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Abstract: Information and communication technologies (ICT) play a central role in the transition to knowledge - based economies. In this paper we analyse the effects of human capital in fostering output growth in ICT manufacturing and services using data from a sample of twenty OECD countries over the period 1980-2002. We focus on within country between industry differences and estimate a system of simultaneous equations to account for simultaneous effects of human capital on physical investment and output growth. The results of our econometric analysis suggest that countries with a high human capital stock experienced faster output growth in ICT producing manufacturing and ICT using services. Also, in countries with high human capital improvement over the analysed period output grew relatively faster in ICT producing manufacturing industries. Furthermore, we find that past country level educational attainment reflected in the human capital stock and human capital accumulation over the analysed period had a direct positive and significant effect on physical capital investment. Our findings indicate that in developed countries human capital is an important factor driving the ICT industries growth.

Key words: Human capital, ICT industries, Economic growth

JEL classification: E62, F43, O33

The Effect of Human Capital on Output Growth in ICT Industries: Evidence from OECD countries[*]

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1 Introduction

Information and communication technologies (ICT) play a central role in the transition to knowledge - based economies. In this paper we analyse the effects of human capital in fostering output growth in ICT manufacturing and services in a sample of twenty OECD countries over the period 1980-2002. We focus on within country between industry differences and control for country and industry specific effects an a set of macroeconomic variables.

The question whether human capital fosters economic growth, in particular the output growth in ICT industries is interesting and relevant for both research and policy. First, notwithstanding a well established theoretical literature showing the positive effects of human capital on economic growth, existing empirical evidence is mixed. Second, ICT is at the core of the knowledge driven economy and there is growing evidence suggesting that ICT-linked knowledge, innovation and technological changes are strong determinants of growth differentials and the ability of countries to benefit from globalization. The renewed Lisbon Strategy agreed in March 2005 put a special emphasis on the role ICT can play in boosting growth, competitiveness and cohesion in the European Union (EU). A large amount of EU expenditure over the period 2007-2013 has been allocated to ICT investment. Furthermore, the ICT strategy at the EU level outlined in the i2010 Communication of the EU Commission points to ICT investment, research and use as a main explanation for differences in economic performance among industrialised countries. Third, our research about the relationship

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between human capital and ICT growth is relevant for education policy in developed countries.

In comparison to existing literature, the novelty of this paper is fivefold. First, we link human capital to ICT output growth by focusing on within country, between industry differences. We employ a cross-country, cross-industry analysis and control for country and industry specific effects which is less subject to criticism about an omitted variable bias and model specification. Second, in contrast to most of the existing studies examining the correlation between human capital and growth, we provide empirical evidence for a sectoral channel through which human capital affects growth.

Third, given the multiple observations per country, by exploiting the within country variation in the data we alleviate the limited degrees of freedom problem. Fourth, we investigate the effect of human capital on ICT growth using measures for the stock of human capital and accumulation of human capital. Fifth, we distinguish between ICT producing and ICT using manufacturing and services.

The main message of this paper is that in developed countries, the past educational attainment reflected in human capital stock affected the ability to produce ICT in manufacturing and use ICT in services while educational attainment improvement affected the ability to produce ICT in manufacturing. Specifically, the following key findings support this message:

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 of physical capital investment.

The remainder of this paper is organised as follows. In Section 2 we discuss briefly the related theoretical and empirical literature. Further in Section 3 we present our empirical strategy, model specifications and explain how we test and account for potential econometric issues. Section 4 analyses summary statistics of the main variables. In Section 5 we discuss our regression results. Finally, we conclude in Section 6.

2 Related Theoretical and Empirical Literature

The effects of ICT on economic growth

The analysis of the effects of ICT on economic growth has gained an increased interest. While earlier studies have found little evidence about a link between ICT and productivity growth, more recent studies point to a positive effect of ICT investment on GDP growth (Oliner and Sichel, 2000; Daveri, 2001, Roeger, 2001; van Ark, 2001; Pilat and Lee, 2001; OECD, 2001).

