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The Effects of Human Capital on Output Growth in ICT Industries: Empirical Evidence from OECD Countries

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Outline

- Introduction
- Related theoretical and empirical literature
- Data and measures
- Empirical strategy and model specifications
- Summary statistics
- Regression results
- Conclusions

Research Question

Broadly

- Does human capital (HC) foster economic growth by facilitating new technology adoption?

Specifically

- Have countries with a more educated workforce experienced faster output growth in ICT industries? Cross-country, cross-industry analysis over 1980-2002: 20 OECD countries, 54 industries

Why is it interesting?

Existing literature

- ICT is at the core of the knowledge based economy
- ICT-linked knowledge, innovation and ongoing technological changes: strong determinants of growth differentials
- The impact of human capital on economic growth: well established theory but mixed empirical evidence

Policy relevance

- Education policy and its relation to ICT output growth
- The renewed Lisbon Strategy: a special emphasis on the role of ICT
- i2010 Communication on the Information Society
  ICT: a powerful driver of growth and employment;

Value Added

- Link human capital to ICT growth by focusing on within country, between industry difference, control for country and industry-specific effects (less subject to criticism about an omitted variable bias and model specification)
- Provide evidence for a sectoral channel through which HC affects growth rather than examining the correlation between HC and growth
- Multiple observations per country: alleviates the limited degrees of freedom problem
- We investigate the effects of HC on ICT output growth using both a measure for the quantity HC stock and HC accumulation
- We distinguish between ICT producing and ICT using manufacturing and services

Main Findings

- In developed OECD countries with an a priori high human capital stock the output in ICT producing manufacturing and ICT using services grew relatively faster
- In countries with a high human capital improvement, ICT producing manufacturing grew relatively faster
- Human capital stock and human capital accumulation had a positive and significant effect on physical capital investment

The role of human capital on growth: Theoretical models

Becker (1964), Nelson and Phelps (1966), Lucas (1988), Romer (1990), Mankiw, Romer and Weil (1992)

Two approaches

- "Nelson-Phelps" approach - Economic growth driven by the stock of human capital
- "Lucas" approach - Economic growth driven by human capital accumulation

The effects of human capital on growth: Empirical evidence

Examine the relationship between higher levels of education or greater improvements in education and output growth

Cross-country growth regressions

Romer (1990), Benhabib and Spiegel (1994), Cohen and Soto (2001), Temple, (1999); de la Fuente and Domenech (2001, 2005), Topel (1999)…

- Empirical results are mixed.
- Cross-country growth regressions suffer from a number of shortcomings
  - Do not control for unobserved heterogeneity
  - limited degrees of freedom

Cross-country cross industry analysis

Rajan and Zingales (1998),Ciccone, Papaioannou (2006)

- Exploit within country variation between industries

Empirical strategy

- Builds on the framework of Rajan and Zingales (1998), and Ciccone and Papaioannou (2006)
- Country level (growth) of human capital linked to growth in ICT industries
- Models the effects of country human capital on output growth in ICT industries compared to all other industries

Hypotheses

1) ICT industries grew faster in countries with a high initial stock of Human Capital
2) ICT industries grew faster in countries with a greater *improvement* in Human Capital

Econometric issues

Endogeneity

Human capital accumulation may be correlated with the error term. Gemmel (1996)

Simultaneity

Indirect effect of human capital on growth via physical investment. Romer (1990)

Variables	Description	Source
Dependant Variable		
$\Delta Y_{i,k,T}$	Average annual growth in real gross value added in country i, industry k, 1980-2002	www.ggdc.net
Explanatory Variables		
Human capital variables		
$HC_{i,t0}$	Average number of years of schooling in 1980	Cohen and Soto (2001)
$\Delta HC_{i,T}$	Growth in average number of years of schooling between 1980-2000	Cohen and Soto (2001)
Control variables		
$Share_{i,t0}$	Industry 's share of total gross value added at country level in 1980	www.ggdc.net
$GDPWP_{i,t0}$	GDP per working age population, 1980	Internatioanl Financial Statistics, IMF and OECD
INV_{iT}	Average investment ratio over 1980-2002	Penn World Tables 6.2
ΔLF_{iT}	Average annual labour force growth over 1980 -2002	OECD
$OP_{i,T}$	Average ratio of exports and imports to real GDP 1980-2002	Penn World Tables 6.2

ICT Taxonomy

(c.f. Appendix in Paper)

This ICT taxonomy is based on the OECD STAN Database on National Accounts, industries are classified into the following categories depending on whether they produce ICT goods or services, and whether they use intensively ICT or they do not use ICT intensively.

