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Intangible Capital Agglomeration and Economic Growth

A Regional Analysis of Finland

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Intangible Capital Agglomeration and Economic Growth: A Regional Analysis of Finland

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Abstract

Employing a large, linked employer–employee dataset, mixed firm and regional-level strategies related to organizational, R&D (research and development) and ICT capital (information and communication technologies) are analyzed, and their effects on economic performance are assessed. Proxy variable regressions for Finland from 1997 to 2011 yield robust evidence that internal knowledge in the form of own-account organizational, R&D and ICT capital promotes productivity and profitability whereas agglomeration benefits are more related to urbanization. Recent policy recommendations based on R&D as the preferred type of innovative effort ignore the need to simultaneously invest in core internal organizational and ICT knowledge and thus to have a comprehensive measure of the true innovation potential.

Keywords: intangible capital; organizational capital; R&D capital; agglomeration; linked employer-employee data
JEL classification: J30, O30, M12

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1 INTRODUCTION

This paper examines firm strategies for investing in productive inputs, such as organizational capital, research and development (R&D) capital and information and communication technologies (ICT) capital, as well as the regional agglomeration of this knowledge. Models of urban growth based on agglomeration economies have not typically incorporated intangible capital other than R&D (see, e.g., Fujita and Thisse 2002). While R&D creates new products and services, organizational and ICT capital is needed to market new inventions. A micro approach provides broad coverage of these primarily own-account intangibles.[2] Because organizational and R&D investment are correlated, ignoring the former may lead to biased estimates of the latter. Indeed, it would be incorrect to assume that only engineers (who are more often engaged in R&D work than individuals in other professions) are innovative and management and marketing are pure expenses for a firm. Internal knowledge, as measured by organizational investment, is created largely through firm-level management and marketing and is difficult to measure because it is not associated with any specific price mechanism. Therefore, organizational investments are typically considered expenses rather than contributions to value added over longer periods of time. However, these investments are more clearly owned by the firm than other types of intangibles (Youndt, Subramaniam and Snell 2004, Subramaniam and Youndt 2005, Lev and Radhakrishnan 2003 and 2005).

Own-account R&D is likely to be less firm-specific and compete with purchased R&D; therefore, it is more marketable than organizational capital. Thus, own-account R&D also encourages the absorption of knowledge available in the market (Cohen and Levinthan 1989). Antonelli, Patrucco and Quatraro (2011) also find that the benefits of R&D accumulation (patenting) are non-linear because R&D input costs are convex, whereas the sale of knowledge outputs provides linear revenues from licensing. The competition between firm-specific patented knowledge and purchased knowledge may explain why Singh (2008) and Lahiri (2010) obtain conflicting results on the effects of multinational firms geographically distributing R&D across the US. Firm may purchase knowledge or have interunit knowledge-sharing that enables knowledge from one location to be utilized at a different location. Audretsch and Feldman

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[2] Intangibles purchased on the market (external knowledge) such as architectural design, engineering design, new financial products and training also partly enter the intermediates used in the production of own-account intangibles. Purchased intangibles are more easily measured in the country-level estimates in Jona-Lasinio and Iommi (2011) and Corrado, Hulten and Sichel (2006).

(2004) find evidence that the correlation between R&D inputs and innovative outputs may be weak (for further evidence, see e.g., Audretsch and Feldman 1996; Jaffe et al. 1993).

Prior studies using aggregate data have demonstrated that R&D capital is spatially concentrated, with the highest R&D capital intensity in metropolitan areas and the lowest in rural areas (Duranton and Puga 2005, Markusen and Schrock 2006). Because similar agglomeration patterns may occur for organizational capital, we do not know which type of intangible capital is important for promoting regional productivity and growth. The gains from agglomeration may not only follow from an industry-specific factor, such as the presence of other organizational or R&D capital-intensive firms in the region (localization benefits), but they may also be related to the size of the city (urbanization benefits). Jacobs (1969) highlighted the benefits derived from the economic diversity associated with urbanization: ideas and innovations are transferred from one industry to another, and the literature has largely focused on the diffusion of this external knowledge.

A number of Swedish and Finnish calculations (Karlsson and Pettersson 2004, Loikkanen and Susiluoto 2011)—consistent with findings from other countries (Ciccione and Hall 1996, Ciccione 2002)—suggest that urban productivity increases by approximately 5% each time the employment density doubles. Another important geographic characteristic is the availability of a highly educated workforce. Rodriguez-Pose and Crescenzi (2008) argue that investments in a peripheral area relative to an area with intense R&D activity has low returns because of an insufficient supply of skilled labor and training. Skilled labor is a complement to all types of intangible capital. The labor market pooling of skilled workers also facilitates the job search efforts of dismissed workers in agglomerated areas where there is sufficient demand for specialized knowledge.

Finland is a small country with 5.3 million inhabitants with one metropolitan area surrounding the capital, Helsinki. It is possible to identify 55 economic areas in Finland by combining 80 NUTS 3 areas.[3] Individuals work and live in NUTS 3 areas; hence, these are the natural areas for spillovers from labor market pooling of any type. These economic areas should be considered when describing any geographically embedded innovation process in a space with its own social

[3] NUTS, Nomenclature of Units for Territorial Statistics, is a standard developed and regulated by the European Union.

and institutional conditions (Lundvall 1992, Asheim 1999). Focusing on one country also eliminates the country-level differences that are explained by country-specific institutions. The linked employer–employee data (LEED) from company balance sheets and the employee data include occupational classifications that have been harmonized across 6 countries as part of the INNODRIVE project.[4] Geppert and Neumann (2011) adopted a regional perspective based on LEED and the same occupational classification for Germany, while Riley and Robinson (2011) did so for the UK; thus, our results can be viewed from a broader perspective.

This paper also employs the Olley-Pakes (1996)/Levinsohn-Petrin (2003) method of proxy variable estimation to account for the possibility that the measures of the intangibles, particularly regional spillovers, are correlated with productivity shocks. Our findings suggest that policies to attract firms that are intensive in not only R&D but also in organizational and ICT capital are crucial to any regional policy designed to promote growth. Our results indicate clear urbanization effects but limited spillovers from high regional intangible capital intensity.

The remainder of this paper is organized as follows. Section 2 describes the dataset, the measures of intangible capital and the approach employed to evaluate the relationship between firms and their industrial environments. Section 3 presents descriptive results that indicate the regional distribution of intangible assets, technology and innovative activities in Finland from 1997 to 2011. Section 4 provides estimates of the factors that determine the productivity and wage levels of individual firms and assesses productivity and profitability. Section 5 summarizes the findings.

