	0.0012	0.0876	0.0876
SCHOOLE	**0.6525**	**0.0222**	**0.0867**	**0.1123**	**0.2524**	**0.0921**	**0.0921**
Standard Error	0.1336	0.0309	0.0287	0.0207	0.0632	0.0199	0.0199
P-value	0.0000	0.4741	0.0027	0.0000	0.0001	0.0000	0.0000
AWWH	**98.5265**	**43.4913**	**38.0074**	**49.9000**	**7.4670**	**53.725**	**53.725**
Standard Error	35.1478	8.5635	7.9543	5.3383	17.5412	5.2858	5.2858
P-value	0.0052	0.0000	0.0000	0.0000	0.6705	0.0000	0.0000
AWWH^2	**-6.5194**	**-2.8063**	**-2.4507**	**-3.2933**	**-0.5961**	**-3.5563**	**-3.5563**
Standard Error	2.3192	0.5636	0.5235	0.3503	1.1591	0.3468	0.3468
P-value	0.0051	0.0000	0.0000	0.0000	0.6072	0.0000	0.0000
Number of Observations	606	584	584	663	610	702	702
Number of Countries	58	57	57	61	58	62	62
R-squared	0.9308	0.9536	0.9516	0.9917	0.7130	0.9916	0.9915
Estimated Model	FEM	FEM	FEM	FEM	REM	FEM	FEM
Hausman-statistics	40.9109	156.284	165.734	120.316	10.6561	121.348	116.233

Table 4. Multivariate Model Estimation Results (Continue)

	LPROD3	LPROD4	MAN	PCV	PLV	SERV
Constant	**-193.46**	**-192.24**	**-40.6271**	**-281.7342**	**-284.8862**	**-143.7433**
Standard Error	20.129	20.177	126.2370	64.3670	63.0409	66.2879
P-value	0.0000	0.0000	0.7478	0.0000	0.0000	0.0306
INTERNET	**0.1176**	**0.1168**	**0.4651**	**0.4071**	**0.3838**	**0.3977**
Standard Error	0.0064	0.0064	0.0321	0.0201	0.0197	0.0216
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GROSSCF	**0.0317**	**0.0344**	**0.3154**	**0.3773**	**0.2032**	**0.2036**
Standard Error	0.0185	0.0187	0.1078	0.0578	0.0566	0.0567
P-value	0.0876	0.0666	0.0037	0.0000	0.0004	0.0004
SCHOOLE	**0.0921**	**0.0944**	**0.3992**	**0.3522**	**0.3033**	**0.3575**
Standard Error	0.0199	0.0200	0.1094	0.0619	0.0606	0.0649
P-value	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000
AWWH	**52.725**	**52.567**	**11.6185**	**78.1317**	**79.2293**	**40.2675**
Standard Error	5.2858	5.2985	33.2975	16.9200	16.5714	17.4951
P-value	0.0000	0.0000	0.7274	0.0000	0.0000	0.0217
AWWH^2	**-3.5563**	**-3.5459**	**-0.7164**	**-5.3092**	**-5.3704**	**-2.6907**
Standard Error	0.3468	0.3476	2.1954	1.1117	1.0888	1.1540
P-value	0.0000	0.0000	0.7444	0.0000	0.0000	0.0201
Number of Observations	702	697	360	635	635	610
Number of Countries	62	61	48	58	58	58
R-squared	0.9935	0.9934	0.9668	0.9751	0.9715	0.9723
Estimated Model	FEM	FEM	FEM	FEM	FEM	FEM
Hausman-statistics	121.3481	117.2847	16.5646	40.9255	37.9068	25.5793

lationship between internet penetration and productivity is statistically significant remains valid in both bivariate and multivariate analyses at very high significance level.

Conclusion

In addition to other determinants of productivity, this study examines the explanatory power of the internet penetration. By using thirteen productivity indicators, we test the hypothesis that the internet penetration contributes to increase in productivity over the period 2000 to 2013. The largest sample includes 162 countries. We identified a positive correlation between internet penetration and productivity. This finding is statistically significant and valid for thirteen different productivity indicators. Thus, the results suggest that the internet penetration has a positive and significant effect on productivity, controlling for other factors that may contribute to labor productivity.

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