ICT have become a general purpose technology in developed economies (Carlsson, 2004) and they play a central role in the transition to the knowledge based economy ("the digital economy"). While early research found ICT *producing* industries to be an important factor of economic growth, more recent research found a significant contribution to economic growth from ICT *using* industries. Carlsson (2004) and Hollestein (2004) find evidence suggesting that ICT had a positive effect on economic growth via new products and services and new organisation methods.

The effects of human capital on economic growth

There is a well-established theoretical literature on the effect of human capital on growth initiated by Becker (1964) and followed by the seminal papers of Nelson and Phelps (1966), Lucas (1988), Romer (1990) and Mankiw, Romer and Weil (1992).

Two approaches can be distinguished in the theoretical literature. The first strand of literature focuses on the *stock* of human capital as an explanation of cross-country growth differentials as suggested by Nelson and Phelps (1966). The second approach looks at human capital as an input factor in a production function as in Lucas (1988) and points to the *accumulation* of human capital as the main factor driving growth differentials among countries.

The theoretical literature indicates different channels through which human capital affects economic growth. Nelson and Phelps (1966) show that high levels of human capital facilitate the adoption of new technologies. In contrast to this view, Lucas (1988) focuses on skill acquisition as an input in an aggregate production function. Romer (1990) assumes that both the stock as well as the growth of human capital generate ideas for new designs and goods which in turn drive endogenously physical capital investment and growth. Mankiw, Romer and Weil (1992) include physical capital and human capital investment rates (as ratios of GDP) as distinct arguments in an extended Solow model.

Most empirical analyses use education attainment as a proxy for human capital and investigate the relationship between the level of education or education improvement and output growth at country level. In most of the existing studies model specifications explain the growth of GDP or GDP per capita with a series of macroeconomic variables including educational attainment.

The results obtained with cross-country growth regressions are mixed. While Romer (1990), Benhabib and Spiegel (1994) found a positive effect of the schooling level on output growth, Cohen and Soto (2001) found no link. The same mixed evidence has been found in the case of the relationship between improvements in education and growth. In contrast to a significant positive correlation between improvements in education and growth found by Temple (1999), Cohen and Soto (2001), de la Fuente and Domenech (2001, 2005), no effect of schooling improvement on growth is found in other studies (Benhabib and Spiegel, 1994; Barro and Sala-i-Martin, 1995; Casseli, Esquivel and Lefort, 1996). Furthermore, Topel (1999) and Lindhal (2001) find a positive effect of the education level as well as of education improvement on economic growth.

Cross-country growth regressions have several shortcomings (no controls for unobserved heterogeneity, limited degrees of freedom, among others). Analysis at industry level across countries can correct for these limitations by exploiting the within country variation between industries. Rajan and Zingales (1998) use a cross-country cross-industry analysis to examine whether financial development fosters economic growth. They find that industries that are dependent on external finance grew faster in countries with more developed financial markets. Using a similar analysis at industry level in a large sample of countries, Ciccone and Papaioannou

(2006) find that industries that are more dependent on human capital grew relatively faster in countries that initially have more human capital.

3 Empirical Strategy, Model Specifications and Econometric Issues

In this paper we examine the relationship between the stock and accumulation of human capital at country level and the output growth in ICT industries. We estimate the effect of human capital at country level on the output growth in ICT industries building on the methodology used by Rajan and Zingales (1998) and Ciccone and Papaioannou (2006).

On the basis of the theoretical and empirical literature discussed above, we test the the hypothesis that ICT industries grew faster in countries with an initial high stock of human capital and greater improvement in human capital. To this effect, we estimate a system of simultaneous equations using the 3SLS estimation procedure.

Simultaneity and Endogeneity

Romer (1990) argues that both the stock and the growth of human capital generate ideas for new designs and goods which in turn drive physical capital investment and economic growth. There is also the possibility that the growth (accumulation) of human capital could be endogenous as countries with a high income level or fast growing economies are able to allocate a higher proportion of their resources to education Gemmel (1996). The estimation of the system of equations using the 3SLS estimator enables us to account for both the direct and indirect effects (i.e. via physical capital investment) of human capital stock and accumulation on industrial output growth while controlling for potential simultaneity and endogeneity problems.