DATA AND MEASUREMENT

This study relies on a register-based, linked employer–employee (LEED) dataset for Finland, which combines employee data from the Confederation of Finnish Employers database and the Statistics Finland Regional Accounts database with balance sheet data collected by the private company Suomen Asiakastieto. Our primary data source is thus not a survey; rather, it provides a variety of information on occupations and the qualifications associated with them. It covers the entire business sector rather than being limited to manufacturing, as most analyses of R&D are,

[4] The countries with LEED in the INNODRIVE project financed by the EU 7th Framework Programme are Finland, Norway, the UK, Germany, the Czech Republic and Slovenia. An example is the harmonization of management and marketing in the production of organizational capital (OC). A Eurostat labor force survey of Germany estimates that management only represents a 3% share of all work, whereas the corresponding figure from the LEED data is 9%.

and approximately 80% of the firms have intangible capital workers of some type. [5] The LEED dataset from 1997 to 2011 offers information derived from employee data, such as information regarding employment, wages, and all occupations, including those related to intangible capital work, which is linked to balance sheet data (e.g., tangible capital, turnover, value added). NUTS 4 regions are merged into 55 self-contained regions, with a median population of 60,000 in 2011.

We use establishment employment data to derive firm-level variables across regions. The regional firm dummies include the share of establishment employment in each region (39% of firms have more than one establishment, or half among firms with at least 30 workers). These dummies are also used to allocate a firm's intangible capital across areas. In multiplant firms, subsidiaries often utilize the resources of larger units or corporate headquarters and may consequently create cross-border spillovers (Aarland et al. 2006, Duranton and Puga 2005). Organizational knowledge of the top management and the headquarters, typically located in a metropolitan area, thus benefits all establishments on the basis of their size. Our 13-year period ranges from the peak performance years of 1998–99 to a trough in the business cycle in 2000–01, the relatively strong growth period from 2002 to 2008 and the financial crises period 2009-2011.

2.1 Intangible capital

Organizational, R&D and ICT investments are derived from the number of employees engaged in the respective intangible investment and are adjusted to allow for the share of working time devoted to (longer term) investments. Related wage costs are multiplied by the use of capital and complementary intermediate inputs.[6] In addition to this expenditure-based approach, organizational investment is also measured on the basis of its performance. The capital stock measures are obtained using the perpetual inventory method.

In Görzig, Piekkola and Riley (GPR) (2010), intangible capital is produced by organizational (management, marketing), R&D (research, development) and ICT (information and communication technologies) occupations, where a share of these employees' effort is devoted to the production of intangible investment goods. The related intermediate and capital costs

[5] In the LEED data, services represent half of value added. Here, R&D workers include all employees with technical tertiary education and not performing another type of intangible work. Partly due to this broad definition, half of R&D investment takes place in services.

[6] Piekkola (2010) depicts the occupational structure when individuals with the lowest qualifications are excluded when employed in work other than R&D.

incurred in the production of intangible capital goods are evaluated from the input-output tables in the following business services in category 7 of the Classification of Economic Activities in the European Community (NACE Rev. 2):

- Other business activities (Nace 71) as a proxy for organizational goods,
- Research and development (Nace 72) as a proxy for R&D goods, and
- Computer and related activities (Nace 62) as a proxy for ICT goods.

Input-output tables in these business services are considered an indicator of the cost structure in the own-account production of these types of goods in the firms from other industries.[7] The nominal value of intangible capital investment of type IC, IC=OC, R&D, or ICT for firm i in industry/cluster j at time t is given by

$$P_t^N N_{it}^{IC} \equiv z_{jt}^{IC} M_{jt}^{IC} w L_{it}^{IC} \text{ with } IC = OC,\ R\&D, ICT \ , \qquad (1)$$

where labor costs are multiplied by z_{jt}^{IC}, which is the productivity/wage ratio of an intangible worker of type IC – set at unity in an expenditure-based approach – and by M_{jt}^{IC}, the combined multiplier, to assess the total investment expenditures on intangibles (as discussed), and wL_{it}^{IC} is nominal annual earnings. The parameter P_t^N is the investment deflator in business services (Nace 69-75), which is assumed to represent the deflator for intangible assets in all sectors. We use annual earnings instead of hourly wages because they include performance-related pay and workers in managerial positions are not paid for overtime hours, and their recorded hours are therefore lower than the actual number of hours. The combined multiplier M_{jt}^{IC} is the product of the shares of organizational, R&D and ICT effort that produce intangible goods and the factor multiplier from the input-output tables. The real stock R_{it}^{IC} of intangible capital of type IC for a firm i is given by

$$R_{it}^{IC} = R_{it-1}^{IC}(1-\delta_{IC}) + N_{it}^{IC},\ R_i^{IC}(0) = N_i^{IC}(0)/(\delta_{IC}+g), \qquad (2)$$

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[7] The input-output tables are from the EU KLEMS database, which is the product of the 6th framework research project financed by the European Commission to analyze productivity in the European Union at the industry level.

where $N^{IC}(0)$ is the initial investment, $R^{IC}(0)$ is the starting intangible capital stock, δ_{IC} is the depreciation rate and g is the growth of the intangible capital stock of type IC using the geometric sum formula. The initial intangible investment $N_i^{IC}(0)$ is set at the average investment over the five-year period following the first observation year. The average is used to assess the average investment rate over the business cycle. The growth rate g is set at 2%, which follows the sample average growth rate (2%) of real wage costs for intangible capital-related activities.

GPR provide the value of a combined multiplier M_{jt}^{IC}, which is time-invariant in the expenditure-based approach. The share of workers producing intangible goods is set at 40% for organizational occupations (twice the share used in GPR), 70% for R&D occupations and 50% for ICT occupations. The factor multiplier from the intermediate and capital costs is set to be representative for the entire EU27 area and is a weighted average of the factor multipliers for Germany (40% weight), the UK (30% weight), Finland (15% weight), the Czech Republic and Slovenia (both 7.5% weights).[8] The factor multipliers used to account for the use of capital and intermediate inputs are 1.76 for organizational wage expenses, 1.55 for R&D wage expenses and 1.48 for ICT wage expenses. Table 1 summarizes the combined multiplier M^{IC} (the product of the share of effort devoted to IC production and the factor multiplier) and the depreciation rates employed.

