UNIVERSITY OF CYPRUS
ECONOMICS RESEARCH CENTRE

Economic Policy Papers

Labor Productivity and ICT Capital

Elena Ketteni
Department of Economics, Accounting and Finance
Frederick University

Theofanis P. Mamuneas
Department of Economics
University of Cyprus

No. 09-11

December 2011

Publication Editor: Sofia N. Andreou

ERC Sponsors (in alphabetical order)

Association of Cyprus Commercial Banks

Central Bank of Cyprus

Cyprus Tourism Organisation

Economics Department, University of Cyprus

Ministry of Finance

Ministry of Labour and Social Security

Planning Bureau

University of Cyprus

Labor Productivity and ICT Capital

Elena Ketteni, Theofanis P. Mamuneas

Abstract

The aim of this study is to examine the relationship between ICT capital and labor productivity for a number of European countries and Cyprus. ICT capital, as indicated from a large literature has a positive and significant effect on productivity and economic growth. For our analysis we will be using a number of European countries, for which data for ICT are available, for the period 1980-2005. Data for ICT in Cyprus are not available, so we will try to describe the situation in Cyprus and then link it to the results of the other countries. For our estimation we will be using a general cost function from which the demands for all inputs can be derived and jointly estimated. Using the results the effect of ICT on labor productivity will be obtained, and then linked to the Cyprus economy. The results indicate that the labor productivity is positive. Intermediate inputs, non-ICT capital and total factor productivity contribute to the positive labor productivity. With respect to ICT we can see that the contribution its positive and its close to the one from non-ICT capital. Using the average contribution of ICT, we calculate its contribution for Cyprus to be 0.0014. We expect that this contribution will increase as the share of this input into the production process increases along with its large growth rate.

CONTENTS

Παραγωγικότητα Εργασίας και Τεχνολογίες Πληροφορικής και Επικοινωνιών

Έλενα Κεττένη, Θεοφάνης Μαμουνέας

ΠΕΡΙΛΗΨΗ

Η επίδραση των τεχνολογιών πληροφορικής και επικοινωνιών (ICT) στην παραγωγικότητα έχει απασχολήσει εκτεταμένα τη διεθνή βιβλιογραφία με αμφιλεγόμενα συμπεράσματα. Η παρούσα μελέτη εξετάζει:

1. την επίδραση του κεφαλαίου ICT στην παραγωγικότητα της εργασίας σε χώρες της ΕΕ, και

2. την επίδραση του κεφαλαίου αυτού στην παραγωγικότητα της εργασίας στην Κύπρο (με χρήση των αποτελεσμάτων για τις Ευρωπαικές χώρες)

Η έρευνα περιλαμβάνει εκτίμηση του βαθμού που η τεχνολογία παραγωγής στηρίζεται στο ICT και non-ICT κεφάλαιο, εργασία, πρώτες ύλες, και εξωγενείς τεχνολογικές αλλαγές. Οι συναρτήσεις ζήτησης των εν λόγω συντελεστών που προκύπτουν από αυτή την ανάλυση μας επιτρέπουν να εξάγουμε συμπεράσματα για τον ακριβή ρόλο που διαδραματίζουν οι νέες τεχνολογίες πληροφορικής και επικοινωνιών στην παραγωγή και στην παραγωγικότητα της εργασίας. Η εμπειρική ανάλυση στηρίζεται σε στοιχεία της βάσης δεδομένων EU KLEMS, όπου υπάρχουν πληροφορίες για την οικονομική μεγέθυνση, αύξηση της παραγωγικότητας, καθώς και για τη χρήση των διαφόρων συντελεστών της παραγωγής (ICT και non-ICT κεφάλαιο, εργασία, πρώτες ύλες κλπ).

Η παραγωγικότητα της εργασίας είναι θετική σε όλες τις χώρες του δείγματος μας. Η μεγαλύτερη συνεισφορά στην θετική παραγωγικότητα της εργασίας προέρχεται από τις ενδιάμεσες εισροές. Αυτό όμως μπορεί να είναι και λόγω του μεγάλου μεριδίου που έχουν στο συνολικό προϊόν. Όσον αφορά το κεφάλαιο για νέες τεχνολογίες βλέπουμε ότι η συνεισφορά του είναι κοντά σε αυτή του φυσικού κεφαλαίου. Χρησιμοποιώντας τη μέση συνεισφορά των Ευρωπαϊκών χωρών προσεγγίζουμε την συνεισφορά για την Κύπρο να είναι 0.0014. Αναμένουμε αυτή να αυξηθεί όσο το μερίδιο αυτού του κεφαλαίου θα αυξάνετε μαζί με τον ταχύ ρυθμό ανάπτυξης του.