Our model specification is as follows:

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:

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

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

In the primary equation, the dependent variable ($\Delta Y_{i,k,T}$) is a measure of industry output growth, specifically, the average annual growth rate of the real gross value added at industry (k) level within country (i) over the analysed period (T). The main explanatory variables are four interacted variables capturing the effect of human capital stock (HC) and accumulation (ΔHC) on the output growth of ICT industries. We use the following dummy variables (ICT_s) to distinguish between four categories of ICT industries following the taxonomy[1] proposed by Robinson et al (2003):

- ICT_{pm}: 1 if industry is ICT producing manufacturing and 0 otherwise
- ICT_{ps}: 1 if industry is ICT producing services and 0 otherwise
- ICT_{um}: 1 if industry is ICT using manufacturing and 0 otherwise
- ICT_{us}: 1 if industry is ICT using services and 0 otherwise

Our sample includes 20 countries[2] and 54 industries[3]. The data set covers the period 1980 until 2002 resulting in a number of 1080 observations. Details about data sources are given in Appendix A2 and summary statistics of the main variables are shown in Tables 1-4.

The stock of human capital (HC) is measured as average years of schooling at a point in time taken from Cohen and Soto (2001). The respective regressions include the natural logarithm of the average years of schooling at country level in 1980 (hc_i).

The human capital improvement (ΔHC) is measured by the growth in the average years of schooling or educational attainment over the analysed period (dhc_i).

[1] Details about the ICT taxonomy are given in Appendix A1.

[2] Australia Austria, Belgium, Canada, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Sweden, Germany, United Kingdom, United States and South Korea.

[3] See Appendix A1

We control for country specific (λ_i) and industry specific (μ_k) growth effects. Country specific growth effects include unobserved factors affecting economic growth at country level such as economic policy, social norms, and political stability. Industry specific growth effects include unobserved industry characteristics such as price changes and technological innovation at industry level.

Other control variables include:

- the share of each industry in total real gross value added at country level in the initial year ($share_{t_0}$)
- gross domestic product per working age population at country level in the initial year (gdp_{t_0})
- the ratio of investment to GDP at country level, average over the analysed period ($inv_{i,T}$)
- labour force at country level in the initial year (lf_{i,t_0})
- labour force growth at country level over the analysed period ($dlf_{i,T}$)
- the ratio of trade to GDP (openness measure) at country level over the analysed period ($op_{i,T}$)

$\varepsilon_{i,k}$ is the error term.

If in the primary equation (1) $\beta_1, \beta_2, \beta_3, \beta_4 > 0$, ICT output growth was relatively faster in countries with an initial high human capital stock (HC) and if $\beta_5, \beta_6, \beta_7, \beta_8 > 0$, ICT output growth was relatively faster in countries with high human capital growth (ΔHC).

In the structural equations for investment, $INV_{i,T}$ denotes the average over the analysed period (T) of the physical capital investment to GDP ratio at country level. ICT_S denotes the ICT sector dummy variable i.e. $s = (pm, ps, um, us)$. Initial human capital stock, human capital growth over the analysed period, initial labour force stock, labour force growth over the period, GDP per working age population at country level in 1980 as well as country specific effects are used as instruments for investment.

In the structural equations for human capital accumulation we use the initial human capital stock, lagged human capital growth, GDP per working age population at country level in 1980, physical capital investment as well as country specific effects as instruments for human capital growth.

The 3SLS estimates are reported in Table 5.

Heterogeneity of slopes

The model specifications discussed above assume a homogeneous impact of human capital on ICT output growth across countries. However, the effects of human capital may vary across different groups of countries. To test the homogeneity of slopes across different groups of countries, we include in model specifications an interacted variable obtained by interacting a dummy variable with the human capital variables. We then test the null hypothesis that the coefficient of this variable is equal to zero.