Table 1. OC and R&D&I combined multipliers in the expenditure-based approach and depreciation

	OC	R&D	ICT
Employment shares	40%	70%	50
Combined multiplier M^{IC}	70%	110%	70%
Depreciation rate δ_{IC}	20% production 25% services	15%	33%

[8] These were the countries with LEED data in INNODRIVE.

Organizational and ICT investments represent 70% of wage costs in the occupations considered (in ICT, the figure is an approximation of the combined multiplier of 0.74). In R&D activities, the total wage costs are close approximations of the total investment, with a combined multiplier of 110%. The depreciation rate for organizational investments is set at 20% in production, while the higher Corrado, Hulten, and Sichel (CHS) (2005) depreciation rate of 25% is retained in services. This higher rate is used because of the longer life cycle of an organizational investment in production. Recent estimates of depreciation from surveys by Whittard et al. (2009) and Awano et al. (2010) indicate that the R&D depreciation rate is closer to 15% than the 20% figure used in CHS. ICT investments are assigned a 33% depreciation rate.

The estimations are performed for five clusters, which are formed via the partition cluster method based on the use of factor inputs including intangibles. Each cluster is selected to minimize the differences from the median values of intangible and tangible investments. Intangible-intensive clusters are intensive in organizational, R&D or ICT investment, and thus multicollinearity issues in the cluster-specific analysis are substantially reduced. Certain service and production industries are first treated as a separate heterogeneous group that is not included in the cluster analysis: agriculture, finance, public administration, education, health, arts, entertainment and recreation and rest (Nace industries A, K, O, P, Q, R, S, T, U, and X). Clustering results in four optimal clusters with other industries forming the fifth cluster. Table 2 presents the clusters.

Table 2. Clusters and their share of total value added and the factor income shares of OC, R&D, ICT and fixed investment, %

Clusters: the largest industries and their share in the cluster in parentheses, %	Obser-vations	Cluster share of total value added	OC investment %-share of factor income	R&D investment %-share of factor income	ICT investment %-share of factor income	Fixed investment %-share of factor income
1 Fixed capital intensive 0.9: paper and pulp (0.46), transportation (0.15), electricity, gas, steam (0.09), wholesale, retail (0.07), real estate (0.04)	7,261	19.1	3.6	3.0	0.4	90.3
2 Fixed capital intensive 0.57 and OC intensive 0.0355: wholesale, retail (0.21), information (0.13), basic metal (0.08), chemicals (0.06), paper and pulp (0.05)	8,862	26.4	21.8	15.2	2.9	56.6
3 R&D intensive 0.57: construction (0.22), machinery and equipment (0.21), electrical equipment (0.1), scientific (0.06), food (0.05)	5,996	25.3	22.4	57.1	3.3	15.8
4 OC intensive 0.68: wholesale, retail (0.41), information (0.17), transportation (0.11), administrative (0.1), accommodation (0.08)	5,537	14.1	68.3	8.8	4.4	16.7
5 Other industries 0.22: arts recreation (0.16), information (0.16), financial (0.13), scientific (0.12), transportation (0.07)	4,385	15.1	25.2	16.6	2.9	52.5
All	32,041	100.0	26.3	19.4	2.7	49.1

The clusters are the following: (i) fixed capital intensive with a mean 90% factor input share, (ii) fixed capital and organizational capital intensive, where the respective factor input shares are 57% and 4%, (iii) R&D intensive, with a mean 57% factor input share, (ii) organizational capital intensive, with a mean 68% factor input share, and (v) other industries.

In what follows, we use a performance-based measure of organizational capital that fixes the total multiplier in (1) to the productivity return of accumulated organizational capital.[9] Performance-based measures of the intangible inputs are estimated using a production function that assumes constant returns-to-scale and begins with expenditure-based estimates of the intangible capital stock as an input. The explanatory variable is value added and includes

[9] Piekkola (2010) instead applies the expenditure-based measure because organizational-capital-intensive firms are underrepresented among the listed companies.

investments in all types of intangibles $Y_{it} = VALADD_{it} + \sum_{IC} N_{it}^{IC}$ for firm *i* in year *t* (the deflator for value added is producer prices). The production function for firm i in cluster j allows the quality-adjustment of labor q_{it} to change from year to year and is given by

$$Y_{it} = b_{0j}(q_{it} L_{it})^{b_{Lj}} \prod_{IC} \left(R_{it}^{IC} \right)^{b_{ICj}} K_{it}^{\ b_{Kj}} \ exp(e_{it}), \qquad (3)$$

where $b_{Lj} + \sum_{IC} b_{ICj} + b_{Kj} = 1$, $q_{it} L_{it}$ is quality-adjusted labor (L_{it} is the total number of employees, and q_{it} is the quality index), R_{it}^{IC} refers to the capital stocks of an intangible asset of type *IC*=OC, R&D and ICT, K_{it} is tangible capital (plant, property and equipment using the deflator for fixed-capital investment), and e_{it} is an error term. Following the analysis of the productivity of intangible workers as in Piekkola (2010), the quality-adjusted labor is

$$\begin{aligned} q_{it} L_{it} &= \sum_{IC} a_j^{IC,NON-IC} L_{it}^{IC} + (L_{it} - \sum_{IC} L_{it}^{IC}) \\ &= L_{it} \left[1 + \sum_{IC} (a_j^{IC,NON-IC} - 1) \frac{L_{it}^{IC}}{L_{it}} \right] \end{aligned} \quad . \qquad (4)$$

The relative rent (marginal productivity) of IC occupations differs from that of the other workers in cluster j by the factor $a_j^{IC,NON-IC}$, which should be compared to the wage ratio for IC occupations relative to non-IC occupations in industry $w^{IC,NON-ICj}$; thus z_{jt}^{IC} = $a_j^{IC,NON-IC} / w^{IC,NON-ICj}$ in (1). We can approximately write in log form $\log q_{it} = \log\left[1 + \sum_{IC} (a_j^{IC,NON-IC} - 1) L_{it}^{IC} / L_{it} \right]$ $\approx$ $\sum_{IC} (a_j^{IC,NON-IC} - 1) L_{it}^{IC} / L_{it}$ because the number of workers in organizational, R&D and ICT occupations is a minor share of all workers (the second term in squared brackets does not deviate significantly from zero). Using this log form combined with (3) and (4) yields

$$ln Y_{it} = ln b_0 + b_{Lj} \ ln L_{it} + \sum_{IC} b_{LICj} \frac{L_{it}^{IC}}{L_{it}} + \sum_{IC} b_{ICj} \ ln R_{it}^{IC} + b_{Kj} \ ln K_{it}, \qquad (5)$$

