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KNOWLEDGE CAPITAL

AS THE SOURCE OF GROWTH

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ABSTRACT: This paper considers knowledge capital in explaining firm-level and regional growth using micro-level linked employer-employee data for Finland. We find evidence of firm-level catching up within sufficiently narrowly defined industries but increasing regional divergence in productivity growth since 1995. The most important contributors to growth are educational-based and occupational human capital and related agglomeration. R&D also boosts stronger firm-level growth, whereas regional spillovers are absent.

Theme: 18. Regional labour market

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Keywords: regional growth, endogenous growth, catching-up, technology transfer.

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TIIVISTELMÄ: Tutkimus tarkastelee yritysten kasvua ja alueiden kehitystä käyttäen mikrotason yhdistettyä yritys- ja työntekijäaineistoa Suomessa. Yritysten välillä tapahtuu selvää kiinnikuromista toimialan sisällä, mutta eri alueiden tuottavuuserot ovat kasvaneet vuodesta 1995. Tärkeimmät inhimillisen pääoman tekijät ovat koulutus ja ammatillinen osaaminen ja näiden kasautuminen tietyille alueille. Tutkimus- ja kehitystoiminta on myös tärkeä tekijä yrityksen kasvussa, mutta alueelliset tuottavuusvaikutukset ovat vähäiset.

1. Introduction

Regional disparities are of major policy concern in the European Union, not least because of the inclusion of new transition economies into EU, see Tondl and Vuksic (2003). Until the 1990s, disparities in growth between countries decreased gradually. At the same time, migration has lead to a population concentration to the urban regions and big cities. Quah (1997) finds that among the Cohesion countries, Spain and Portugal have grown most rapidly converging towards the rest of Europe, but that they have also experienced a divergence in growth between regions within the countries. Cappelen, Castellani et al. (2003) note that within the old EU member states, very little convergence has occurred between regions since the 1980s (Finland entered EU in 1995 and is therefore not included in their study). Ottaviano and Pinelle (2002) and Piekkola (2005), among others, find a negative convergence of GDP growth among the Finnish regions since 1994, while Ottaviano and Pinelle find clear convergence in the first period 1977-1990. Kangasharju and Pekkala (2001) show that manufacturing industries is the most important segment explaining the increase in regional disparities in Finland. At the same time, in contrast to Ciccone and Hall's (1996) study of US states, Böckerman (2002) finds only limited spillovers from economic density after control for the industrial structure of the region. With all this in mind, this paper examines the role of human capital agglomeration and technology concentration for growth in Finland in firms members of the Confederation of Finnish Industries, where 75% of firms belong to the manufacturing sector.

Human capital accumulation can explain growth through schooling and learning-by-doing (Lucas, (1988), Mankiw, Romer et al. (1992). De la Fuente and Domenech (2000) and Bassanini and Scarpetta (2002) find the elasticity of output with respect to educational human capital (years of education) to be about one third in the OECD countries. Benhabib and Spiegel (1994) and Brunello and Comi (2004) find that the growth rate of total factor productivity depends particularly on a nation's level of human capital and not on the growth rate of human capital.[1] Thus education provides a permanent advantage that may increase in importance with time in the labour market. Finland also exhibits clear growth in higher educational attainment levels relative to the rest of Europe (see e.g. comparisons across countries at NUTS-2 level in Badinger and Tondl, (2002). Human capital can also have a specific role in a small open economy with a regulated labour market. Bassanini and Ernst (2001) argue that countries with co-ordinated industrial-relations systems and strict employment protection tend to specialize in industries with a cumulative knowledge base.

The share of the labour force employed in innovation activity is also an important part of knowledge capital. Romer (1990) was one of first to describe technological innovations as nonrival and stemming from monopolistic competition. Benhabib and Spiegel (2005) separate innovations driven growth from the catch up process, which can be based on Romer type imitation of new technology. They find non-linear relationship Nelson-Phelps type catch up model of technology diffusion. This is because countries with too low initial human capital stock exhibit slower total factor productivity growth than the leading nation. Faberberg, Verspagen et al. (1997) find that the superior growth performance of rich regions in the 1980s can be explained by the share of the business sector workforce employed in R&D. Finland is a knowledge- and R&D-driven economy and thus innovation activities are an important source for regional growth, see Lehto (2000).

This study uses linked employer-employee data for Finland. This type of linked data is extensively used in the study of human capital formation, starting with Abowd, Kramarz and Margolis

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1 Krueger and Lindahl (2001) argue this to be due to measurement errors in growth rates. Temple (2001), assuming a different functional relationship between income and human capital, replicates the Benhabib and Spiegel study and concludes that also changes in human capital do have an effect on growth rates.

(1999). Linked employer-employee data allow the estimation of wider concepts of human capital that include returns from individual and firm-specific experience and unobserved human capital. Abowd et al. (2003) examine the share of workers in firms below the 25th and above the 75th percentile of overall human capital over the period 1986-2000 in seven states in the US, and the interactions of the shares. They find that aggregate human capital is positively related to labour productivity.

Three main firm-level and regional growth determinants are examined in this paper: (i) the productivity growth effects of education, experience and unobserved human capital and related agglomeration of human capital, (ii) the growth effects of firm-specific occupational human capital, R&D work and related regional spillovers, and (iii) the catching up process at firm and regional levels. The rest of the paper is structured as follows: Section two presents the model, and Section three describes the procedure for assessing person- and firm-specific human capital. Section four gives some stylized facts of regional growth and human capital, and Section five presents the results of the estimation. Section six concludes.

2. The Model

Benhabib and Spiegel (2005), hereon BS, integrate two types of processes often studied in the context of disaggregated models of technology diffusion. [2] The first one is the Nelson-Phelps model of technology diffusion:

$$\frac{\dot{A}_{jt}}{A_{jt}} = g(KC_{jt}) + c(KC_{jt})\left(\frac{A_{Mt}}{A_{jt}} - 1\right) \tag{1}$$

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2 An endogenous growth model such as Badinger and Tondl (2002) also links human capital explanations to catching-up theory (see also Abramovitz, (1997; Castellani & Zanfei, 2003). Griffith, Redding and Van Reenen (2003) include a positive spillover from the assimilation of existing R&D capacity. Pigliaru (2003) examines convergence caused by technological catching-up.

where A_{jt} is total factor productivity TFP, $g(KC_{jt})$ is the component of TFP that depends on the level of knowledge capital KC_{jt} in firm j (human capital in a country in BS) and $c(KC_{jt})\left(\frac{A_{Mt}}{A_{jt}}-1\right)$ shows the catching up with the leader firm M in the industry. The level of knowledge capital KC_{jt} affects the speed of catching up. It is natural to assume choice of knowledge capital such that $c(.)$ and $g(.)$ are increasing functions. The technological leader with the fastest growth will emerge within finite time. Beyond that point the followers lagged behind in the level of TFP catch up the leading firm until the growth rate of TFP is the same for all the firms. This also implies that firms most abundant in initial human capital are closest to the leader and experience slower growth in the adjustment process.

The alternative model formulation presented by BS uses a logistic model of technology with opposite spillover effects given by

$$\frac{\dot{A}_{jt}}{A_{jt}} = g(KC_{jt}) + c(KC_{jt})\left(1 - \frac{A_{jt}}{A_{Mt}}\right) \tag{2}$$

$$= g(KC_{jt}) + c(KC_{jt})\frac{A_{jt}}{A_{Mt}}\left(\frac{A_{Mt}}{A_{jt}} - 1\right)$$

The difference in the dynamics under the logistic model is the extra term A_{Mt} / A_{jt}. The distance to the frontier firm slows down the adoption speed, which creates a non-linear relationship between the technological capital and catching up. An example of this is new technology in some other industry. This can be more easily adopted if the industries are closely the same in knowledge capital structure. BS show that for constant knowledge capital and therefore for constant technological progress $g_j(KC_j)$ and catching up $c_j(KC_j)$:

$$\lim_{t\to\infty}\frac{\mathrm{A_{jt}}}{\mathrm{A_{Mt}}}=\begin{cases}\dfrac{\mathrm{c_j+g_j-g_M}}{\mathrm{c_j}} & \mathrm{c_j+g_j-g_M>0}\\ \dfrac{\mathrm{A_{jt_o}}}{\mathrm{A_{Mt_o}}} & \mathit{if}\quad \mathrm{c_j+g_j-g_M=0}\\ 0 & \mathrm{c_j+g_j-g_M<0}\end{cases} \tag{3}$$

The steady-state growth relationship thus depends on the catch-up rate $\mathrm{c_j}$ and the difference in the growth rate due to innovative capability $\mathrm{g_j - g_M}$. For high enough catch up rate, $\mathrm{c_j + g_j - g_M}$ >0, the leader will pull others towards the same technological level and productivity differences will converge. For low enough catch up rate, $\mathrm{c_j + g_j - g_M}$ <0, the level of human capital is too low and growth rates continue to diverge. The logistic type of technological diffusion thus allows the emergence of non-converging industries. The level of knowledge capital has to be high enough for the adoption of new technology, see also Basu and Weil (1998). Impediments to the transfer of a specific technology, such as the location of R&D activity, are not the major issue. BS also discuss the Romer type (1990) split of human capital to raise either returns to innovations $\mathrm{g_j}$, or to imitation, raising catch up $\mathrm{c_j}$. With linear technology, it is obvious that all human capital can be used either for innovations or for imitations.