We consider the following groups of countries: a) countries with human capital stock below and above the sample average; b) countries with a human capital improvement below and above the sample average.

We use the following dummy variables to distinguish between countries below and above the sample average with respect to the human capital measures:

- *ed*: 1 if country is below average human capital stock and 0 otherwise;
- *edg*: 1 if country is below average human capital growth and 0 otherwise;

The 3SLS estimates are presented in Table 6.

4 Descriptive Analysis

Table 1 shows summary statistics of the main variables included in our model specifications. The average annual output growth across all countries was 3.80 per cent over the analysed period. Average output growth across ICT industries was 5.84 per cent compared to 2.02 per cent for non-ICT industries. Inspection of the four ICT industry classifications which combine to make up the ICT industry grouping shows ICT producing industries have recorded the strongest performance with an average annual output growth rate of 14.03 per cent for ICT producing manufacturing and 7.44 per cent for ICT producing services. ICT using manufacturing and services industries have grown notably slower with average growth rates of 1.76 per cent and 3.88 per cent respectively.

Table 1 here

Table 2 provides a summary of average output growth rates over the full period by countries and industry groupings. In terms of average output growth, Korea and Ireland have outperformed all other countries across all ICT producing and using defined industry groupings.

Table 2 here

The above GVA growth summary statistics give some indication to the increasing importance of the ICT industry sectors to a country's economic development. It suggests the emphasis the Lisbon Agenda places on capturing, promoting and sustaining the dynamism associated with the ICT industry sectors is warranted.

Human capital measured in terms of average years of schooling is unsurprisingly high (10.03 years) for the sample in 1980 given that the countries are relatively well developed. Portugal and Spain had the lowest educational attainment levels whilst Germany and Australia recorded the highest levels (see Table 3).

Table 3 here

Those countries with the lowest levels of educational attainment tended to experience the highest rates of human capital accumulation over the full period (correlation between the two series is -0.85).

The average country level investment ratio is 23.1 per cent. Table 4 presents a cross-country summary of the investment ratio. Japan and Korea emerge as the countries with the highest investment ratios, in excess of 30 per cent. The average annual labour force growth was 1.04 per cent for the full period of investigation.

Table 4 here

5 Estimation Results

Table 5 shows the 3SLS estimates of the simultaneous effects of human capital measures on physical capital investment and ICT output growth following Romer (1990).

Table 5 here

We find that countries with a high initial stock of human capital and human capital accumulation experienced faster output growth in ICT producing manufacturing industries relative to non-ICT industries. Also in countries with high human capital stock, ICT using services such as Research and Development and Financial Intermediation grew relatively faster. In the primary equation we find that countries with high investment ratios experienced relatively lower growth in ICT producing manufacturing industries.

The estimates from the investment equations suggest that human capital stock and accumulation at country level had a direct positive and highly significant effect on physical capital investment.

Over three quarters of the variation in industrial output growth is explained by our model.

Table 6 shows the results of the regressions testing the heterogeneity of slopes across different groups of countries.

Table 6 here

The values of the corresponding F tests indicate that the difference between the slopes of the compared groups are not significantly different from zero with one exception, in the case of the human capital accumulation interacted with ICT producing manufacturing. The significant and positive coefficient in this case indicates that output growth in the ICT producing manufacturing grew significantly faster in countries with human capital accumulation below the sample average (i.e. countries with an *a priori* high human capital stock).

6 Summary and Conclusions

In this paper we investigated the effects of human capital on the output growth in ICT industries using data from a sample of twenty OECD countries and 54 industries over the period 1980-2002. We focused on within country, between industry differences and control for country and industry specific effects and a set of macroeconomic variables. We distinguished between ICT producing and ICT using manufacturing and services. Furthermore, we analyse the effects of both human capital stock and human capital accumulation.