where $b_{LICj} = b_{Lj} \left(a_j^{IC,NON-IT} - 1 \right)$ and $L_{ICit} / L_{NONICit}$ is the IC type labor share in each firm. The output elasticity $\overline{b}_{ICj}$ from the estimation of (5) equals the value added share of intangible investment $\overline{b}_{ICj} = P_{jt}^R r_j^{IC} R_{jt}^{IC} / P_{jt}^Y Y_{jt}$ under constant returns, where P_t^R is the physical capital deflator in business services (71 in Nace rev. 1), which is assumed to represent the deflator for intangible capital in all sectors, P_{jt}^Y is the producer price deflator and the rental rate r_j^{IC} equals depreciation and the external rate of return of 4%. IC investment N_{jt}^{IC} (and hence $z_{jt}^{IC}M_{jt}^{IC}$ from (1)) is obtained by solving $\bar{b}_{ICj}$ using (2) in the form $R_{jt}^{IC} = N_{jt}^{IC} / (\delta_{IC} + g_{jt}^{IC}(1-\delta_{IC}))$, where $g_{jt}^{IC} = (R_{jt}^{IC} - R_{jt-t}^{IC}) / R_{jt}^{IC}$ is approximated by the growth implied by the expenditure-based estimates in industry j. Given the IC investment N_{jt}^{IC}, the total multiplier $z_{jt}^{IC}M_{jt}^{IC}$ in (1) must satisfy

$$z_{jt}^{IC}M_{jt}^{IC} = \bar{b}_{ICj}\frac{P_{jt}^{Y}Y_{jt}}{(P_t^R / P_t^N)wL_{jt}^{IC}}\frac{g_{jt}^{IC}(1-\delta_{IC}) + \delta_{IC}}{r_j^{IC}}. \tag{6}$$

The estimations are performed for five clusters that are similar to those used in Piekkola (2010). Organizational assets are on average 40% higher using the performance-based measure, see the summary in Appendix A. The performance-based approach yields a much higher value for organizational work in the organizational-capital-intensive cluster and in the cluster that is also intensive in fixed-capital investments. R&D investments are, in turn, even more concentrated in the R&D-intensive cluster, and we prefer the expenditure-based measure given its exogenous nature. Performance-based organizational capital and expenditure-based R&D capital are uncorrelated, while expenditure-based organizational and R&D capital would be highly multicollinear (with a correlation of 0.68).

2.2 Human capital

Our primary proxy for human capital is years of education (secondary or less=9 years, upper secondary=12 years, vocational =13, lower tertiary=15 years, higher tertiary=17 years, doctoral=19 years). The alternative general human capital uses the firm average for person effects in a two-way fixed-effect estimation.. The general human capital $\ln HC_k$ of employee *k* over his working career is obtained from a wage equation that is estimated using an individual-level dataset with more than 9.7 million observations of workers and 68,754 observations of firms over the period from 1995 to 2011. Estimating the human capital variable separately from firm-effects is possible due to job mobility between firms. Virtually all firms have at least one employee who was hired or left the firm, and hence human capital can be estimated separately from firm-specific effects. The wage regression only includes time-varying characteristics as the deviations from their means. The dependent variable is the log of the wage $\ln(w_{\mathrm{kit}})$ of a person *k* working in firm *i* at time *t*, measured as the deviation from the individual mean μ_{wk}. This variable is expressed as a function of individual heterogeneity, firm heterogeneity, and measured time-varying characteristics as follows

$$\ln(w_{\mathrm{kit}}) - \mu_{wk} = \theta_k + \psi_{i(k,t)} + \beta(x_{kt}^{\exp} - \mu_i^{\exp}) + e_{kit} \,. \tag{7}$$

where θ_k is the time-invariant general human capital (the individual fixed effect), $\psi_{i(k,t)}$ captures the effect of unmeasured employer heterogeneity, and *i(k,t)* indicates employer *i* at date *t*. The expression $\beta(x_{kt}^{\exp} - \mu_i^{\exp})$ indicates the compensation for time-varying, experience-based human capital, which is stated as the deviation from the individual mean, and e_{ijt} represents a statistical error term. Experience-based human capital includes both work experience and seniority.[10, 11] From the estimation of (7), experience capital is

$$HC_{kt}^{\exp} = \sum_{b=1\ldots4} \beta_b^{\exp}(x_{kt}^{\exp})^b + \sum_{c=1\ldots2} \beta_c^{sen}(x_{kt}^{sen})^c \tag{8}$$

where work experience (exp) has been evaluated up to the fourth power and seniority at firm (sen) up to the second power. The effect of education is obtained in an OLS regression that explains the average human capital effect of worker k by education and female dummies

$$\theta_k = \sum_{a=1\ldots20} \beta_a^{edu} x_{a,k}^{edu} + \beta^{fem}\mathrm{female} + e_k \,, \tag{9}$$

where 20 educational capital dummies $x_{a,k}^{edu}$, k=1,…,20 account for the degree of educational attainment and which distinguish between technical and non-technical education (with elementary education as the reference) and the regression includes a female dummy (e_k is the

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10 Experience is measured by age minus years of education minus age when beginning school, and seniority is the amount of time spent on the job measured in years.

11 Abowd, Creecy, and Kramarz (2002) developed a numerical solution to address a large set of firm dummies when evaluating both individual and firm fixed effects simultaneously. We use the method applied in Stata by Ouazad (2008).

residual). Unobserved human capital is the individual fixed effect less the effect of education and experience capital.

$$HC_{kt}^{unobserved} = \theta_k - \sum_{a=1...20} \beta_a^{edu} x_{a,k}^{edu} - HC_{kt}^{\exp}, \quad (10)$$

Unobserved human capital is negatively correlated with the effect of education (-0.74), and hence years of education are used in the estimation (with a correlation of -0.31 with unobserved human capital). The variation in the unobserved human capital component addresses some of the institutional constraints, including regional ones, which were suggested as a component of general human capital by Iranzo et al. (2007). Similar to years of education, experience and unobserved human capital are treated as an average over the employees employed by the firm in year t.