By defining $B_{jt}=\dfrac{A_{jt}}{A_{jt_0}}e^{-g_M t}$ we can express the growth equation in terms of stationary variables:

$$\frac{\dot{\mathrm{B}}_{\mathrm{jt}}}{\mathrm{B_{jt}}}=\mathrm{c(KC_j)+g(KC_j)\text{-}g(KC_M)\text{-}c(KC_i)B_{jt}} \tag{4}$$

Let $d\ln A_{j,t}$ represent the growth rate in log TFP of firm j. The empirical testable specification may be written following BS as

$$d\ln A_{j,t} = b + \left(g - \frac{c}{s}\right)\ln KC_{j,t} + \frac{c}{s}\ln KC_{j,t}\ln\left(\frac{A_{M,t}}{A_{j,t}}\right)^{s} + \varepsilon_{j}, \qquad (5)$$

where s equals 1 if the pure catch up model holds following a Nelson-Phelps type model of technology diffusion, and s equals -1 if the logistic form of technological diffusion is appropriate. In the Nelson-Phelps type model (s=1) catching up is positive and positively related to the level of knowledge capital. In the logistic specification (s=-1), knowledge capital intensive firms grow faster with no convergence. The coefficients to be estimated are b, g, c using firm-size dummies and regional characteristics as additional controls. The estimation results can also be used to evaluate the appropriate value of s. We do not instead use the interaction of the catch-up term with knowledge capital because of the endogenous nature of this interaction with other explanatory variables. Each of the industries may instead be considered to contain its own human capital specific catching up process that is taken into account.

We find it useful to analyse education capital, unobserved skills and experience separately. Knowledge capital $KC_{j,t} = \xi(h_{j,t}, l_{j,t,h<h(Q1)}, l_{j,t,h>h(Q3)}, \psi_{j,t})$ is a function of average education and firm-specific human capital $h_{j,t}$, a function of the fraction of workers in different skill categories for experience and unobserved human capital, and a function of the firm effect $\psi_{j,t}$. $l_{j,t,h<h(Q1)}$ represents the fraction of workers below the 25th percentile for overall experience-based and unobserved human capital across firms over the period and $l_{j,t,h>h(Q3)}$ captures the corresponding fraction of workers above the 75th percentile. $\psi_{j,t}$ is a firm effect in addition to the time-specific human capital explained by seniority, performance related pay, R&D-work and occupations. These capture intangible human capital that is related both to human resource management and the innovative capabilities of a firm, which are not necessarily transferable across firms. We include in the knowledge capital regional knowledge capital spillover, $SPIL_{r,t}$, which is independent of the catching up process, where subscript r indicates region r (1,…,R). This consists of the spillover from knowledge capital in region r and the influence of other regions. As described in the appendix A, spatial weights are based on a negative exponential function with the distance decay parameter depending on the distances between neighbouring regions, following Funke and Niebuhr (2000). The half-decay distance that reduces the spatial interaction by one-half is set, on average, at 122 kilometres for educational human capital and at 289 kilometres for R&D spillovers (an average double higher in Northern Finland with long distances).

The leading technology is assessed in 22 industries (for similar productivity analysis using Finnish data, see Ilmakunnas, Maliranta et al., (2004)). Frontier technology is the firm with the highest average productivity in the industry. We do not use the interaction of the catch-up term with knowledge capital because of the endogenous nature of this interaction with other explanatory variables. Each of the 22 industries may instead be considered to contain its own human capital specific catching up process that is taken into account here.

TFP in firm j is also measured relative to other firms and time periods. We apply the multilateral total factor productivity index (TFP) introduced by Caves (1982). Firm j is compared to a hypothetical average benchmark firm so that

$$d \ln A_{j,t} = \ln(TFP_{j,t}) - \ln(TFP_{j,t-1}) \text{ , where} \tag{6}$$

$$\ln(TFP_{j,t}) = \ln(\frac{V_{j,t} / L_{j,t}}{\bar{V}_{j,t-1} / \bar{L}_{j,t-1}}) + \frac{S_{j,t} + \bar{S}_{j,t-1}}{2} \ln(\frac{K_{j,t} / L_{j,t}}{\bar{K}_{j,t-1} / \bar{L}_{j,t-1}}), \tag{7}$$

and where $V_{j,t} / L_{j,t}$ = labour productivity, $K_{j,t} / L_{j,t}$ = capital intensity and $S_{j,t}$ = one minus the labour cost share of value added. Upper bar superscript indicates the respective values for the average-firm benchmark. The index has the advantage that it is based on a translog production function thus being a second-order approximation of the true but unknown production function. The index is exact if the true production function is translog.

3. Estimation of Human Capital

A firm devotes resources to both human capital investments and R&D in order to ensure its future success. The dependent variable is the natural log of the hourly wage $\ln(y_{\mathrm{ijt}})$ of a person i working in firm j at time t measured as a deviation from the individual mean wage over the time period. Following the two-step method suggested by Andrews, Schank and Upward (2004), the dependent variable is first expressed as a function of individual heterogeneity, firm heterogeneity and measured time-varying characteristics for movers.

$$\ln(y_{\mathrm{ijt}})\text{-}\mu_{yi} = \beta(x_{it}-\mu_{xi})+\gamma(w_{it}-\mu_{wi})+\theta_i+\delta(\psi_{j(i,t)}\text{-}\mu_{\psi i}) + e_{ijt} \quad . \tag{8}$$

$\beta(x_{it}-\mu_{xi})$ shows the compensation for time-varying human capital stated as a deviation from the individual mean human capital: hence it contains time dummies and experience expressed up to the fourth power. $\gamma(w_{it}-\mu_{wi})$ shows the respective time-demeaning for all firm-specific variables: occupations, seniority, R&D-work, performance-related pay PRP. θ_i is the compensation for time invariant human capital (individual fixed effect). $\psi_{j(i,t)}$ captures the effect of unmeasured employer heterogeneity, where $j(i,t)$ indicates the worker's job in the employer *j* at date t. $\delta(\psi_{J(i,t)}\text{-}\mu_{\psi i})$ shows the time-demeaning of firm-dummies. e_{ijt} represents a statistical error term.

The formation of linked employer-employee data is described in Appendix B. The original data included 2,359 firms and the firm-effect could be identified for 1,421 firms based on job transferees. The sample including all observations for employees with one or more job transferees in the considered time period (286,000) accounts for only 13% of all observations in the 1,421 firms with at least 30 job transferees, 2.09 million (the requirement of at least 30 job transferees in a firm decreased the number of observations by 3,000). Given the data dimension with 1,421 firm dummies, it was not possible to solve even the reduced two-step method suggested by Andrews, Schank and Upward (2004) using the Stata econometrical package in the Windows environment. Instead, we adopted an analogous estimation procedure using the SAS system for Windows. The estimation of the first-stage wage equation (8) is shown in column 1 in Table A.1 in the appendix. Time-varying human capital includes experience up to the fourth potency. Time-varying firm characteristics include seniority, performance-related pay, the share of R&D-employees and job mobility across occupations (blue-collar work and white-collar work divided into 17 categories as listed in Table A.1). The firm effect $\delta\hat{\psi}_{j(i,t)}$ is obtained from the estimation results of (8) as a deviation from the mean in the pool (where δ is a scalar). Almost all, 99.8%, belong to the largest pool, where firms are linked to each other via job transferees across firms (two firms are linked by job transferee and these two firms are linked to a third firm by job transferee etc.). In the second step, $\delta\hat{\psi}_{j(i,t)}$ is placed at following equation

$$\ln(y_{ijt})-\mu_{yi} \;=\; \beta(x_{it}-\mu_{xi})+\gamma(w_{it}-\mu_{wi})+\theta_i+\delta(\hat{\psi}_{j(i,t)}-\mu_{\psi i})\;+e_{ijt}\;. \qquad (9)$$

The second step estimation covers all workers in the sample of firms for which the firm effects were identifiable. Results from the second-stage estimation (9) are reported in column 2 in Table A.1 in the appendix. The coefficients for the first-stage estimation for the sample with job transferees do not largely differ from the coefficients for the larger sample covering also non-movers, see columns 1 and 2 in Table A.1 and also Table 4 in Andrews, Schank and Upward (2004). As can be seen in column 2 which includes all workers, the returns to experience are very similar to those in column 1 which includes only the transferees. Seniority returns are lower than for mobile workers. The latter finding is explained by the fact that seniority returns are high especially in the first years of service. The occupations are primarily available in white-collar work. It is seen that earnings are on average higher in the blue-collar than in white-collar occupations in the manufacturing.