Our model specifications accounted for endogeneity and the simultaneity effects in the relationship between human capital and output growth. The results of our econometric analysis suggests that in the OECD countries, past educational attainment reflected in the human capital stock affected the ability of countries to produce ICT in manufacturing and use ICT in services. On average, other things equal, in countries with an *ex-ante* high level of human capital stock, ICT producing manufacturing and ICT using services grew relatively faster in comparison with the other industries. Human capital improvement over the analysed period had a significant effect on output growth in ICT producing manufacturing industries. On average, other things equal, in countries with high human capital accumulation, ICT producing manufacturing grew relatively faster in comparison with the other industries. Furthermore, we find that human capital stock and human capital improvement had a positive and significant effect on physical capital investment.

Our findings indicate that in developed countries human capital is an important factor driving the ICT industries growth.

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Appendix A1

ICT Taxonomy

The source of this ICT taxonomy is Robinson et al (2003). On the basis of the latest OECD STAN Database on National Accounts, industries are classified in the following seven 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)**

Office machinery (30); Insulated wire (313); Electronic valves and tubes (321); Telecommunication equipment (322); Radio and television receivers (323); Scientific instruments (331). *2. ICT Producing – Services* (ICTPS): Communications (64); Computer &related activities (72).

3. ICT Using – Manufacturing **(ICTUM)**

Clothing (18); Printing & publishing (22); Mechanical engineering (29); Other electrical machinery & apparatus (31-313); Other instruments (33-331); Building and repairing of ships and boats(351); Aircraft and spacecraft (353); Railroad equipment and transport equipmentnec (352+359);Furniture, miscellaneous manufacturing; recycling (36-37).

4. ICT Using – Services **(ICTUS)**

Wholesale trade and commission trade, except of motor vehicles and motorcycles (51); Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52); Financial intermediation, except insurance and pension funding (65); Insurance and pension funding, except compulsory social security (66); Activities auxiliary to financial intermediation (67); Renting of machinery & equipment (71); Research & development (73); Legal, technical & advertising (741-3).

5. Non-ICT Manufacturing **(NICTM)**

Food, drink & tobacco (15-16); Textiles (17); Leather and footwear (19); Wood & products of wood and cork (20); Pulp, paper & paper products (21); Mineral oil refining, coke & nuclear fuel (23); Chemicals (24); Rubber & plastics (25); Non-metallic mineral products (26); Basic metals (27); Fabricated metal products (28); Motor vehicles (34).

6. Non-ICT Services **(NICTS)**

Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel (50); Hotels & catering (55);Inland transport (60); Water transport (61); Air transport (62); Supporting and auxiliary transport activities; activities of travel agencies (63); Real estate activities (70); Other business activities, nec (749); Public administration and defence; compulsory social security (75); Education (80); Health and social work (85); Other community, social and personal services (90-93); Private households with employed persons (95); Extra-territorial organizations and bodies (99).

7. Non-ICT Other **(NICTO)**
Agriculture (01); Forestry (02); Fishing (05);Mining and quarrying (10-14); Electricity, gas and water supply (40-41); Construction (45)

In this paper we combine NICTM, NICTS, NICTO as one group (non-ICT industries).

Appendix A2

Data Sources

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)
$HQ_{i,t0}$	Measure of a country's human capital quality based on international test scores	Hanusek and Kimko (2000)
Control variables		
$\text{Share}_{i,t0}$	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

Table 1: Summary Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Dependant variable					
Average annual real gross value added growth rate, 1980-2002 (%)	1080	3.80	7.20	-14.40	51.30
Human capital measures					
Average years of schooling, 1980	20	10.03	1.87	5.57	12.65
Average years of schooling, 2000	20	11.47	1.50	7.28	13.12
Human capital accumulation, 1980-2000 (%)	20	14.30	8.40	2.30	30.30
Human capital quality	20	55.50	5.93	44.20	65.50
Other control variables					
Industry share in total gross value added at country level, 1980 (%)	1080	1.80	2.20	0.00	15.20
GDP per working age population (US dollars '000)	20	15.33	6.03	3.28	24.70
Investment to GDP ratio (%)	20	23.03	3.99	17.26	35.29
Average annual labour force growth (%)	20	1.04	0.62	0.15	2.09