1. INTRODUCTION

In recent years, economists have observed a rapid diffusion of information technology and its related equipment, specifically computers, in European economies. Some economists suggest that this fact is a direct consequence of the dramatic decline in the price of ICT – related equipment, which has let to a substitution of ICT equipment for other forms of capital and labor. Based on that, they suggested that this substitution generates substantial returns for agents who undertake ICT investment and also has a very significant impact on productivity and economic growth.

The literature on ICT is vast, and the major conclusion is that the firms, industries and countries that produce and use ICT have experienced considerable resources and benefited from the extraordinary technological progress than enabled them to improve their performance which is measured as rapid total factor productivity (TFP) growth. In general, the literature suggests a significant positive relationship among ICT investment and productivity growth (see for instance Hoon; 2003, Colecchia and Schreyer; 2002, Jorgenson and Vu; 2005, Basu e. al.; 2003, Matteucci et. al.; 2005, Timmer et. al.; 2007, Stiroh; 2002, Oliner and Sichel; 2003).

The aim of this study is to analyze the effect of Information and Communication Technology Capital (ICT capital) on labor productivity in Cyprus and a number of European countries.

The countries were chosen based on their availability of ICT data. Data for Cyprus are not available for ICT expenditures and prices so the estimation analysis can not take place. We will be using though general information in order to describe the situation in Cyprus and then try to link it with the estimation results from the other European countries.

For the estimation purpose we will be using a general cost function, from which we will derive the demands for all inputs and therefore jointly estimated them to obtain our results. Using the results we will be able to derive also the effect of ICT on labor productivity.

In the first section we describe the situation in Cyprus and compare it to other European countries. In the second we explain the specification and data we will be using for our estimation. Then the results from the estimation are presented, and linked to the Cyprus economy. Finally the last section concludes. In the Appendix we have a detailed description of the empirical model along with the labor productivity decomposition and construction of data using the EUKLEMS database.

2. ICT IN CYPRUS

Cyprus is not included in the estimation analysis since there are no data available for the construction of ICT capital stock and its price. We have obtained though some data on the use of ICT in Cyprus by households and enterprises. The data will show us a picture for ICT in Cyprus which we will compare to other European countries and then link it to the results from our estimation analysis.

The first set of information about ICT in Cyprus can be obtained from the Statistical Service of Cyprus.

Based on the data from the Statistical Service of Cyprus we observe that the percentage of enterprises that used computers, had access to the internet, had a broadband connection and had a website has increased from 2004 to 2011. The increase is larger with respect to the percentage that had a broadband connection (from 82% to 92%) and a website (from 35% to 82%), while the percentages of enterprises that used computers remained relatively stable (from 94% to 96%).

The percentage of enterprises in 2011 that used computer, had access to the internet and also a website is larger in Manufacturing (94% and 60.1% respectively), Construction (95.7% and 50% respectively), wholesale and retail trade (99.4% and 54.5% respectively) and information and communication, real estate, professional, scientific, administrative and technical activities (99.8% and 80% respectively).

Households also show an increase in the use of computers. The percentage of households with computers, internet access and broadband connections has increased in the last years reaching 91%, 53% and 48% respectively in 2009. Females appear to use the internet less than males (but still the percentage of both is high, 47.9% for males and 41.7% for females).

The interaction with public authorities via the internet has also increased (mainly for enterprises, from 35% to 72% in 2009). Finally, the usage of computers for primary, secondary and tertiary education has increased. Computers per 100 pupils reached 16 for primary education, 22.9 for secondary and 15 for tertiary.

Secondly, we have obtained some data from Eurostat in order to compare Cyprus with other European counties. Based on Eurostat, the percentage of ICT sector value added (at total value added) in Cyprus is 3.48 in 2008. This is close to the other European countries such as Spain (3.63), Italy (3.56), Portugal (3.63) and Austria (3.21). Finland has the highest percentage (7.06) and Austria the lowest. Furthermore, the percentage of ICT personnel on total employment in Cyprus is

the lowest among these European countries. It is 1.7 in 2008. Finland again has the highest percentage in 2008, reaching 4.12.