The person effect is the person average using the second-step estimation results: $\theta_i = \mu_{yi} - \hat{\beta}\mu_{xi} - \hat{\gamma}\mu_{wi} - \mu_{\psi i}$, where $\hat{\beta}$ and $\hat{\gamma}$ are the estimated values of the coefficients. Person effect θ_i can now be regressed against all time-invariant variables. The decomposition of the person effect θ_i uses the estimates of

$$\theta_i = Int + z_{i\in e} u_e \eta_e + u_2 Gen_i + \varepsilon_i \ , \tag{10}$$

where Int is the intercept, η_e is the education level (from $e = 1,...,E$), u_e is the respective coefficient, $z_{i\in e}$ indicates the worker belonging to this education group (zero otherwise), Gen_i indicates gender and ε_i is the statistical error. Six educational levels are identified for five fields: ((i) general education, humanities, aesthetics, medical and health, field unknown, (ii) commercial and clerical work, law, social science, (iii) technology and natural science, (iv) transport and communication and (v) agriculture and forestry (industrial field not specified at the elementary or doctorate level and vocational education also includes an unspecified field). Unobserved human capital is the person effect that cannot be explained by education and gender $\alpha_i = \theta_i - z_{i\in e}\hat{u}_e\eta_e - \hat{u}_2 Gen_i$.

Table A.2 in the appendix shows the estimation results (in what follows we only use data for 1,421 firms with estimable firm effect covering 2,096,523 employees). As is seen, returns to education increase monotonously with the educational level, at least within the education fields. All workers with higher university education, except those in the health and service sector, belong to the highest quartile for overall human capital.

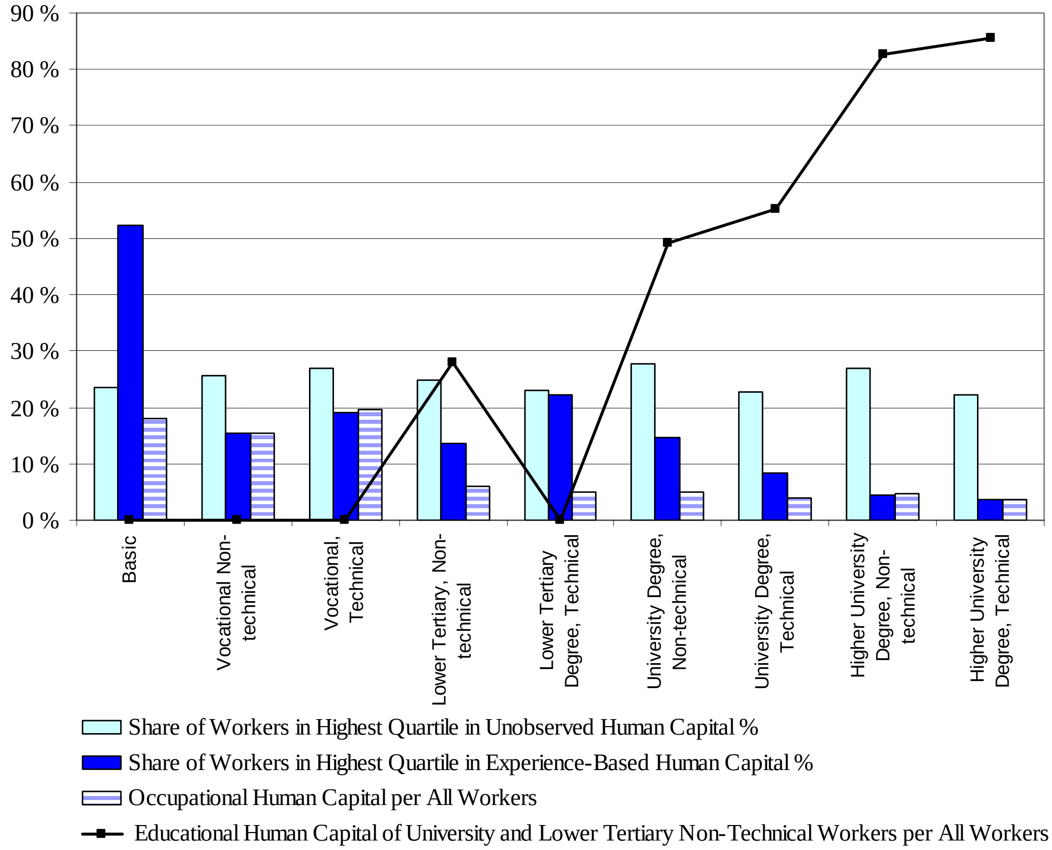
As a measure of educational human capital we take into account both the share of high educated and the relative rate of return in each high educated group

$$Educational\ HC_{j,t} = \sum_{i_t=1}^{I_t} z_{i_t \in H} u_H \eta_H / \sum_{i_t=1}^{I_t} i\,, \tag{11}$$

where $z_{i \in H}$ indicates that the worker belongs to the high educated group H (where the rates of return are indicated by the solid line in Figure 1). The difference to a pure weighted average measure thus is that the denominator is not the number of highly educated, but all workers in the firm. We also include non-technical lower-level tertiary degrees in the highly educated group. The exclusion of workers with technical lower-level tertiary degrees can be justified by the lower wages in the technology section or by the inclusion of many of these individuals in the alternative variable measuring the share of R&D workers. The selected workers closely form the share of workers belonging to the highest quartile of educational human capital.

The following figure shows the breakdown of experience-based human capital and unobservable human capital into nine educational categories, using five educational degrees (basic, vocational, lower tertiary degree, university degree, higher university degree) divided, with the exception of the first category, into technical and non-technical fields.

Figure 1. Educational and Occupational Human Capital and Share of Workers over 75th Percentile of the Overall Unobserved or Experience-Based Human Capital



It can be noted that the share of individuals belonging to the highest quartile of experience-based human capital generally decreases with the educational level although variation in average ages causes some heterogeneity at the vocational and lower tertiary levels. Unobserved human capital is fairly evenly distributed, as expected by design of the model. Occupational human capital decreases with the educational level, which can also be explained by the relatively higher income level of blue-collar occupations in manufacturing.

4. Regional Distribution of Productivity and Resources

In the following, we shall first take a graphical look at total factor productivity and human capital in the regions by controlling for industry (22 industry dummies), years, and interactions between industry and year in the period 1996-2002. The regional distribution of employees at the establishment level is taken into account in the setting of region dummies for each firm. Each region is given the weight of establishment-level employment located there relative to total employment in the firm (region dummies for each firm hence sum to unity). 20% of employees are located in Helsinki. Using the location of head-office as the reference would instead give more than twice a higher share 50%. In addition, we use constrained OLS regression. The purpose is that the reference is the representative employee rather than any single region (as when a single region dummy is omitted). The separate constraint states that region dummies weighted by manufacturing employment sum up to zero.

Starting from 85 NUTS-4 level regions (1999) those with only a few manufacturing plants are combined, the municipalities of Espoo and Vantaa are considered as separate from the greater Helsinki area, and a satellite region around greater Helsinki area is constructed (initially establishment data is available at the municipal level). The overall number of regions totals 56. Figure 2 shows total factor productivity using (8). Figure 3 shows educational human capital across regions.

Figure 2 suggests that total factor productivity is higher in the municipalities located in the Helsinki region, and in those situated along the railway line and motorway from Helsinki to Pirkanmaa (including Tampere) and in the central part of Finland around the Jyväskylä region. The coastal area in western Finland has also performed well. Also regions with paper and pulp or metal industry such as Kotka-Hamina, Imatra and Lappeenranta have higher productivity than the country average.

Figure 2. Total Factor Productivity.