REGIONAL DISTRIBUTION OF INTANGIBLE CAPITAL AND ITS COMPONENTS

Glaeser and Maré (2001), Head and Mayer (2004), and Rosenthal and Strange (2003), among others, find that wages and productivity are substantially higher in dense areas than in non-agglomerated regions. Another stylized fact from empirical research is that externalities are subject to steep decay with distance. Most studies found that the relevant ranges for externalities are well below 100 kilometers (Duranton and Overman 2005, Graham 2008, Henderson 2003), whereas only a few have found evidence of somewhat more extensive externalities (Rodriguez-Pose and Crescenzi 2008). This study employs sufficiently small regions to form reasonable labor market pools. Typically, such pools include a city and 4–5 surrounding municipalities (following NUTS 4), where no decay parameter needs to be employed. The surrounding regions generally have another city center, and we have not attempted to evaluate the decay parameter for this neighboring cluster. The functional planning regions are derived by merging the northern Finland NUTS 4 regions into larger units and dividing the greater Helsinki area (1.44 million inhabitants) into Helsinki, Vantaa, Espoo and satellite municipalities (371 thousand inhabitants).[12]

[12] The satellite regions are Hyvinkää, Järvenpää, Karkkila, Kerava, Kirkkonummi, Lohja, Mäntsälä, Nurmijärvi, Pornainen and Vihti.

Four settlement types are also considered:

(1) The Helsinki metropolitan area, with a population of 1.4 million;

(2) Four small metropolitan areas with core cities with populations ranging from 100,000 to 400,000 inhabitants: Tampere, Turku, Oulu and Lahti;

(3) The 10 small cities with population densities greater than or equal to 30 inhabitants per square kilometer of land and Kuopio with 216,000 inhabitants (Etelä-Pirkanmaa, Hämeenlinna, Jyväskylä, Kotka-Hamina, Pori, Porvoo, Rauma, Riihimäki, Vaasa, Kuopio); and

(4) The 39 rural regions that have population densities lower than 30 inhabitants per km^2 of land.

Urbanization effects include, in addition to spatial productivity, hierarchy dummies for areas ranging from large metropolitan regions to rural regions in terms of employees per square kilometer of land.

A total of 50% of intangible capital is located in metropolitan areas, where 30% of the population resides. If intangible capital were allocated based on the locations of the firms' main establishments, the share would have increased to 58%. The regions that attract one component of intangible capital tend to also attract the other components. The geographical correlation between performance-based organizational capital and R&D capital is high, $R^2 = 0.56$ ICT capital is also highly correlated with other intangibles, especially with R&D capital $R^2 = 0.92$.[13] Therefore, regional intangibles are considered jointly.

General human capital is the average over the establishments in the region, thus ignoring the skills employees have in other regions even if they belong to the same firm. The potential source of externalities is switching plants in the area, whereas job mobility across regions is limited. Educational capital (years of education) is somewhat less correlated with the metropolitan dummy (R-squared 0.30) and industrial diversity (R-squared 0.21) than is general human capital (the R–squared value is 0.42 for the metropolitan dummy and 0.23 for industrial diversity).

Industrial diversity is measured using the inverse Herfindahl index (Henderson 2003):

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[13] R^2 values from individual regressions using logarithms.

$$D_j = 1/\sum_j \sqrt{\frac{L_{jr}}{L_r} - \frac{L_j}{L}} \quad , \tag{11}$$

which calculates the inverse of the sum of the squared differences between the employment shares of industry j in region *r*, L_{jr} / L_r, and the national economy, L_j / L (for 76 industries). Higher figures suggest that workers are more dispersed across industries in the region than in the economy at large. Next, we cross-tabulate the intangible capital per worker for particular regions and determine their labor productivity and hourly wages in 2011. The y-axis in Figure 1 measures hourly wages, and Figure 2 depicts productivity, while the x-axes of these figures measures intangible capital per hour worked.