1. ICT Producing - Manufacturing (ICTPM)

e.g. Telecommunication equipment (322); Scientific instruments (331), etc.

2. ICT Producing – Services (ICTPS)

e.g. Communications (64); Computer & related activities (72), etc.

3. ICT Using – Manufacturing (ICTUM)

e.g. Mechanical engineering (29); Aircraft and spacecraft, etc.

4. ICT Using – Services (ICTUS)

e.g. Financial intermediation, except insurance and pension funding (65); Research & development (73), etc.

5. Non-ICT

e.g. Food, drink & tobacco (15-16); Public administration and defence, etc.

Empirical strategy and model specifications

The effect of human capital stock and accumulation on ICT output growth

Primary equation:

$$\Delta Y_{i,k,T} = \alpha + \sum_s \beta_s (HC_{i,t_0} * ICT_s) + \sum_s \delta_s (\Delta HC_{i,T} * ICT_s) + \sum_s \theta_s (INV_{i,T} * ICT_s) + \lambda_i + \mu_k + \sum_j \eta_j Other + \varepsilon_{i,k} \quad (1)$$

Structural equations:

$$INV_{i,T} * ICT_s = \rho_1 + \sigma_1 (HC_{i,t_0} * ICT_s) + \sigma_2 (\Delta HC_{i,T} * ICT_s) + \sigma_3 (gdp_{i,t_0} * ICT_s) + \sigma_5 (dlf_{i,T} * ICT_s) + \sigma_6 (lf_{i,t_0} * ICT_s) + \lambda_i + \omega_{1i,k} \quad (2)$$

$$\Delta HC_{i,T} * ICT_s = \phi_1 + \eta_1 (HC_{i,t_0} * ICT_s) + \eta_2 (\Delta HC_{i,T-1} * ICT_s) + \eta_3 (gdp_i * ICT_s) + \eta_4 (INV_i * ICT_s) + \pi_i + \psi_{1,i,k} \quad (3)$$

i = 1, …,20 (countries)
k = 1,…, 54 (industries)
S = pm, ps, um, us.
T = 1980-2002
t_0 = 1980

Table 1: Summary of Main Variables

	Mean annual real gross value added growth rate by country and sector 1980-2002 (%)							HC Stock 1980	HC Growth rate 1980-2000 (%)
Country	Total	ICT	Non ICT	ICTUM	ICTPM	ICTPS	ICTUS		
Australia	2.4	3.00	1.80	1.12	23.25	8.72	4.65	12.20	7.04
Austria	4.1	6.3	2.10	1.95	15.61	7.70	3.97	10.31	10.31
Belgium	3	4.6	1.50	1.67	13.11	3.94	1.96	9.24	15.97
Canada	2.6	3.2	2.21	1.22	4.53	6.18	3.64	11.59	12.02
Denmark	3.5	5.5	1.92	1.45	14.70	9.24	2.76	11.03	10.08
Spain	3.7	5.5	2.13	3.32	12.22	6.76	2.87	7.45	24.31
Finland	4.4	6.9	2.27	1.31	19.11	7.45	3.83	9.49	20.76
France	3.2	5.7	1.14	1.51	16.61	5.61	2.20	9.34	13.87
Greece	3.4	5.3	1.83	1.34	12.22	8.47	3.91	7.72	24.87
Ireland	6.5	10.1	3.55	4.27	25.01	8.29	6.01	8.94	12.89
Italy	3.1	5	1.47	1.36	13.40	6.78	2.74	7.96	26.06
Japan	3.6	6.6	1.01	1.76	16.95	6.19	4.71	11.20	11.86
Netherlands	3.5	5.3	2.06	1.79	12.55	7.16	3.47	10.28	9.81
Norway	2.4	3.7	1.23	-1.47	11.34	7.74	2.65	11.56	7.66
Portugal	4.4	6.7	2.57	3.61	15.29	6.65	3.85	5.57	26.77
Sweden	3.2	5.1	1.51	0.60	12.59	5.61	4.64	11.26	4.00
Germany	2.6	4.6	0.82	0.35	12.6	6.60	3.56	12.65	2.34
United Kingdom	3.1	5.1	1.41	0.47	13.54	7.81	3.40	11.57	12.57
United States	3.8	5.4	2.46	0.50	14.45	6.99	4.21	12.19	3.55
South Korea	9.4	13.1	6.19	8.36	23.74	16.52	9.80	9.11	30.35
Mean	3.80	5.80	2.03	1.77	14.03	7.43	3.88	10.03	14.35
Std. Dev.	1.61	2.30	1.14	1.97	5.21	2.46	1.70	1.88	8.40
Sample Variance	2.58	5.20	1.30	3.87	27.19	6.06	2.90	3.53	70.50
Minimum	2.40	3.00	0.80	-1.40	2.00	3.90	1.90	5.57	2.34
Maximum	9.40	13.0	6.10	8.30	25.00	16.50	9.80	12.65	30.35