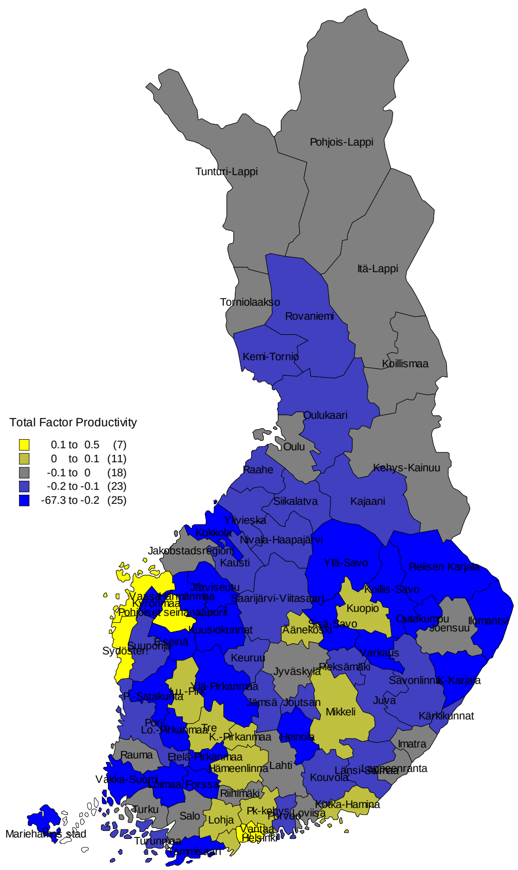
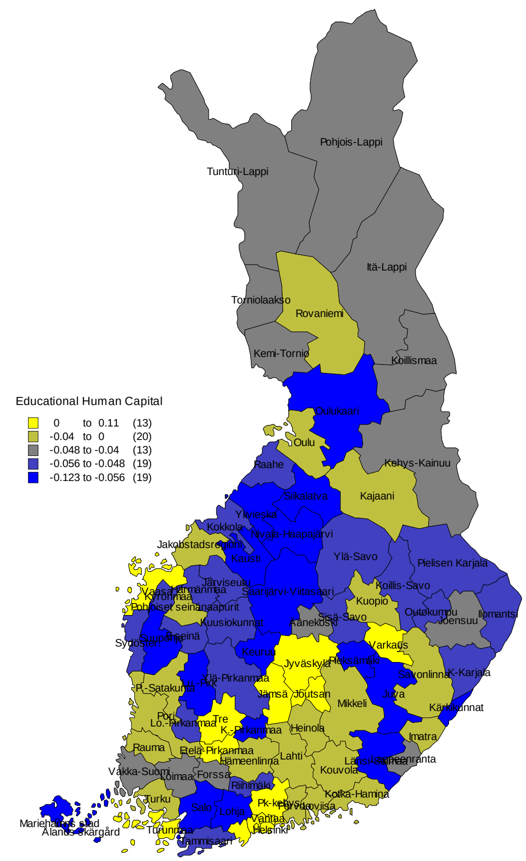


Figure 3. Educational Human Capital



Our most important measure of human capital is educational human capital. Figure 3 shows the regional educational human capital. It indicates that regions with higher than average total factor productivity tend to have human capital intensive manufacturing. Only Varkaus and Turunmaa, although rich in manufacturing based on educational human capital, are low total factor productivity regions. These are regions where many large industrial firms have closed down and also regional GDP growth 1.8% was below the national average of 3.6% in 1996-2002.

Piekkola (2005) constructs a regional competitiveness index, which includes these human capital components at the personal, firm and regional level. In addition, alternative measures of innovativeness are included covering also renumerations and the share of R&D workers. Badinger and Tondl (2002), reviewing patent applications, find Uusimaa, South-Finland and North-Finland to be among the most innovative regions in Europe, and R&D workers are concentrated in high total factor productivity areas within these larger regions. Piekkola (2005) shows that the frontier of the R&D intensive research area stretches from Helsinki via the Lahti motorway towards Jyväskylä as well as towards Tampere. It is interesting to note that the eastern most parts of Finland exhibit very little R&D research, although workers there have above average educational levels.

5. Human Capital as an Engine for Growth

This section uses the constructed human capital variables to explain firm-level productivity growth and regional productivity growth resulting from knowledge capital. Table 1 summarizes the variables and correlations between the individual- and firm-specific human capital variables using information for those firms for which firm-effect was estimable. The average figures and the correlations are very similar for all firms, since the use of 1,421 firms with identifiable firm-effect instead of the original 2,359 firms reduces the number of employees in the data only by 110,000. This represents 5% decrease in the number of person-year observations.

Table 1. Summary and Correlation Table

Person-Average

Variable	Person Effect	Human Capital	$u\eta$	α	Exper. H.C.	Gender H.C.	ψ	Occupat. H.C.	Seniority H.C.*10	PRP	R&D H.C.
Mean	1.179	2.723	0.239	1.187	1.297	-0.247	0.030	0.142	0.034	0.009	-0.002
Std	0.491	0.382	0.230	0.422	0.394	0.087	0.283	0.101	0.033	0.009	0.004
Number of Obs	2096523	2096523	2096523	2096523	2096523	2096523	2096523	2096523	20965230	2096523	2096523
Person Effect	**1.00**	0.59	0.47	0.86	-0.63	0.21	-0.43	-0.08	-0.37	0.06	-0.21
Human Capital	0.59	**1.00**	0.22	0.57	0.23	0.01	-0.59	-0.19	0.17	0.14	-0.11
Education $u\eta$	0.47	0.22	**1.00**	0.00	-0.37	0.02	0.05	-0.42	-0.27	0.15	-0.42
Unobserved α	0.86	0.57	0.00	**1.00**	-0.52	0.02	-0.53	0.11	-0.29	-0.02	0.00
Experience H.C.	-0.63	0.23	-0.37	-0.52	**1.00**	-0.03	-0.03	-0.05	0.63	0.07	0.14
Gender H.C.	0.21	0.01	0.02	0.02	-0.03	**1.00**	0.01	0.13	0.02	0.04	-0.07
Firm Effect ψ	-0.43	-0.59	0.05	-0.53	-0.03	0.01	**1.00**	0.02	0.00	0.08	-0.06
Occupational H.C.	-0.08	-0.19	-0.42	0.11	-0.05	0.13	0.02	**1.00**	-0.05	-0.23	0.36
Seniority H.C. * 10	-0.37	0.17	-0.27	-0.29	0.63	0.02	0.00	-0.05	**1.00**	0.10	0.11
PRP	0.06	0.14	0.15	-0.02	0.07	0.04	0.08	-0.23	0.10	**1.00**	-0.18
R&D H.C.	-0.21	-0.11	-0.42	0.00	0.14	-0.07	-0.06	0.36	0.11	-0.18	**1.00**

Firm-Average

Variable	Educat. H.C.	Educat. H.C. of Highly Educated	Unobser. H.C.	ψ	Occup. H.C.	Seniority H.C.*10	Share of R&D Workers	Highly Educat. Spillover	R&D Worker Share Spillover	Log TFP Growth	Log TFP Catching Up
Mean	0.210	0.094	1.137	0.018	0.156	0.028	0.092	0.007	0.012	-0.017	-0.203
Std	0.092	0.103	0.382	0.383	0.067	0.015	0.142	0.015	0.038	0.574	1.312
Number of Obs	7532	7532	7532	5698	7532	7532	7532	7532	7532	5490	7532

Human is the sum of educational $u\eta$, unobserved α and experience-based human capital. Educational human capital at firm level is the per capita value of the sum of educational human capital $u\eta$.

Abowd et al. (2001) find that the firm effect is positively related to the level of human capital, while here the correlation is negative (Table 1). Andrews, Schank and Upward (2004) discuss the potential bias in the method, which can lead to a negative correlation of the unobserved worker quality with the unobserved firm quality. The bias would be of particular importance when the probability of transfer from one firm to another is purely random or not explained by the observed individual and firm characteristics. The firm effect, ψ_i has a negative correlation in particular with the unobserved human capital (correlation of -0.53). All other individual-based components of log wages *ln(y)* are not correlated strongly with the firm effect. We continue to analyse all components of human capital separately, since the estimation problem is particularly valid for unobserved talents. Unobserved human capital remains fairly large but has no significant direct productivity effects.