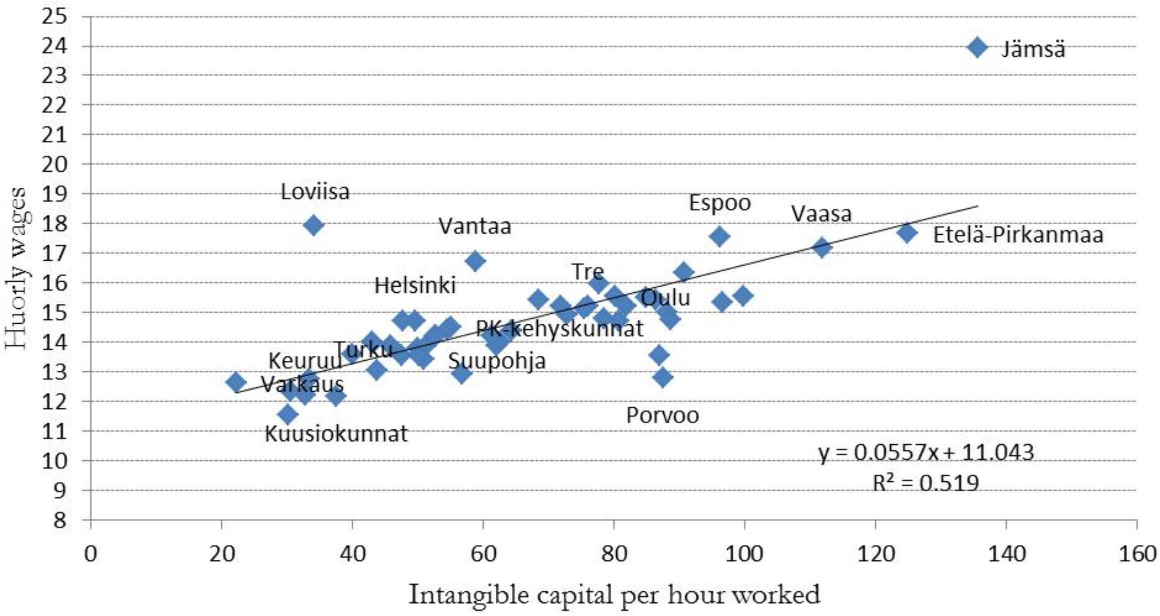

Figure 1. Regional hourly wages in 2011

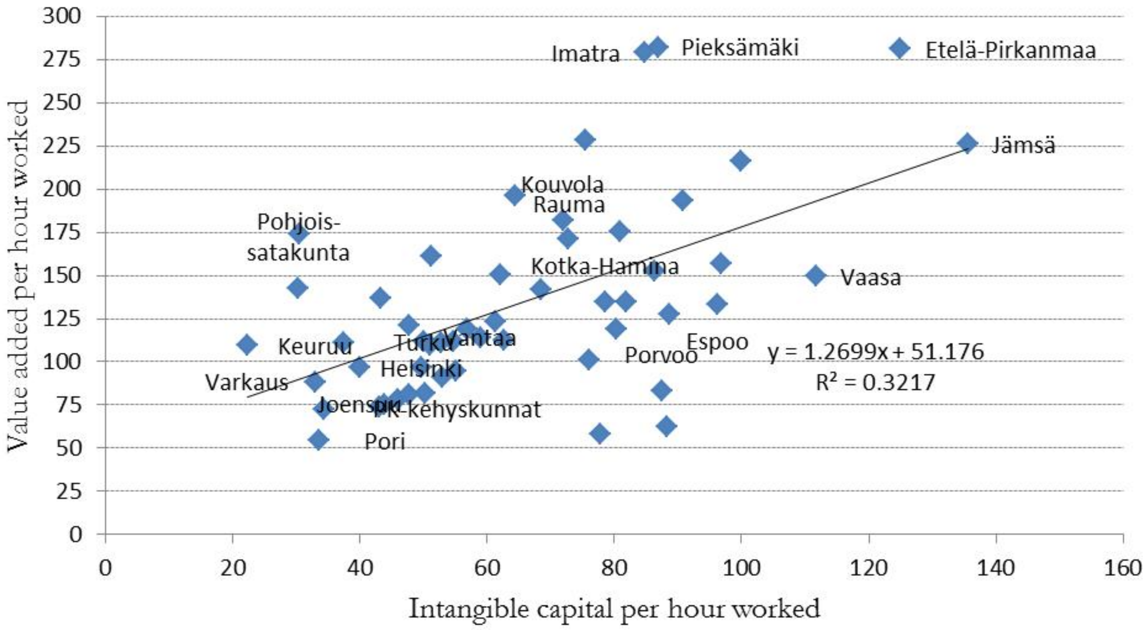

Figure 2. Regional productivity in 2011

There is a positive correlation at the regional level between intangible capital per worker and hourly wages (R^2=0.52 in Figure 1) and between intangible capital per worker and labor productivity (R^2=0.31 in Figure 2). Finland has a lower correlation between intangible capital intensity and productivity than that obtained for Germany (R^2=0.80) in Geppert and Neumann (2011), as certain NUTS 4 areas, such as the paper and pulp industry in Joensuu and the logistic clusters in Suupohja, have low intangible capital per worker and high value added per employee.

ESTIMATION

This section analyzes firm strategy by considering the use of skills, intangible capital and regional spillovers to improve performance. The descriptive statistics, including the correlation table, are summarized in Appendix B. The sample includes approximately 4,241 firms, of which 2,460 have more than 30 employees on average. The sample firms are responsible for 40% of the value added and 31% of employment in the non-farm private business sectors, comprising 447,000 employees annually on average.[14]

[14] Agriculture, mining, public administration, education and household activities are not included in the analysis.

We chose explanatory variables following the well-established assumption (when regional and industry effects are not taken into account) that establishments in urban areas and areas that are intensive in intangible (R&D) and human capital may be more productive. The dependent variables ($\ln P_{it}$) are labor productivity $\ln Y / hour_{it}$ and hourly wages $\ln w_{it}$. The explanatory variables include the performance-based measure of organizational capital $\ln K_{it}^{OC} / hour_{it}$ and the expenditure-based measures of R&D and ICT capital $\ln K_{it}^{R\&D} / hour_{it}$ and $\ln K_{it}^{ICT} / hour_{it}$. The organizational capital per hour worked using the performance-based is €17 (and €12 using the expenditure-based measure), R&D capital per hour worked is €19 and the ICT capital per worker is €2.6. Intangibles together equal one-fourth of the tangible capital per hour worked.[15] We estimate the following equation:

$$\ln P_{it} = b_{0i} + \alpha_i X_{it} + \beta_{rt} \ln R_{rt} + \ d_t [Year] * IND_{jt} + e_{it} \quad , \qquad (12)$$

where X_i indicates the characteristics of firm i (i.e., intangible capital, tangible capital, human capital); R_{rt} represents the regional intangible capital per worker, the regional general human capital and other urbanization and localization effects (i.e., employees per km^2 of land, industrial diversity, and settlement type of the region). The settlement type dummies are equal to the regional establishment's share of the total employment of the firm across regions; thus, these dummies receive a value of one if the firm has only one establishment. The time-industry fixed effects $d_t [Year] * IND_{jt}$ control for national shocks to productivity in three industries: manufacturing, non-manufacturing production and services. Firm size dummies are not used because they would capture a significant share of the effect of intangible capital. R&D capital per worker and organizational capital per worker are approximately twice as large in small firms with an average of below 30 employees than in the rest of the firms. Small firms that are members of the Employee Federation are hence biased towards being knowledge intensive.

We assume that intangible capital is a state variable that does not immediately adjust to productivity shocks, in contrast to firms' hiring and intermediate input decisions. The proxy

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[15] The preferred performance-based organizational capital estimate is uncorrelated with R&D capital per hour worked (-0.12), while experience-based organizational and R&D capital per hour worked would be correlated (0.32). ICT capital per worker hour is also relatively uncorrelated with R&D capital per hour (around 0.12) and performance-based organizational capital (0.07).

variable estimation introduced by Olley and Pakes (1996) accounts for the possibility that the lagged values of intangibles are still correlated with productivity shocks.[16] The earlier literature used materials or investment as proxies for capital accumulation, whereas Ilmakunnas and Piekkola (2013) innovatively combine the hiring rate for all workers and the use of materials as proxy variables for productivity shocks.[17] The hiring rate is defined as the number of firm employees in the final quarter of year *t*, but not in the previous year, divided by the average employment in periods *t* and *t*-1.[18] Hiring h_t and intermediate inputs m_t in period t are a function of the period *t*-1 state variables $\ln K_{ICt-1} / hour_{it}$, IC=OC; R&D; ICT, $\ln K_{TANt-1} / hour_{it}$ and the productivity shock s_t. Inverting this relationship yields the productivity shock s_t as a function of the state variables lagged by one and two periods, $s_t = f^{-1}(\ln K_{IC} / hour_{it-1}, \ln K_{TAN} / hour_{it-1}, \ \ln K_{IC} / hour_{it-2}, \ln K_{TAN} / hour_{it-2}, h_t, m_t)$.