Additional information was collected and is presented in the tables below. The tables show the percentage of enterprises using computers, have internet access, have a fixed broadband access and interact with public authorities, for a number of European countries, including Cyprus. These are the same European countries we will be using later for our estimation analysis, and try to link their results to Cyprus economy. Here we will provide a comparison among these countries.

Table 1: Enterprises using computers

GEO/TIME	2004	2005	2006	2007	2008	2009
Belgium	98	97	97	98	98	99
Denmark	98	98	98	99	99	99
Germany	97	97	96	97	97	99
Spain	97	97	98	98	98	99
France	:	:	99	99	98	99
Italy	97	96	96	97	96	97
Cyprus	93	94	95	95	94	95
Netherlands	95	95	100	100	100	100
Austria	96	97	98	98	98	99
Portugal	92	91	95	95	96	97
Finland	98	99	99	99	99	100
Sweden	97	96	96	97	97	97
United Kingdom	94	94	96	96	95	96

These tables indicate that 95 percent of enterprises in Cyprus use computers in 2009. For most European countries this percentage is 99, while in Netherlands and Finland it reaches 100 percent. The percentage for UK is 96 and 97 for Italy and Portugal. This percentage is relatively stable the last few years in most European countries.

The percentage of enterprises with internet access in Cyprus is 92 in 2009. Finland again has the highest percentage, which reaches 100. The rest of the countries have percentages between 95 and 98. Note though that for most European countries this percentage is relatively stable in the last few years. For Cyprus it was 82 in 2004 and it became 92 in 2009, indicating a large increase in comparison to the other European countries. This may suggest that this percentage will be eventually the same in 2011 or 2012.

Table 2: Enterprises with Internet access

GEO/TIME	2004	2005	2006	2007	2008	2009
Belgium	96	95	95	97	97	97
Denmark	97	97	98	97	98	98
Germany	94	94	95	95	95	98
Spain	87	90	93	94	95	96
France	:	:	94	96	95	97
Italy	87	92	93	94	94	95
Cyprus	82	85	86	88	89	92
Netherlands	88	91	97	99	99	96
Austria	94	95	98	97	97	98
Portugal	77	81	83	90	92	95
Finland	97	98	99	99	99	100
Sweden	96	96	96	95	96	95
United Kingdom	90	90	93	93	93	95

Table 3: Enterprises Internet connection: fixed broadband access

GEO/TIME	2004	2005	2006	2007	2008	2009
Belgium	70	78	84	86	91	89
Denmark	80	82	83	80	80	80
Germany	54	62	73	80	84	89
Spain	72	76	87	90	92	94
France	:	:	86	89	92	93
Italy	23	57	70	76	81	84
Cyprus	35	40	55	69	79	87
Netherlands	54	71	82	87	86	87
Austria	55	61	69	72	76	77
Portugal	49	63	66	76	81	85
Finland	71	81	89	91	92	94
Sweden	:	83	89	87	89	89
United Kingdom	50	65	77	78	87	88

Table 4: Enterprises using Internet for interaction with public authorities

GEO/TIME	2004	2005	2006	2007	2008	2009
Belgium	60	61	59	51	69	81
Denmark	85	87	87	88	90	90
Germany	36	44	49	56	56	65
Spain	50	55	58	58	64	65
France	:	:	66	69	73	75
Italy	65	73	87	84	82	83
Cyprus	35	40	44	54	65	72
Netherlands	47	57	70	81	85	83
Austria	74	75	81	81	80	79
Portugal	57	58	60	72	75	77
Finland	91	91	93	94	95	96
Sweden	92	80	80	79	78	86
United Kingdom	34	39	52	54	64	68

The percentage of enterprises with a fixed broadband access in Cyprus was 87. The highest percentage is 94, in Spain and Finland and the lowest is 80 in Denmark. Again the increase in the percentage is very high in Cyprus. In 2004 the percentage was 35 and it became 87 in 2009. Similar increase holds for some European countries such as Italy, Germany and UK.

Finally, the percentage of enterprises using the internet for interaction with public authorities in Cyprus is 72 in 2009. The highest percentage is 96 in Finland and the lowest is 65 in Germany and Spain. Cyprus is basically on the average of these European countries (in the middle), having an increase in the percentage from 35 in 2004.

Based on the above, we can see that ICT usage in Cyprus has been growing in the last years. Even though there are no data available, we can conclude that Cyprus is approximately in the middle (on the average) of the countries included in our sample, as far as ICT is concerned. Therefore the average results for ICT from our estimation can be used to approximate the situation in Cyprus, and the effect of ICT on the labor productivity of the economy.