Table 2. Total Factor Productivity Growth

	Random Effects			OLS	OLS Firm Size Weight
Constant	-0.331***	-0.270***	-0.252***	-0.254***	-0.024
	[4.186]	[3.275]	[3.042]	[3.243]	[0.071]
Catching Up Frontier Firm	0.133***	0.130***	0.129***	0.121***	0.092*
	[15.605]	[15.343]	[15.167]	[14.682]	[1.701]
Highly Educated H.C.	0.498***	0.574***	0.29	0.538***	0.993**
	[2.902]	[3.328]	[1.383]	[3.287]	[2.086]
Dif Educational H.C.	-0.427**	-1.658***	-1.481***	-1.618***	-0.907
	[2.311]	[4.111]	[3.612]	[4.031]	[0.737]
Workers Above 75% for Unobserved H.C.	-0.042	-0.05	-0.048	-0.038	-0.018
	[0.626]	[0.748]	[0.729]	[0.611]	[0.126]
Workers below 25% for Experience H.C.	-0.038	-0.325**	-0.321**	-0.324**	-1.12
	[0.373]	[2.436]	[2.405]	[2.522]	[1.436]
Workers Above 75% for Experience H.C.	0.067	-0.209	-0.184	-0.203	-1.172
	[0.613]	[1.492]	[1.310]	[1.511]	[1.196]
Workers below 25%, Above 75% for Experience H.C.		1.865***	1.834***	1.756***	6.469*
		[3.280]	[3.223]	[3.206]	[1.695]
Female Share	-0.013	-0.012	-0.012	-0.005	0.115
	[0.226]	[0.211]	[0.200]	[0.094]	[0.777]
Firm Effect	0.029	0.02	0.021	0.025	-0.012
	[0.704]	[0.485]	[0.508]	[0.647]	[0.138]
Occupational H.C.	1.616***	1.562***	1.371***	1.477***	1.164**
	[6.833]	[6.611]	[5.490]	[6.582]	[2.259]
Highly Educated H.C., Occupational H.C.			4.449**		
			[2.386]		
Dif Highly Educated H.C., Occupational H.C.		8.641***	7.721***	8.456***	5.239
		[3.476]	[3.070]	[3.421]	[0.764]
Returns to PRP	0.152	-0.062	-0.341	-0.119	-6.020*
	[0.106]	[0.044]	[0.238]	[0.090]	[1.751]
Returns to R&D Research	24.285**	23.311**	14.897	22.557**	46.029
	[2.070]	[1.990]	[1.217]	[1.994]	[1.192]
R&D Worker Share	0.234*	0.201	0.105	0.194	0.374
	[1.896]	[1.636]	[0.814]	[1.629]	[1.061]
Seniority H.C./100	-0.565***	-0.583***	-0.636***	-0.581***	-1.134
	[2.663]	[2.761]	[2.991]	[2.859]	[1.442]
Seniority H.C. Squared/1000	0.274***	0.304***	0.297***	0.300***	0.435
	[3.424]	[3.790]	[3.704]	[3.867]	[0.928]
Employees 50-700	0.041	0.034	0.03	0.03	0.03
	[1.632]	[1.361]	[1.197]	[1.272]	[0.738]
Employees > 700	0.110***	0.099***	0.092***	0.095***	0.172**
	[3.306]	[2.962]	[2.749]	[2.988]	[2.082]
Highly Educated Agglomeration	1.355**	1.239**	1.244**	1.201**	3.131**
	[2.297]	[2.105]	[2.114]	[2.047]	[2.283]
R&D Agglomeration	-0.385	-0.39	-0.389	-0.393	-3.33
	[1.532]	[1.552]	[1.552]	[1.575]	[1.552]
Provincial Center	-0.01	-0.015	-0.014	-0.015	-0.135**
	[0.422]	[0.595]	[0.565]	[0.643]	[2.521]
Industrial Region	-0.053*	-0.054**	-0.053*	-0.054**	-0.100**
	[1.901]	[1.977]	[1.926]	[2.076]	[2.108]
Country-side	-0.066**	-0.067**	-0.065**	-0.066**	-0.107
	[2.224]	[2.276]	[2.232]	[2.405]	[1.596]
Peripheria	-0.068	-0.062	-0.054	-0.063	-0.137*
	[1.150]	[1.057]	[0.919]	[1.145]	[1.650]
Observations	4494	4494	4494	4494	4407
Number of Firms	972	972	972	972	972
Wald Chi / R^2	479(45)	504(47)	511(48)	0.097	0.244

Absolute value of z statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimation includes 19 industry and year dummies.

It is seen that occupational human capital interacts negatively with educational human capital and positively with R&D work. Experience-based and seniority human capital also have very high correlation. In the growth model (5), we use average seniority rather than returns to seniority. This also captures both the heterogeneity and age of firms. Finally, it is seen that TFP growth has, on average, been negative and cathing-up is negative so that the growth has lagged behind the most productive firms in the industry. This is especially the case in the food, textiles, oil and mineral industries. Table 2 shows the estimation results of (5).

The random effect and the closely equivalent OLS estimations in columns 2 and 3 are the preferred models, while the first column excludes interaction terms. The last column 4 uses weighted regression according to average employment, thus placing greater emphasis on large firms. Spillovers from the agglomeration of educational human capital and R&D workers turned out to have a low enough correlation (below 0.5) so they are both included.

It is seen from Table 2 that low-productivity firms are prone to catch up with the top-productivity firm in the industry. The variation is likely to be high, however, as indicated by the standard deviation of catching up in Table 1 (with the mean value being negative). The catching up term stands out as insignificant in column 4, where employment-weighted OLS was used. Hence, the catching-up is limited to small firms.

It is seen from Table 1 that firms with more education capital generate stronger growth. It was also discussed in the introduction that the rate of change in the education level may have a positive effect on productivity growth. Instead, we find the growth of education capital to be negatively related to TFP growth (results not reported). These findings are similar to those of Benhabib and Spiegel (1994) who explain, using more aggregated measures of educational human capital, productivity growth in 61 countries. The importance of the level of knowledge capital and catching up is in line with the Nelson-Phelps model of technological diffusion at the firm level and within industries. Firms tend to convergence within sufficiently narrowed industries.

We also included the growth rate of educational-based human capital and its interaction with occupation human capital. It is seen that the growth rate of educational-based human capital is negatively related to growth, while the interaction with occupational human capital has a significant positive coefficient. The negative coefficient gives further support for the use of level estimates. Educational human capital is thus important for the adoption of new technologies and can be less interpreted in terms of pure labour productivity augmenting technology. The interaction with occupation human capital also shows that growth of educational-based human capital is highly endogenous and explained by the adoption of human resource practises. The positive interaction indicates a positive relation between investment in new educational-human capital and occupational careers, where the latter encompasses many white-collar occupation types.

Abowd, Lengerman and McKinney (2002) document an increase in the level of overall human capital which cannot be explained by the educational level alone. It is seen that unobserved human capital has a negative effect on growth. The interaction term in column 2 reveals that unobserved human capital is relatively more productive in firms with high occupational human capital. This suggests that a large share of unobserved human capital is related to occupational careers. It is further seen that experience-based human capital has an insignificant effect on growth. However, the coefficient for the interaction between the highest and lowest quartile is positive.

The firm effect can be considered as a proxy for the unobserved components of technology (intangible capital, managerial ability) that is also captured by occupational human capital, R&D work and PRP. In our study, we find no significant positive impact from the firm effect on growth. Instead occupational human capital, R&D work and PRP are important (and correlating surprisingly little with the firm effect in Table 1). We note that seniority payments have no statistically significant effects. The positive growth associated with occupation mobility was noted already earlier. The returns to R&D work and the share of workers in R&D are also indicative of high-growth firms. Note, however, that a large share of R&D workers on its own is not an indicator of strong growth. Strong growth is identified when the R&D work pays off well, which is also the reason for including both the measure of the share of R&D workers and that of returns to R&D work. Consider finally the human resource practices in a firm as explained by performance-related pay (PRP). Ichniowski and Shaw (2003) emphasize the complementarily of PRP to knowledge capital. The related human capital compensation effects have here a positive but insignificant effect on growth. The effect is even strongly negative when large firms are given higher weight as in column 4.

Consider next the human resource practices in a firm as explained by performance-related pay (PRP). Ichniowski and Shaw (2003) emphasize the complementarity of PRP to knowledge capital. PRP has increased in popularity in the late 90s. Piekkola (2004), who uses the same data as here, finds that about 58% of the employees with an educational level at vocational college or higher (32% in 1996) and 34% of the lesser educated workers (21% in 1996) received PRP in 2002. The once-and-for-all decision to use PRP was shown to be associated with positive productivity effects of around 6%. The PRP have here a positive but insignificant effect on growth. The effect is even strongly negative when large firms are given higher weight as in column 4.

Despite our evidence for firm-level catching up, regional growth may still follow the logistic model of technological diffusion. The reason is that human capital is agglomerated. We experimented by interacting the catching-up term with the average productivity of the region at the two-digit level and find this interaction to be positive (not reported). Thus catching-up takes place especially in low-productivity firms in human capital abundant high productivity areas and, thus, does not contribute to regional convergence. The existence of low productivity firms in high productivity areas is also supported by the productivity dispersion being highest in high productivity areas, see Böckerman and Maliranta (2003).

The theoretical approach by BS emphasises knowledge capital level as the basis for technological adoption rather than any technology transfer impediments. The absence of human capital in the region may make it difficult to adopt distant technologies. External economies of scale and agglomeration include localisation economies from the concentration of firms within the same industry (e.g. the share of R&D workers in firms across the same industry) as well as urbanisation economies related to population size and variability of human capital (captured by region dummies and partly by the spillovers from education capital). It is seen that educational human capital agglomeration does indeed have a significant effect on firm-level growth (and the more so for regional growth). The division of firms according to the greater Helsinki area, cities, provincial centres, industrial regions, rural areas and periphery sites also shows that growth is some 5 log-points higher in the greater Helsinki area and in the provincial centres.

Spillovers from R&D are also less clear. The share of white-collar workers engaged in R&D creates even insignificant negative spillovers. Similarly, Böckerman (2002) finds ICT manufacturing not to boost labour productivity in other industries in the region. This provides evidence that R&D spillovers can be global in character rather than being restricted to the area, where the firm is located. Technological transfers through R&D investment appear not to be geographically limited within the region (Pigliaru, 2003) or within the borders of neighbouring regions (Maurseth, 2001).

Before analysing regional growth in greater detail, we first use Monte Carlo simulation to determine the magnitude of the productivity effects and to assess the robustness of our estimates (see King, Tomz and Wittenberg, (2000)). The simulation is based on the OLS estimation.