In the first step, we estimate the production function by including as controls the polynomials of the proxy and lagged state variables and their interactions to approximate the true, unknown relationship among the variables. The first stage gives the coefficients for human capital and the regional variablesand sheds light on the firm-specific shocks in terms of the estimated polynomial and intangible variables. In the second step, assuming a second-order Markov process for the productivity shock given the two proxies, we regress the log of the dependent variable minus the contribution of the variable inputs on the intangible variables and a polynomial of the lagged shocks. We also control for the selectivity caused by firm exits. A firm's exit probability in the unbalanced panel is explained by the state variables (organizational, R&D, ICT capital per hour), educational capital, financial position (own capital/all capital, long-term debt, log of the operating margin), firm age and the dummies for three industries, years and their interaction. The predicted probability is used as an additional variable in the second step (see Ilmakunnas and Piekkola (2013) for a further description of the method).

The productivity and wage effects of intangible capital are compared by applying the methodology of Hellerstein et al. (1999) as employed by Ilmakunnas and Piekkola (2013). The

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[16] The estimation procedure is an adaptation of that used by Yasar et al. (2008).
[17] Ilmakunnas and Piekkola combine these instruments in the benchmark approach. The difference when only one instrument (hiring) is used is not large.
[18] Note that hiring that is reversed during the year is not observed. Therefore, the hiring rate is greater than or equal to zero but cannot exceed 2 (which would be the case assuming the entry of a new firm).

crucial factor in the location decision for any firm is not productivity; rather, it is the potential profitability of economic activity in the region. The difference between the coefficients of the intangible capital variables (i.e., OC, R&D capital and ICT capital), human capital and regional effects in the productivity equation and the wage equation is defined as the productivity–wage gap for the respective variables (Ilmakunnas and Maliranta 2005, Ilmakunnas and Piekkola 2013).[19] The productivity–wage gap reflects the degree to which intangible capital, human capital and regional effects improve profitability (i.e., the portion of improved productivity that is not paid out in the form of higher wages). For example, employees of firms located in metropolitan areas exhibit wage levels that are 10% higher than those in rural areas, even after all of the controls are considered. Higher wages in metropolitan areas may be explained by higher costs of living rather than by higher productivity. Similarly, Hellerstein et al. (1999) find that the productivity of managers exceeds their wages.[20] This effect cannot be explained by any standard theory of labor economics. Ilmakunnas and Piekkola (2013) also find that in Finland, organizational, R&D and ICT workers significantly increase profitability.

In Table 3, the shares of variation explained in the full model are approximately 17% for labor productivity and 62–71% for hourly wages.

[19] Hellerstein et al. (1999) analyzed these values using a systemic estimation, while we separately estimate productivity and wage regressions and use a linear approximation rather than a nonlinear estimation.
[20] One additional explanation is that managers are partly remunerated in shares; therefore, their wages do not reflect their full remuneration. Rent sharing has also become more common but is not typically intended to provide employees with all benefits. Finally, the profit maximizing labor productivity decisions of firms depend not only on the technology of the production function, but also on the demand function in the product market and the supply function in the labor market.

Table 3. Labor productivity and annual earnings, proxy variable estimation

	Labor productivity		Hourly wages	
Organizational capital per hour worked	0.0345**	0.0251*	0.0142***	0.00976***
	(3.04)	(2.43)	(5.96)	(6.67)
R&D capital per hour worked	0.0439**	0.026	0.0255***	0.00784***
	(4.39)	(1.67)	(1.29)	(3.49)
ICT capital per hour worked	0.0950***	0.0785***	0.0205	0.00835
	(11.11)	(3.68)	(3.01)	(1.11)
Tangible capital per hour worked	0.188***	0.185***	0.00694**	0.00147
	(0.62)	(10.71)	(1.93)	(0.88)
Regional intangible capital per hour worked	-0.0164	-0.0377	0.0326***	0.0297***
	(0.6)	(1.44)	(6.49)	(6.94)
Education, years	0.00974	0.0678***	0.0782***	0.131***
	(1.23)	(7.43)	(53.45)	(88.36)
Experience capital		1.175***		1.786***
		(5.39)		(50.32)
Unobserved human capital		0.528***		0.480***
		(12.51)		(69.76)
Regional general human capital	0.13		0.0907***	
	(0.9)		(3.36)	
Employees/land km^2 in the region		0.0244***		0.00297**
		(4.27)		(3.19)
Industrial diversity	-0.0261*	-0.0381**	-0.00544*	-0.0035
	(2.18)	(3.09)	(2.46)	(1.74)
Metropolis	0.160***	0.0351	0.0961***	0.0487***
	(6.15)	(1.14)	(19.97)	(9.76)
Small metropolis	0.114***	0.0904***	0.00876*	0.00347
	(4.97)	(3.93)	(2.07)	(0.93)
Small city	0.131***	0.115***	0.000943	-0.0044
	(5.9)	(5.16)	(0.23)	(1.21)
Observations	21140	21140	21140	21140
R Squared	0.165	0.172	0.621	0.71

All figures except for the human capital variables and dummies (and hiring in the proxy variable estimation) are in logs. The year and industry dummies and their interactions are included. The proxies in the proxy variable estimation include the hiring rate and the use of materials up to the fourth potency and their interactions, lagged organizational capital per hour worked, lagged R&D capital per hour worked, lagged ICT capital per hour worked and lagged tangible capital per hour worked up to fourth potency and their interactions. The number of repetitions in the bootstrap is 30.

p values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A 10% increase in organizational capital per hour (an average of €17), R&D capital per hour (€19) or ICT capital per worker (€6.4) improves labor productivity by approximately 0.4%, or 0.9% for ICT capital (Table 1, column 1). One year of additional education increases labor productivity by 0.9%, but the coefficient is insignificant. The effect of intangible capital on hourly wages is half this size, while hourly wages and educational attainment are closely related. One additional year of education increases hourly wages by 8%, which is in line with numerous other studies. The second proxy variable estimation includes experience-based capital and unobserved human capital as explanatory variables. Both the productivity and profitability effects of intangible capital decrease, but the relative difference – i.e., the profitability effects – does not. The profitability effects of years of education also remain unchanged. Experience-based capital and unobserved human capital also appear important but have negative effects on profitability. A basic finding from these two sets of explanatory variables is that intangible capital has a strong independent effect on profitability by increasing productivity. Second, human capital tends to increase wage costs by at least as much as productivity.

It is also interesting to consider the profitability effects of regional variables. Previous studies have shown that workers with high observed and unobserved skills tend to gravitate toward metropolitan areas. As a result, wage levels increase in those areas (Borjas et al. 1992).[21] Regions with higher shares of educated employees exhibit higher earnings, while their labor productivity changes insignificantly. The concentration of highly educated workers in specific regions as such is not related to better performance by firms located there.