In the next section we present the empirical specification and data we will be using for our estimation.

3. EMPIRICAL SPECIFICATION, DATA AND ESTIMATION

For our estimation we will be using a symmetric generalized McFadden functional from cost function introduced by Diewert and Wales (1988). Using the specified cost function the factor demands are obtained, which will be the base of the empirical model. This model is reduced to a system of equations which includes all the observed input demands. The equations are jointly estimated by the nonlinear SUR estimator. There are four factors of production for each country (ICT, non-ICT, labor and intermediate inputs), and thus our system consists of four equations.

Using the results from the estimation, the effect of ICT capital on labor productivity can be obtained. Specifically, the labor productivity growth rate is equal to the total factor productivity from the cost estimation and the other terms show us the substitutions among the other inputs and labor. If a term is positive that means that the specific input substitutes labor, while if its negative this means that the specific input is substituted by labor. A detailed description of the empirical model and the labor productivity decomposition is presented in the Appendix.

For our estimation, we will be using the EU KLEMS database. This database is the result of a research project financed by the European Commission. The EU KLEMS Growth and Productivity Accounts include measures of output growth, employment and skill creation, capital formation and multi-factor productivity (MFP) at the industry level (2-3 digit industries) for European Union member states from 1970 onwards. The input measures include various categories of capital (such as ICT capital, ICT services, and non-ICT capital and services), labor (high skilled, medium skilled and low skilled), energy, materials and service inputs.

For our analysis we will be using countries for which data for ICT are available. These include: Austria, Denmark, Belgium, Spain, Finland, France, Germany, Italy, Netherlands, Sweden, Portugal and UK. The data cover the period 1980-2005.

The variables used are: Gross output at current and constant prices, Intermediate inputs at current and constant prices, Number of employees and persons engaged, Total hours worked, Labor compensation, ICT capital compensation, Non-ICT capital compensation and ICT and Non-ICT capital services at current and constant prices. For details on construction of data see Appendix.

4. RESULTS

The results from the demand system estimation are presented in Table 5.

Table 5: Parameters estimates

Parameter	Estimate	St. Error	Parameter	Estimate	St. Error
β_{LL}	-0.097	0.0057	β_{LT}	-0.0043	0.0003
β_{LK}	0.03	0.0035	β_{KT}	-0.0008	0.0001
β_{LI}	0.0058	0.0012	β_{IT}	0.0016	0.0001
β_{LM}	0.069	0.0056	β_{MT}	-0.0029	0.0004
β_{KK}	-0.1005	0.0045	a_L	25514	2672.4
β_{KI}	-0.0018	0.0004	a_K	1426.77	1061.3
β_{KM}	0.0693	0.0046	a_I	-550.38	961.7
β_{II}	-0.0014	0.0006	a_M	-913.89	1885.2
β_{IM}	-0.0034	0.0011	β_{MM}	-0.1052	0.007
β_L	0.2977	0.0081	β_I	-0.0015	0.0049
β_K	0.5095	0.0052	a_t	-320.122	171.83
β_M	0.51	0.0107	a_{tt}	0.0002	0.0004
Equation		St. Error		R^2	
Labor		0.024		0.889	
Non-ICT		0.008		0.811	
ICT capital		0.01		0.913	
Materials		0.009		0.748	
Log of LF			3855.23		

Using the results from the cost estimation, the labor productivity decomposition is presented in Table 6.

The results from this table suggest that Labor productivity growth is positive in all countries except Netherlands, while Total factor productivity (TFP) growth is positive in all countries.Labor productivity growth in Netherlands is negative due to the negative components of mainly materials and some due to non-ICT capital. The contribution of ICT and TFP is positive.

In all countries we observe that ICT capital substitutes labor. In all countries, except Netherlands, same holds for non-ICT capital and materials. They appear to substitute labor. In Netherlands, the negative components imply that labor substitutes non-ICT capital and materials.