Figure 4. Educational Human Capital

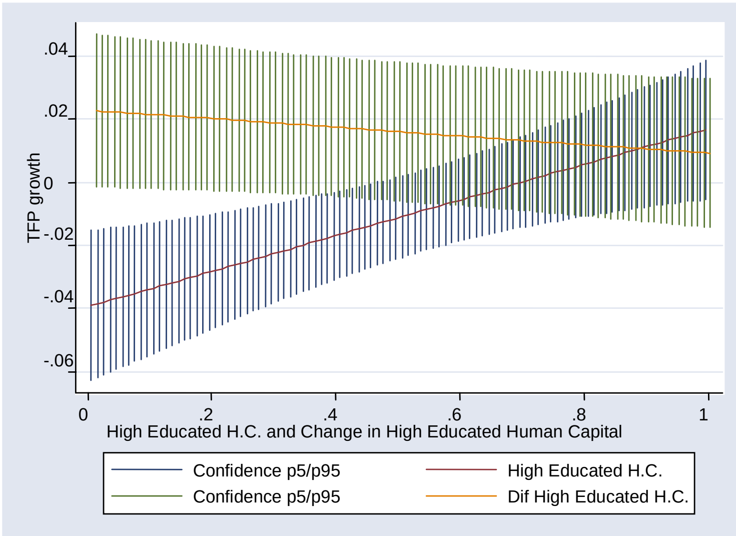


Figure 5. Occupational Human Capital

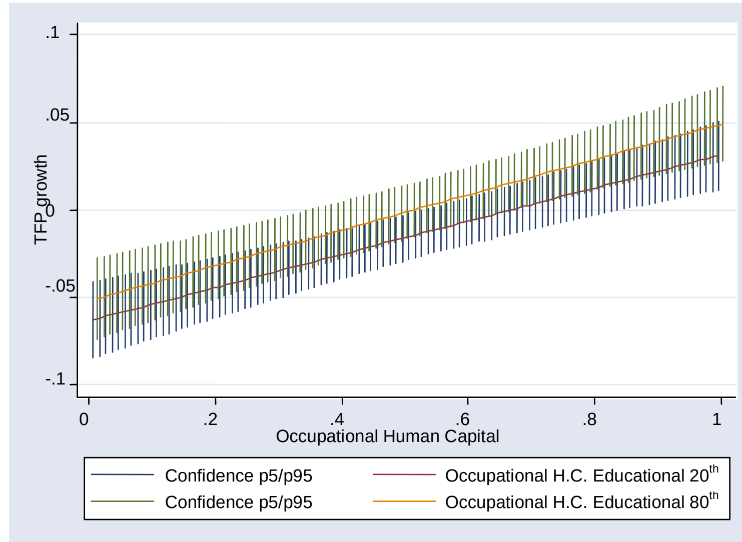


Figure 6. Experience-based human capital and Seniority

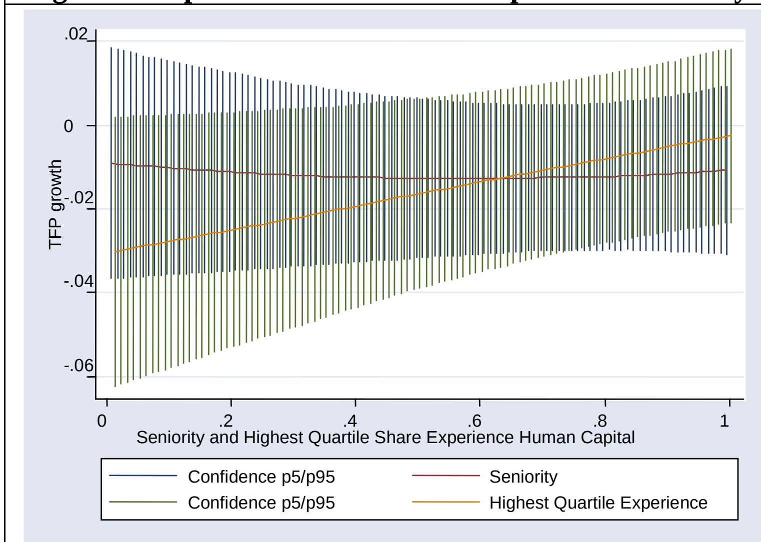
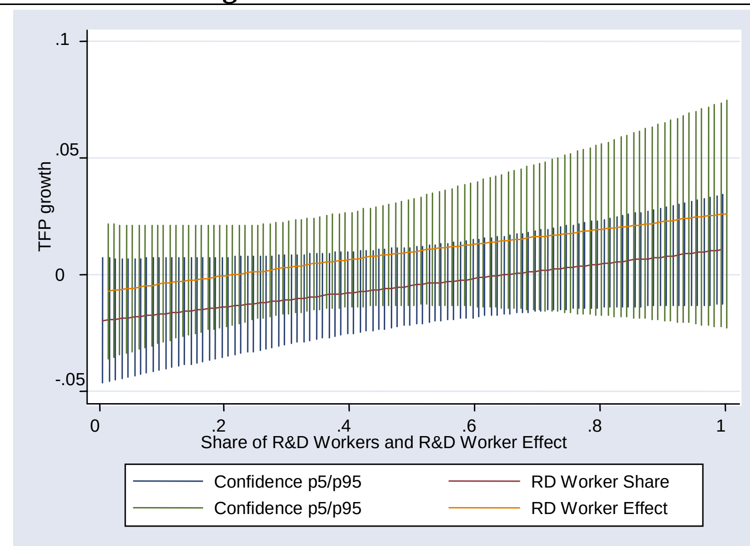


Figure 7. R&D Workers



We have run 10,000 simulations and the quantitative effects are estimated from the average of each variable. The X-axis is set to reflect a one standard deviation increase in the explanatory variable around the mean. The Y-axis shows 10-100 log-points fluctuation of productivity around the zero mean (standard deviation is 56.7, see Table 1). Note that if knowledge capital is purely augmenting the productivity of labour, labour productivity effects are two times higher than total factor productivity effects as the average labour share of value added is 0.53.

Figure 4 shows that an increase in education capital by one standard deviation (14 log-points) raises productivity growth by around 6 log-points (by 12 when multiplied by the factor share). This effect reflects a noticeable fraction of the standard deviation in total factor productivity growth (56.7 log points). Note also that the productivity effect was double this size in large firms, as evidenced by column 4 in Table 1. However, the change in educational human capital does not raise productivity. The productivity effects can, hence, be interpreted to accrue from long-term investment in human capital and how educational human capital affects technical efficiency. In addition to this, one standard deviation increase in education agglomeration raises productivity by 1.5 log-points (not shown here).

Figure 5 shows that the growth effect associated with occupational human capital is rather sizeable. Recall that occupational and educational human capital are negatively correlated. However, the interaction term is positive in Table 2. It is seen that occupational human capital yields higher productivity growth in educational capital intensive firms.

Figure 6 shows that a higher share of workers in the highest quartile of experience-based human capital raises productivity growth somewhat when the share of workers in the lowest quartile of overall experience is set at its mean. This confirms the importance of having both new and experienced workers in a firm. Figure 6 also shows that average seniority has very

Figure 8. Total Factor Productivity Growth

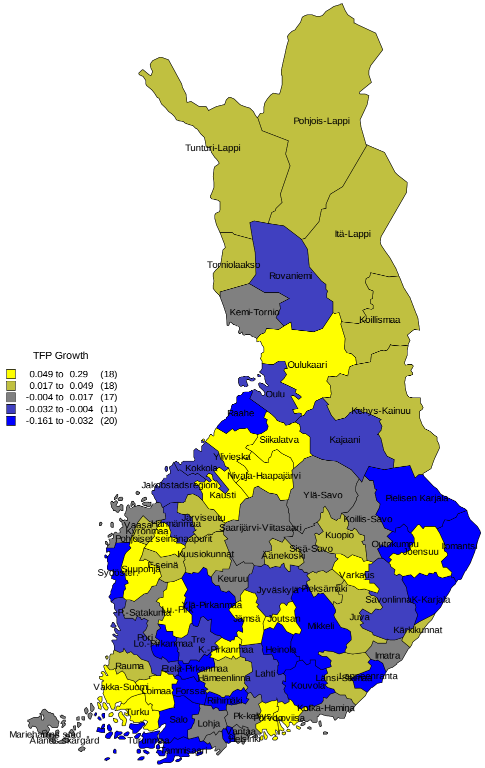
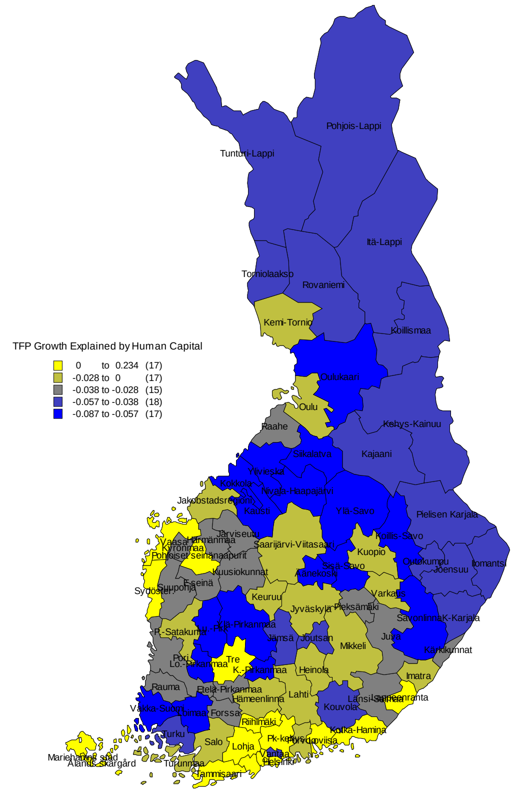


Figure 9. Total Factor Productivity Growth Explained by Knowledge capital



small productivity effects. Finally, last Figure 7 indicates that the R&D worker share and R&D human capital are both indicative of somewhat stronger productivity growth.