Table 2: Average annual real gross value added growth rate by country and sector, 1980-2002 (%)

Country	Total	ICT	Non ICT	ICTUM	ICTPM	ICTPS	ICTUS
Australia	2.4	3.0	1.8	1.0	2.0	8.7	4.6
Austria	4.1	6.3	2.1	1.9	15.6	7.7	3.9
Belgium	3.0	4.6	1.5	1.6	13.1	3.9	1.9
Canada	2.6	3.2	2.2	1.2	4.5	6.1	3.6
Denmark	3.5	5.5	1.9	1.0	14.7	9.0	2.7
Spain	3.7	5.5	2.1	3.3	12.2	6.7	2.8
Finland	4.4	6.9	2.2	1.3	19.1	7.4	3.8
France	3.2	5.7	1.1	1.5	16.6	5.6	2.2
Greece	3.4	5.3	1.8	1.3	12.2	8.4	3.9
Ireland	6.5	10.1	3.5	4.2	25.0	8.2	6.0
Italy	3.1	5.0	1.4	1.3	13.4	6.0	2.7
Japan	3.6	6.6	1.0	1.7	16.9	6.1	4.7
Netherlands	3.5	5.3	2.0	1.7	12.5	7.1	3.4
Norway	2.4	3.7	1.2	-1.4	11.3	7.7	2.6
Portugal	4.4	6.7	2.5	3.6	15.2	6.6	3.8
Sweden	3.2	5.1	1.5	0.6	12.5	5.6	4.6
Germany	2.6	4.6	0.8	0.3	12.6	6.6	3.0
United Kingdom	3.1	5.1	1.4	0.4	13.5	7.8	3.4
United States	3.8	5.4	2.4	0.5	14.0	6.9	4.2
South Korea	9.4	13.1	6.1	8.3	23.7	16.5	9.8
Mean	3.8	5.8	2.0	1.8	14.0	7.4	3.9

Table 3: Human capital variables by country

Countries	HC Stock 1980	Growth rate (%) 1980-2000	HC quality
Australia	12.20	7.04	59.0
Austria	10.31	10.31	56.6
Belgium	9.24	15.97	57.1
Canada	11.59	12.02	54.6
Denmark	11.03	10.08	61.8
Spain	7.45	24.31	51.9
Finland	9.49	20.76	59.6
France	9.34	13.87	56.0
Greece	7.72	24.87	50.9
Ireland	8.94	12.89	50.2
Italy	7.96	26.06	49.4
Japan	11.2	11.86	65.5
Netherlands	10.28	9.81	54.5
Norway	11.56	7.66	64.6
Portugal	5.57	26.77	44.2
Sweden	11.26	4.00	57.4
Germany	12.65	2.34	48.7
United Kingdom	11.57	12.57	62.5
United States	12.19	3.55	46.8
Korea	9.11	30.35	58.6
Obs.	20	20	20
Mean	10.03	14.36	55.5
Standard Deviation	1.88	8.40	5.93
Minimum	5.57	2.34	44.2
Maximum	12.65	30.35	65.5

Table 4: Average investment ratio and average annual labour force growth by country

	Average Investment to GDP Ratio (%)	Average Annual Labour Force Growth Rate (%)
Countries	**1980-2002**	**1980-2002**
Australia	23.83	1.74
Austria	23.50	1.04
Belgium	21.42	0.44
Canada	23.31	1.50
Denmark	20.56	0.27
Spain	22.37	1.42
Finland	25.97	0.28
France	22.32	0.65
Greece	20.73	1.36
Ireland	20.77	1.74
Italy	21.66	0.30
Japan	30.83	0.77
Netherlands	21.61	1.94
Norway	24.80	0.93
Portugal	21.01	0.96
Sweden	20.22	0.15
Germany	23.20	1.59
United Kingdom	17.25	0.36
United States	19.88	1.35
South Korea	35.29	2.09
Count	20	20
Mean	23.03	1.04
Standard Dev.	3.99	0.62
Minimum	17.26	0.15
Maximum	35.29	2.09

Table 5: 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 > $\chi^2 = 0.0000$									

Notes:

Robust standard errors in parentheses. *** Significance at the 1% level, ** significance at the 5% level, * significance at the 10% level.