Table 6: Labor productivity decomposition (per country)

	COMPONENTS				
COUNTRY	$\widehat{LP} = \hat{Y} - \hat{L}$	$\widehat{TFP}$	$s_K(\hat{K} - \hat{L})$	$s_M(\hat{M} - \hat{L})$	$s_I(\hat{I} - \hat{L})$
AUSTRIA	0.0217	0.0036	0.002	0.0142	0.0019
BELGIUM	0.0197	0.0021	0.0023	0.0122	0.0032
DENMARK	0.0177	0.0007	0.001	0.0118	0.0042
FINLAND	0.0271	0.0043	0.003	0.0177	0.0021
GERMANY	0.0169	0.0016	0.004	0.0097	0.0016
SPAIN	0.0083	0.0019	0.0007	0.0043	0.0014
ITALY	0.0157	0.0015	0.0019	0.0111	0.0012
NETHERLANDS	-0.0011	0.0022	-0.0005	-0.0047	0.0019
SWEDEN	0.0194	0.0007	0.0049	0.0113	0.0024
UK	0.0153	0.0015	0.0024	0.0085	0.0028
FRANCE	0.0164	0.0016	0.0021	0.0116	0.0012
PORTUGAL	0.0379	0.0046	0.0069	0.0241	0.0023
AVERAGE	**0.0179**	**0.0022**	**0.0026**	**0.0109**	**0.0022**

The largest component of Labor productivity growth appears to be the substitution component of labor and materials. This may reflect though the large share of materials. Based on the construction of the components these depend on two things. The one is the share of each input into the production (cost) and the other is its growth rate.

The average suggests that labor productivity and total factor productivity are positive. The positive effect of the three components suggests that all three factors (ICT, non-ICT and intermediate inputs) substitute labor. The largest component comes from the intermediate inputs. High contribution implies either a large share of the input in the production or a large growth rate or both.

The components from non-ICT and ICT capital are similar. But the share of non-ICT capital is much higher than the share of ICT capital (which is the smallest among all inputs used in the analysis). This implies that the growth rate of ICT capital is larger than the growth rate of non-ICT capital.

On average the contributions are: 12.3% for total factor productivity, 12.3% for ICT capital, 14.5% for labor and 60.9% for materials.

For the labor productivity decomposition in Cyprus we can assume that the contribution of ICT in labor productivity is the average of these European countries and equals 12.3% (using the results in Table 2). The average labor productivity growth in Cyprus for the years 1995 to 2005 is 0.0107. Therefore the contribution of ICT on labor productivity is 0.0014, which also implies that ICT substitutes labor.

Therefore we can conclude that if the growth rate of ICT capital continues to rise, along with its share the contribution of this input in labor or even total factor productivity will be much higher and increasing in all European countries, including Cyprus.

5. CONCLUSION

The aim of this study is to examine the relationship between ICT capital and labor productivity for a number of European countries and Cyprus. ICT capital, as indicated from a large literature has a positive and significant effect on productivity and economic growth.

For our analysis we will be using the following countries: Austria, Denmark, Belgium, Spain, Finland, France, Germany, Italy, Netherlands, Sweden, Portugal and UK. The data cover the period 1980-2005. The countries were chosen based on their availability on data. Data for ICT expenditures, or investment, in Cyprus are not available. So we use all the available resources we have to describe the situation in Cyprus and then compare and link it to the results obtained from the other European countries.

From the information obtained for Cyprus, we observe that the percentage of enterprises using computers, have access to the internet, had a fixed broadband connection and had a website is increasing in the last years. This percentage as observed can be approximated by the average of our sample of European countries. Therefore, we suggest that the average results from these European countries, as far as ICT is concerned, can be applied to the Cyprus Economy.

With regards to the labor productivity results, we can conclude that this appears to be positive. Intermediate inputs are the first component that contributes to the positive productivity. Each component is basically the share of the input to total output multiplied by its growth rate. One of the reasons for the intermediate input component is that the inputs have the largest share in the production process.

With respect to ICT we can see that the contribution is positive and it's close to the one from non-ICT capital. Worth mentioning is that the share of ICT input is the

smallest among all inputs, and therefore this contribution is due to its large growth rate, possibly the largest among all inputs. Using the average contribution from the European countries we find that the contribution of ICT in Cyprus labor productivity is 0.0014, 12.3%.

In conclusion, we expect this contribution to increase as the share of this input into the production process increases along with its large growth rate

REFERENCES

Basu S. et. al. (2003), The case of the missing productivity growth: Or does information technology explain why productivity accelerated in the US but not the UK? NBER Working paper 10010.

Colecchia A. and P. Schreyer (2002), ICT investment and economic growth in the 1990s: Is the United States a unique case? *Review of Economic Dynamics*, 5, 408-442.