Turn next to regional productivity growth to see whether human capital contributes to agglomeration. Table A.3 in the Appendix shows OLS estimates analogous to those in column 4 in Table 2 with 56 regional dummies based on Nuts-4 level (see the method adopted earlier for Figures 2 and 3). Only the results for regional dummies are reported. Figure 8 shows the regional distribution of productivity growth using only industry dummies, time dummies and interaction between industry and time dummies (column 1 in Table A.3). Figure 9 presents the regional distribution of productivity growth, as explained by knowledge capital. This is obtained by subtracting the coefficients with knowledge capital controls from the coefficients for regional dummies (i.e. subtracting column 2 from column 1 in Table A.3).

Note first that only few of the regional dummies are significant. However, regions in close proximity have similar characteristics. In comparing Figure 8 with Figure 2, it can be seen that total factor productivity growth tends to be higher in areas where the TFP level is already high. However, Espoo, Tampere and Oulu, belonging to the top in total factor productivity are not growing much stronger than average. Figure 9 shows that total factor productivity growth is instead particularly well explained by knowledge capital in high productivity areas within a 100 kilometre distance from Helsinki towards Tampere. Knowledge capital appears to generate growth in regions around the university cities of Kuopio and Lappeenranta as well as in the coastal regions south of Vaasa. Thus, according to our results, there is limited catching-up between the productivity levels of the different regions in Finland due to agglomeration of human capital.

6. Conclusions

Finland has experienced agglomeration and divergence in productivity growth at the regional level since 1995. The catching-up process is faster for low-productivity firms in high productivity areas. It is evident that it is important for specific clusters of regions to have access to a regional pool of knowledge capital. The logistic model approach can explain this when catching up process is sufficiently interacted with the level of human capital. Ottaviano and Pinelle (2002) argue that substantial labour mobility within countries explain the large regional agglomeration effects within countries. Traditional geography models since Krugman (1991) consider labour mobility as the key in core-periphery models. However, convergence in productivity should occur, as human capital mobility and agglomeration tend to equalize profitability across regions. Evidence in recent history does not support this hypothesis because insufficient knowledge capital forms a major impediment for all regions to grow. Human capital agglomeration explains no regional convergence, while there still exists clear convergence at firm-level growth.

An aggregate measure of human capital, however, is not a very good measure for growth effects. The educational human capital measure used takes into account both the share of high educated and the educational premium. Educational and occupational human capital turned out to be the two cornerstones of productivity growth. Occupational human capital generates stronger growth especially in firms with high level of educational capital. Finally, experience-based human capital as a whole does not indicate stronger growth, while firms may find it beneficial to have both young and experienced workers.

Similar heterogeneity applies for firm-specific capital. We find that besides occupational human capital R&D related work enhances growth. R&D investment is concentrated in certain areas that may also differ somewhat from the regional dispersion of education capital. However, regional spillovers are even negative. Generally, innovating firms also implement PRP schemes, a fact that seems to have an ambiguous growth effect in this study.

Many studies, including e.g., Baldwin and Martin (2005), show that R&D research benefiting from local knowledge capital leads to increased spatial inequality. This is not a catastrophe as long as all firms can buy the particular R&D research knowledge from another region. Keller (2002) also argues that decreased localization of technology diffusion may be explained by reduced transport costs for high-technology goods or by increased foreign direct investment. In Finland, the principle has been to refrain from spreading R&D investments because of very large local spillovers. Indeed, R&D investments appear to inherit global spillover characteristics, while regional spillovers are absent.

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Appendix A. Construction of spillover effect

Spatial weights w are based on a negative exponential function with distance decay parameter β_{E_r}. Following Funke and Niebuhr (2000) and Tanel and Angelis (1998), spillovers from the regional stock of knowledge capital X_z are measured by

$$SPIL_{r,t} = \sum_{z=1}^{R} X_z w_{rz} = X_r w_{rr} + \sum_{\substack{z=1 \\ z \neq r}}^{R} X_z w_{rz} \tag{A.1}$$

$$= x_r \int_0^{c_r} 2\pi\tilde{c} \exp(-\beta_{E_r}\tilde{c})\, d\tilde{c} + \sum_{\substack{z=1 \\ z \neq r}}^{R} X_z \exp(-\beta_{E_r} d_{rz}) .$$

Knowledge capital utilization in the region (first term) is assumed to be evenly distributed in the area of the region F_r with the corresponding radius $c_r = \sqrt{F_r / \pi}$. The density of knowledge capital utilization is $x_r = X_r / F_r$. In the surrounding regions (second term), d_{rz} shows the distance between the region r and other regions z. β_{E_r} includes the decay parameter γ_E through

$$\beta_{E_r} = -[\ln(1-\gamma_E)] / \bar{D}_{MIN} \ . \tag{A.2}$$

$\bar{D}_{MIN}$ shows the average distance between adjacent neighbouring regions. The parameter γ_E $(0 < \gamma_E < 1)$ measures the percentage decrease of the spatial interaction, a higher value of which represents geographical impediments. Knowledge capital declines with increasing "half-distance" $d_E = \ln 2 / \beta_{Er}$, which is the distance that reduces the spatial interaction by one-half. The half-decay distance is set, on average, at 122 kilometres for educational human capital and at 289 kilometres for R&D spillovers (an average double higher in Northern Finland with long distances). This optimal distance was identified from the variation of the productivity growth effects. Half-life distance is less than that obtained for R&D international spillovers in Keller (2002), where it ranges from 162 to 1,200 kilometres. Note that these half-life distances vary from one region to another, and are greater when neighbouring regions are remote (e.g. 250 kilometres for Oulu region in Northern Finland).

Appendix B. Description of Linked Employer-Employee Data

The data are linked employer-employee data. The two parts of the data are separate and were grouped for this study. The data form an unbalanced panel with a relatively short time dimension 1996-2002. The financial data, mainly to include information on value added and capital intensity (fixed assets), come from Balance Consulting Oy and Suomen Asiakastieto and include 93,559 Finnish firms. The financial data include detailed income statements, full balance sheets and numerous key ratios for corporate analysis. The labour data are from the Confederation of Finnish Industry and Employers. The data with 3,096,771 observations cover the years 1996-2002 and include both blue- and white-collar employees. The data include a rich set of variables covering compensation, education and profession. The white-collar employees receive salaries and the blue-collar workers are remunerated on an hourly basis. The deflator used is the producer price index at the two digit level in manufacturing and three digit level in other industries, yielding 58 industries.

After some adjustment for relevant observations, the estimation for observations with a firm code totals 2,755,716 (20,796 observations discarded for having no education classifcation, 3,157 omitted for no information on seniority, 181,048 dropped for missing hourly wages, 118,243 omitted for log wages deviating more than five standard deviations from the predicted value using experience up to fourth potency, gender and 22 education classes and 17,811 observations dropped for lacking firm codes). This number reduces to 2,096,523 when only employees with estimable firm effect are included.

Following the method developed by Baldwin, Dupuy and Penner (1992), plant births and deaths are considered as a mere transfer of the plant, in instances where people employed either at the old plant at date t-1 or at the new plant at date t constitute more than 40 percent of all employees working in these plants at dates t-1 and t. Thus 43,744 individuals are in (many) small companies that are linked to a large company by giving the same firm code and 16,756 individuals are in large companies that divides into (many) small companies with the same firm code since satisfying this 40 percent criterion. These unnatural deaths and births account for approximately 3 percent of all plant births and deaths. Many of the old or new firms are large and, hence, recoding will affect 9% of employees.