Table 2: The effect of human capital on ICT output growth, 3SLS estimates

	Primary equation	**Structural equations**							
	$dY_{i,k,T}$	inv_i*ict_{pm}	inv_i*ict_{ps}	inv_i*ict_{um}	inv_i*ict_{us}	dhc_i*ict_{pm}	dhc_i*ict_{ps}	dhc_i*ict_{um}	dhc_i*ict_{us}
hc_i*ict_{pm}	0.409***	0.206***				-0.451***			
	(0.111)	(0.006)				(0.028)			
hc_i*ict_{ps}	0.044		0.206***				-0.450***		
	(0.180)		(0.007)				(0.028)		
hc_i*ict_{um}	0.072			0.206***				-0.451***	
	(0.094)			(0.006)				(0.028)	
hc_i*ict_{us}	0.159*				0.206***				-0.460***
	(0.097)				(0.006)				(0.027)
dhc_i*ict_{pm} [(a)]	1.358***	0.400***				0.253***			
	(0.311)	(0.010)				(0.052)			
dhc_i*ict_{ps} [(a)]	0.083		0.400***				0.248***		
	(0.503)		(0.010)				(0.052)		
dhc_i*ict_{um} [(a)]	0.313			0.400***				0.253***	
	(0.263)			(0.010)				(0.051)	
dhc_i*ict_{us} [(a)]	0.420				0.398***				0.239***
	(0.274)				(0.01)				(0.05)
inv_i*ict_{pm}	-1.029**					2.026***			
	(0.404)					(0.154)			
inv_i*ict_{ps}	0.356						2.035***		
	(0.656)						(0.156)		
inv_i*ict_{um}	-0.235							2.026***	
	(0.342)							(0.153)	
inv_i*ict_{us}	-0.321								2.063***
	(0.357)								(0.15)
Obs	1080								
R^2	0.753	0.986	0.986	0.986	0.986	0.870	0.867	0.872	0.868
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	No	No	No	No	No	No	No	No

Test for joint significance of country and industry fixed effects: $\chi^2(224) = 3861.13$ Prob > $\chi^2 = 0.0000$

Table 3: The effect of human capital on ICT employment growth, 3SLS estimates

	Primary equation	Structural equations							
	$dL_{i,k,T}$	inv_i*ict_{pm}	inv_i*ict_{ps}	inv_i*ict_{um}	inv_i*ict_{us}	dhc_i*ict_{pm}	dhc_i*ict_{ps}	dhc_i*ict_{um}	dhc_i*ict_{us}
hc_i*ict_{pm}	0.112**	0.212***				-0.47***			
	(0.055)	(0.006)				(0.027)			
hc_i*ict_{ps}	-0.152		0.208***				-0.458***		
	(0.089)		(0.006)				(0.028)		
hc_i*ict_{um}	-0.023			0.215***				-0.481***	
	(0.047)			(0.006)				(0.025)	
hc_i*ict_{us}	-0.076				0.214***				-0.480***
	(0.048)				(0.006)				(0.025)
dhc_i*ict_{pm} [(a)]	0.366**	0.407***				0.207***			
	(0.152)	(0.01)				(0.047)			
dhc_i*ict_{ps} [(a)]	-0.444*		0.402***				0.237***		
	(0.249)		(0.01)				(0.051)		
dhc_i*ict_{um} [(a)]	0.113			0.410***				0.177***	
	(0.13)			(0.009)				(0.044)	
dhc_i*ict_{us} [(a)]	-0.173				0.408***				0.181***
	(0.134)				(0.009)				(0.044)
inv_i*ict_{pm}	-0.086					2.094			
	(0.169)					(0.138)			
inv_i*ict_{ps}	0.903**						2.05***		
	(0.276)						(0.152)		
inv_i*ict_{um}	0.101							2.134***	
	(0.144)							(0.128)	
inv_i*ict_{us}	0.332**								2.14***
	(0.150)								(0.128)
Obs	1080								
R^2	0.562	0.9872	0.9862	0.9879	0.9877	0.8752	0.8685	0.8801	0.8767

Conclusions

1. On average, other things equal, in countries with an *ex-ante* high stock of human capital, ICT producing manufacturing and ICT using services grew faster

2. In countries with high human capital accumulation, ICT producing manufacturing services grew faster

3. Human capital stock and human capital improvement had a positive and significant effect on physical capital investment