Diewert W.E. and T.J. Wales (1988), A normalized quadratic semiflexible functional form. *Journal of Econometrics*, 37(3), 327-342.

Hoon Y-S. (2003), Does information technology contributed to economic growth in developing countries? A cross country analysis. *Applied Economic Letters*, 10(11), 679-682.

Jorgenson, D.W. and K. Vu. (2005), Information technology and the world economy. *Scandinavian Journal of Economics*, 107(4), 631-650.

Matteucci N. et. al. (2005), Productivity, workplace performance and ICT: Industry and firm level evidence for Europe and the US. Scottish Journal of Political Economy, 52(3), 359-386.

Oliner S.D. and D.E. Sichel (2003), IT and productivity: where are we now and where are we going? *Journal of Policy Modeling*, 25, 477-503.

Stiroh K. J. (2002), Information Technology and the US productivity revival: what do industry data say? *American Economic Review*, 92(5), 1559-1576.

Timmer M. et. al. (2007). EU KLEMS growth and productivity accounts: An overview. *International Productivity Monitor*, 71-85.

APPENDIX

Empirical Model

This section specifies the cost function required to estimate the model. The cost function specified below, is assumed to be the symmetric generalized McFadden functional form introduced by Diewert and Wales (1988).

This functional form is attractive because it is a flexible functional form, which retains flexibility under the imposition of concavity with respect to user costs,

$$c_t = (\sum_{i=1}^{n} \beta_i w_{it} + \frac{0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} w_{it} w_{jt}}{\sum_{i=1}^{n} b_i w_{it}} + \sum_{i=1}^{n} b_{it} t w_{it} + a_{tt} t^2 \sum_{i=1}^{n} b_i w_{it}) y_t + \sum_{i=1}^{n} a_i w_{it} + a_t t \sum_{i=1}^{n} b_i w_{it} \qquad (1)$$

, where the parameters are denoted by the $\alpha's$ and $\beta's$. The $n \times n$ matrix formed by the β_{ij}, parameters is symmetric, and must be negative semi definite so that the function is concave in user costs.

The $b_i,\ i = 1,\ldots,n$ are nonnegative constants that are not all zero for some reference time period τ. For the reference time period, the cost function is homogenous of degree one in user costs if $\sum_{i=1}^{n} \beta_{ij} w_{i\tau} = 0$, and $\sum_{i=1}^{n} b_i w_{i\tau} \neq 0$.

The expression $\sum_{i=1}^{n} b_i w_{it}$ is an index of input prices, and the constants $b_i, i = 1,\ldots,n$, are set equal to the input cost shares in the reference time period.

Based on the specified cost function (1), and dividing the factor demands by output quantity (in order to reduce any possible heteroskedasticity and make calculations with the results more tractable), ith investment demand per unit of output becomes (which is the derivative of the cost function with respect to the user prices):

$$\frac{v_i}{y_t} = \left\{ \beta_i + \frac{\sum_{j=1}^{n} \beta_{ij} w_{jt}}{\sum_{i=1}^{n} b_i w_{it}} - \frac{.5 b_i \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} w_{it} w_{jt}}{(\sum_{i=1}^{n} b_i w_{it})^2} + \frac{a_i}{y_t} + \frac{b_i a_t t}{y_t} + b_i a_{tt} t^2 + b_{it} t \right\}, \quad i = 1, \ldots, n \qquad (2)$$

Equation (2) allows estimation of the coefficients using observed data. Concavity is also imposed.

With the cost function, the empirical model is reduced to the following system of equations: all the observed input demand per unit of output equations. The errors used are assumed to be identically and independently distributed over time, with zero expected value. The equations in the system can be jointly estimated for each country by the Nonlinear Seemingly Unrelated Regression estimator, applied to the EUKLEMS data.

There are four factors of production (ICT, I, and non-ICT capital, K, labor, L, and intermediate inputs, M) for each country, and thus the systems consist of four equations per country. Alternatively the country data can also be pooled into a panel and the system equations can be jointly estimated for all countries simultaneously, using country dummies to allow for differences across countries.