Region dummies

The merged regions are Vakka-Suomi (Vakka-Suomi and Loimaa), Luoteis-Pirkanmaa (Luoteis-Pirkanmaa and Kaakkois-Pirkanmaa), Lounais-Pirkanmaa (Lounais-Pirkanmaa and Ylä-Pirkanmaa), Länsi-Saimaa (Länsi-Saimaa, Kärkikunnat, Juva, Pieksämäki), Ylä-Savo (Ylä-Savo, Koillis-Savo, Sisä-Savo), Outokumpu (Outokumpu, Ilomantsi, Keski-Karjala, Pielisen Karjala), Keuruu (Keuruu, Saarijärvi-Viitasaari), Jämsä (Jämsä, Joutsa), Seinäjoki Etelä (Seinäjoki Etelä, Kuusiokunnat, Järviseutu, Kyrönmaa), Kaustinen (Kaustinen, Oulunkaari, Siikalatva, Nivala-Haapajärvi, Ylivieska), Koillismaa (Koillismaa, Kehys-Kainuu, Torniolaakso, Itä-Lappi, Tunturi-Lappi, Pohjois-Lappi), Maarianhamina (Maarianhamina, Ålands landsbygd, Ålands skärgård, set at average value).

Table A.1 Estimates of the Effects of Experience, Year, Individuals and Firms on the Log of Wages for 1996 to 2002 with Plant Dummies and Firm-Effect

	First-Stage Eqn (8)		Second-Stage Eqn (9)	
Variable	Coefficient	Std	Coefficient	Std
Experience/10	1.239	(0.002)***	1.272	(0.001)***
$Experience^2/100$	-0.438	(0)***	-0.457	(0)***
$Experience^3$ / 1000	0.081	(0)***	0.088	(0)***
$Experience^4$ / 10000	-0.006	(0)***	-0.006	(0)***
Seniority/1000	0.361	(0)***	0.214	(0)***
Seniority/10000	0.052	(0)***	0.028	(0)***
Performance Related Pay	0.023	(0.001)***	0.026	(0)***
R&D Work	-0.063	(0.025)*	-0.016	(0.004)***
Blue-Collar Work	0.213	(0.008)***	0.233	(0.003)***
Other White-Collar Work	0.028	(0.008)***	0.036	(0.003)***
Management Accountancy	-0.008	(0.006)	-0.012	(0.002)***
Invoicing	-0.028	(0.007)***	-0.019	(0.003)***
Secreterial	-0.016	(0.005)**	-0.014	(0.002)***
Construction	0.072	(0.026)**	0.035	(0.004)***
Planning	-0.010	(0.006)	0.009	(0.002)***
Logistic	0.012	(0.004)**	0.008	(0.001)***
Customer Service	0.003	(0.002)	-0.006	(0.002)**
Marketing	0.004	(0.01)	0.013	(0.003)***
Information, data processing	-0.014	(0.009)	-0.003	(0.003)
Legislation 1	0.017	(0.005)***	0.025	(0.001)***
Legislation 2	-0.008	(0.009)	0.002	(0.003)
Office work 1	-0.005	(0.008)	0.009	(0.003)**
Office work 2	0.003	(0.009)	0.015	(0.003)***
Office work 3	-0.001	(0.007)	0.008	(0.003)**
Personnel Policy Work	-0.016	(0.01)	-0.006	(0.003)
Buyer	0.013	(0.01)	0.000	(0.003)***
Purchaser	-0.008	(0.007)	0.024	(0.003)***
Psihat			0.045	(0.002)***
Observation	285,730		2,096,523	
R squared	0.157		0.136	

Estimation includes 1,421 firm dummies and time dummies. * Significant at 95% level, ** Significant at 99% level, *** Significant at 99.9% level.

Table A.2 Education Effects

Variable	Coefficient	Std
Intercep	-47.289	(0.685)***
Upper Secondary Level		
General	0.474	(0.003)***
Teacher	0.099	(0.005)***
Humanities, Arts	0.100	(0.005)***
Natural Science	0.196	(0.02)***
Technology	0.194	(0.002)***
Health, Services, Agriculture	0.211	(0.003)***
Lowest Level Tertiary	0.075	(0.009)***
General, Teacher		
Humanities, Arts	0.294	(0.003)***
Natural Science	0.585	(0.013)***
Technology	0.207	(0.003)***
Health, Services, Agriculture	0.332	(0.009)***
Lowest-Degree, University	0.265	(0.009)***
General, Teacher		
Humanities, Arts	0.621	(0.006)***
Natural Science	0.414	(0.023)***
Technology	0.554	(0.003)***
Health, Services, Agriculture	0.608	(0.02)***
Highest-Degree, University	0.651	(0.008)***
General, Teacher		
Humanities, Arts	0.907	(0.006)***
Natural Science	0.772	(0.009)***
Technology	0.867	(0.004)***
Health, Services, Agriculture	0.893	(0.025)***
Doctoral Level	0.872	(0.011)***
Gender Effect	-0.191	(0.002)***
Number of Observations	142,810	
R-Squared	0.35	

* Significant at 95% level, ** Significant at 99% level, *** Significant at 99.9% level.

Table A.3 Total Factor Productivity Growth, Regional Effects

	OLS Industry Dummies	OLS		OLS Industry Dummies	OLS
Helsinki	0.014	0.046**	Savonlinna	-0.009	-0.071
	[0.711]	[2.050]		[0.117]	[0.962]
Vantaa	0.005	-0.042	Ylä-Savo	-0.004	-0.077
	[0.120]	[1.070]		[0.060]	[1.340]
Espoo	-0.048	0.03	Kuopio	0.017	0.015
	[1.094]	[0.688]		[0.313]	[0.292]
Helsinki area neighbours	-0.004	0.027	Varkaus	0.076	0.072
	[0.114]	[0.825]		[0.896]	[0.876]
Lohja	0.003	0.033	Outokumpu	-0.033	-0.09
	[0.054]	[0.615]		[0.536]	[1.488]
Tammisaari	-0.07	-0.059	Joensuu	0.083	0.037
	[1.207]	[1.029]		[1.275]	[0.590]
Turunmaa	-0.077	-0.101	Jyväskylä	-0.032	-0.049
	[0.760]	[1.028]		[0.744]	[1.159]
Salo	-0.066	-0.089	Keuruu	0.01	0.008
	[0.959]	[1.343]		[0.134]	[0.114]
Turku	0.054*	0.015	Jämsä	0.121	0.082
	[1.762]	[0.498]		[1.231]	[0.864]
Vakka-Suomi	0.062	-0.024	Äänekoski	0.033	-0.028
	[1.205]	[0.477]		[0.277]	[0.237]
Rauma	0.029	-0.007	Suupohja	0.290**	0.260*
	[0.600]	[0.144]		[1.985]	[1.837]
Pori	-0.007	-0.037	Seinäjoki pohjo	0.114	0.139*
	[0.179]	[0.924]		[1.466]	[1.839]
Pohjois-Satakunta	0.007	-0.011	Seinäjoki etelä	0.038	0.001
	[0.073]	[0.123]		[0.575]	[0.021]
Hämeenlinna	0.038	0.013	Härmänmaa	-0.03	-0.059
	[0.643]	[0.234]		[0.382]	[0.764]
Riihimäki	-0.041	-0.031	Vaasa	-0.001	0.01
	[0.672]	[0.511]		[0.012]	[0.179]
Forssa	-0.052	-0.081	Sydösterbotten	-0.153	0.081
	[0.657]	[1.052]		[0.626]	[0.343]
Luoteis-Pirkanmaa	0.049	-0.011	Pietarsaari	-0.025	-0.051
	[0.617]	[0.146]		[0.362]	[0.757]
Etelä-Pohjanmaa	-0.054	-0.092	Kaustinen	0.065	-0.022
	[0.633]	[1.112]		[1.169]	[0.378]
Tampere	-0.014	-0.009	Kokkola	-0.015	-0.077
	[0.551]	[0.341]		[0.221]	[1.145]
Lounais-Pirkanmaa	-0.048	-0.113**	Oulu	-0.017	-0.045
	[0.870]	[2.091]		[0.371]	[0.999]
Lahti	-0.005	-0.019	Raahe	-0.161*	-0.191**
	[0.140]	[0.542]		[1.682]	[2.058]
Heinola	-0.089	-0.104	Koillismaa	0.036	-0.01
	[1.082]	[1.289]		[0.534]	[0.147]
Kouvola	-0.047	-0.088*	Kajaani	-0.024	-0.079
	[0.867]	[1.650]		[0.249]	[0.838]
Kotka-Hamina	0.015	0.024	Rovaniemi	-0.016	-0.065
	[0.277]	[0.461]		[0.190]	[0.776]
Lappeenranta	-0.044	-0.017	Kemi-Tornio	0.005	-0.02
	[0.783]	[0.307]		[0.061]	[0.231]
Länsi-Saimaa	0.021	-0.013	Porvoo	0.178***	0.155**
	[0.256]	[0.157]		[2.643]	[2.365]
Imatra	0.014	0	Loviisa	0.053	0.057
	[0.204]	[0.006]		[0.493]	[0.536]
Mikkeli	-0.056	-0.057	Maarianhamina	-2.044	-8.392
	[0.868]	[0.908]		[0.079]	[0.337]
Observations	0	0.069*			

Absolute value of z statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimation includes industry, regional and year dummies.

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