[(a)] 'Lagged' growth rates of human capital accumulation over the period 1960-1980 are used as instruments in the human capital accumulation equations.

The primary equation includes a constant and the following control variables: the share of each industry in total real gross value added in the initial year; labour force stock in the initial year, labour force growth over the analysed period, the ratio of investment to GDP, average over the analysed period; the ratio of trade to GDP (openness measure) at country level over the analysed period. The structural equations for investment include a constant; gross domestic product per working age population in the initial year; labour force stock in the initial year; labour force growth over the analysed period. The structural equations for human capital accumulation include a constant; gross domestic product per working age population and the ratio of investment to GDP, average over the analysed period The estimates not shown above are available from the authors.

Table 6: Testing the heterogeneity of slopes of the human capital measures, 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}	0.181**	0.212***				-0.515***			
	(0.090)	(0.006)				(0.018)			
hc_i*ict_{ps}	-0.0001		0.212***				-0.515***		
	(0.147)		(0.006)				(0.018)		
hc_i*ict_{um}	0.012			0.212***				-0.515***	
	(0.077)			(0.006)				(0.018)	
hc_i*ict_{us}	0.093				0.212***				-0.515***
	(0.080)				(0.006)				(0.017)
$hc_i*ict_{pm}*ed$	0.004								
	(0.007)								
$hc_i*ict_{ps}*ed$	-0.003								
	(0.011)								
$hc_i*ict_{um}*ed$	-0.002								
	(0.006)								
$hc_i*ict_{us}*ed$	-0.007								
	(0.006)								
dhc_i*ict_{pm} [(a)]	0.781***	0.408***				0.026			
	(0.282)	(0.008)				(0.021)			
dhc_i*ict_{ps} [(a)]	0.001		0.408***				0.025		
	(0.459)		(0.008)				(0.021)		
dhc_i*ict_{um} [(a)]	0.191			0.408***				0.025	
	(0.240)			(0.008)				(0.021)	
dhc_i*ict_{us} [(a)]	0.327				0.408***				0.024
	(0.250)				(0.008)				(0.020)
$dhc_i*ict_{pm}*edg$	0.057***								
	(0.062)								
$dhc_i*ict_{ps}*edg$	0.316								
	(0.072)								
$dhc_i*ict_{um}*edg$	0.018								
	(0.118)								
$dhc_i*ict_{us}*edg$	0.031								
	(0.064)								
Obs	1080								
R^2	0.794	0.986	0.986	0.985	0.985	0.834	0.831	0.837	0.836
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: χ^2 (224) = 4024.17 Prob > χ^2 = 0.0000

Test for joint significance of slope dummies $\chi^2(8)$ = 21.51 Prob > χ^2 = 0.0059

Notes:

Robust standard errors in parentheses. *** Significance at the 1% level, ** significance at the 5% level, * significance at the 10% level.

[(a)] 'Lagged' growth rates of human capital accumulation (over the 1960-1980) are used as instruments in the human capital accumulation equations.

The primary equation includes a constant and the following control variables: the share of each industry in total real gross value added in the initial year; labour force stock in the initial year, labour force growth over the analysed period, the ratio of investment to GDP, average over the analysed period; the ratio of trade to GDP (openness measure) at country level over the analysed period. The structural equations for investment include a constant; gross domestic product per working age population in the initial year; labour force stock in the initial year; labour force growth over the analysed period. The structural equations for human capital accumulation include a constant; gross domestic product per working age population and the ratio of investment to GDP, average over the analysed period The estimates not shown above are available from the authors.

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