Productivity Decomposition

The effect of ICT on productivity can be calculated using the results and the cost function. Since ICT is included in the cost function as a variable input, total factor productivity is equal to:

$$\widehat{TFP} = \left(1 - \frac{\partial C}{\partial Y}\frac{Y}{C}\right)\hat{Y} - \frac{\partial C}{\partial t}\frac{1}{C}$$

$$\Rightarrow \widehat{TFP} = (1 - \varepsilon_{CY})\hat{Y} - \varepsilon_{Ct}$$

Based on that the TFP growth depends on the scale effect (with constant returns to scale the $\varepsilon_{CY} = 1$), and on the technical change effect. Therefore to find the effect of ICT we will follow a different approach.

We will be using a labor productivity growth framework. Based on that we have:

$$\hat{Y} = \sum\nolimits_{i=K,L,M,I} S_i \hat{Q}_i + \widehat{TFP}$$

Using the fact that: $\sum_{i=K,L,M,I} S_i = 1$, then we obtain the labor productivity growth rate:

$$\hat{Y} - \hat{L} = \widehat{LP} = \widehat{TFP} + s_K\left(\hat{K} - \hat{L}\right) + s_M\left(\hat{M} - \hat{L}\right) + s_I\left(\hat{I} - \hat{L}\right)$$

The labor productivity growth rate is equal to the total factor productivity from the cost estimation and the other terms show us the substitutions among the other inputs and labor. If a term is positive that means that the specific input substitutes labor, while if its negative this means that the specific input is substituted by labor.

So using the cost function from which we can obtain the input demand equations, we can estimate the effect of ICT on labor productivity.

Construction of data using the EUKLEMS database

For the construction of output, we use the Gross output variable of each country in current prices (used as the value of output, VY_{it}), along with the price deflator (obtained using the constant prices). The quantity of output is calculated:

$$VY_{it} = PY_{it} \times QY_{it} \Rightarrow QY_{it} = \frac{VY_{it}}{PY_{it}}$$

For labor, we need the price and quantity of labor. We used employment and hours of employment to construct employment in man-hours $EMH_{it=}E_{it} * hours$. The compensation of employees was used as the value of labor. Having the value of labor and employment in man-hours the price of labor was obtained, which was transformed into 1995 prices. The price and the value gave the quantity of labor in 1995 (constant) prices.

The value of each capital was obtained using the compensations from the data. The services were used to approximate the quantity of ICT and non-ICT capital. Having the value and the quantity the prices were obtained.

Finally, the intermediate inputs were used as material in our analysis. Using the current and constant prices the price of intermediate inputs is obtained.

The total cost was constructed using:

$$C_{it} = \sum_{z=K,L,M,I} PZ_{it} QZ_{it}$$

All series in constant prices are in 1995 terms. ICT capital includes hardware, software and communication equipment.

RECENT ECONOMIC POLICY/ANALYSIS PAPERS

08-11 Andreou N. S.. "The Borrowing behaviour of Households: Evidence from the Cyprus Family Expenditure Surveys", December 2011.

07-11 Savva S.C. "Foreign Direct Investments in Cyprus", November 2011 -in Greek.

06-11 Koutsampelas C. "Social Transfers and Income Distribution in Cyprus", November 2011.

05-11 Kalaintzidakis P., T. Mamuneas, V.Tzouvelekas, T. Stengos and P. Gregoriou, "Optimal Tax Rates for Pesticides Usage in Cyprus Agriculture Production", November 2011.

04-11 Pashardes P., A. Polycarpou, "Poverty and Labour Market Participation of Public Assistance Recipients in Cyprus", September 2011.

03-11 Pashourtidou N., A. Tsiaklis and Z. Kontolemis, "Consumers' opinions about macroeconomic variables", August 2011.

02-11 Zachariadis Th. and E. Shoukri, "Direct Effects from the Implementation of the EU Energy and Climate Package on Cypriot Economic Sectors and Households", July 2011.

01-11 Andreou A. and Th. Mamuneas, "Factors explaining productivity in Cyprus", May 2011 – in Greek.

10-10 Andreou E., A. Kourtellos and N. Pashourtidou, "Forecasting toolbox for Cyprus GDP growth", December 2010.

09-10 Pashardes P. and A. Polycarpou, "Taxation, Labour Supply and Welfare: A micro-simulation analysis for Cyprus", December 2010.

08-10 Andreou A. and P. Pashardes, “Distributional Effects of the Economic Crisis”, December 2010 – in Greek.

07-10 Christofides L. N. and Maria Michael, "An application of the LIME Assessment Framework (LAF): The Case of Cyprus", November 2010.

06-10 Savva C. S., “Business Consumer Surveys: Do they help in predicting GDP growth? The case of Cyprus, November”, 2010.