Here, regional intangible capital is assumed to benefit from the intangible activity of the companies located elsewhere to the degree that they have establishments in the area. The innovation activity that is highly concentrated in metropolitan area is thus distributed to the regions depending on the share of total national employment in the area. Such regional intangible capital has no significant effect on productivity, while it increases the wage level.

The metropolitan dummy remains positive and is larger in the productivity than in the wage regression. Employment density in the second estimation also has a higher positive elasticity of 2.5% for productivity than the respective elasticity of 0.3% for wages. Firms in small metro and city regions now have higher productivity than that expected by the linear relationship between productivity and employment density. The agglomeration effect is thus primarily explained by urbanization effects, as observed in Bertinelli and Strobl (2007) and Glaeser and Gottlieb (2009). Glaeser and Maré (2001) and Yankow (2006) argue that the higher wage costs in agglomerated

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[21] For spatial sorting on regional wages, see Combes, Duranton and Gombillon (2008).

regions areas most likely result in part from higher costs of living, but the positive productivity effects are more important.

The localization effects of a less diversified industrial structure are more prominent among R&D-intensive firms. Industrial diversity does not contribute to either productivity or hourly wages.

Table 4 presents the weighted averages of the total firm-level gaps between productivity (measured using hours worked) and hourly wages. The productivity–wage gap observed from 1998 to 2011 is presented as follows: (1) intangibles per worker within the firm (divided into organizational, R&D and ICT capital effects), (2) regional intangibles, (3) human capital (years of education or, in the second estimation, including experience-based capital and unobserved human capital), (4) regional human capital, (5) employment density, and (6) the remaining urbanization effects: regional dummies and industrial diversity. The productivity–wage gap for intangibles per worker within the firm is measured based on a 10% increase in intangibles per worker.

Table 4. The productivity–wage gap as explained by organizational capital, R&D&I capital and other urbanization and regional effects.

	Productivity-wage gap	
	First	Second
Intangibles (10% increase)	0.09	1.20
Organizational capital (10% increase)	0.03	0.19
R&D capital (10% increase)	0.04	0.56
ICT capital (10% increase)	0.03	0.45
Regional intangibles	-0.01	-0.19
General human capital	0.17	-1.27
Regional human capital	0.00	0.09
Employees/land km^2 in the region		0.09
Regional urbanization	0.06	-0.03

Regional urbanization includes regional dummies and industrial diversity. General human capital in the second estimation is measured by the total effect of education, in years, experience capital and unobserved human capital.

Table 4 confirms that the productivity–wage gap created by intangible capital is, on average, positive. Thus, a 10%-increase in intangible capital intensity increases profitability by approximately 0.9%. The increase in profitability is equally attributable to organizational, R&D

and ICT investments. It should be noted that tangible capital has an even greater effect (not reported here). In the second estimation, the profitability effects are more pronounced. The higher wages in companies with intangible investments appear to be explained by experience-based capital, unobserved human capital and urbanization effects, for which we now control. This is also in line with a monopsonistic market for skilled workers in which wages are relatively fixed and firms reap the rents from intangible investment. As discussed above, unobserved human capital and urbanization may capture other institutional factors that explain wages such as strong labor unions or competition in the demand for skilled workers in densely populated areas.

Piekkola and Åkerholm (2013) analyzed analogous clusters and found that firms investing in either tangible or intangible capital have increased productivity, whereas labor-intensive firms with poor intangible and physical capital intensity have lost market share. Our results also reveal that intangible and tangible investments improve profitability. The productivity–wage gap is ambiguous for human capital (positive in the first and negative in the second estimation). Overall urbanization effects are evident when including employment density in the second estimation, while regional intangibles have insignificant spillovers that affect profitability.

ROBUSTNESS CHECK

Table A.2 in Appendix A reports the fixed effect and Table A.3 the OLS estimations. The fixed effect estimate controls for time-invariant, firm-level effects such as other organizational competences that can explain both an increased use of intangibles and greater productivity. Organizational capital is also assessed using expenditure-based estimates, and alternatively, all intangibles rely on the performance-based estimates. Columns 2 and 6 of Table A.2 indicate that explanatory variables have roughly the same coefficients for intangible capital when fixed effects are included as those shown for the first model in Table 3. In column 1, the coefficient estimate for expenditure-based organizational capital is higher than in the proxy variable estimation. The important observation is that the regional effects are biased upwards for regional intangible capital but in a way that profitability declines. Regional general human capital still appears to create no spillovers. The overall conclusion is thus that time-varying productivity shocks bias the productivity and wage effects in the same direction, meaning that the implications for profitability remain unchanged.

The OLS estimates in Table A.2 generally yield lower intangible capital productivity effects than previous estimates, and the same is true with respect to the wage effects, except for ICT capital per hour. The latter is likely attributable to the sensitivity of ICT activity to productivity shocks. The effects of regional intangible capital are biased upwards, as in the fixed effect estimation. One can conclude that notable biases influence the firm and, especially, regional effects identified using OLS, and some evidence such as regional intangible capital spillovers in both OLS and FE effect estimates do not hold in the proxy variable estimation.

A considerable positive relationship also exists between employment density and regional general human capital (R^2=0.52) and regional intangible capital (R^2=0.18). The employment density elasticity was 2.4% in the proxy variable estimation and 3.2% in the ordinary least squares (OLS) estimation with respect to labor productivity, and in both the proxy variable and OLS estimations was 0.3% with respect to the log of hourly wages (with respect to labor productivity, the elasticity is approximately unchanged at 3.1% when only industry and year dummies and their interactions are used as controls).[22] Most studies also value the elasticity of productivity with respect to density at between 2% and 6% (Ciccone 2002, Combes et al. 2008, Gebbert and Neumann 2011, Puga 2010, Rice and Venables 2004, Riley and Robinson 2011). The urbanization effects are thus of the same magnitude as in other studies and tend to be higher for productivity than for wages.

CONCLUSIONS

This study adopted a bottom-up approach in which firms, rather than regions, are the main actors. We identify organizational, R&D and ICT capital as competing tools for improving firm and regional performance. The organizational, R&D and ICT capital possessed by firms are important intangibles assets to increase productivity and profitability but generate relatively few regional productivity spillovers. Intangibles are thus strongly firm-specific capital. One reason can be that the agglomeration effects may appear in a more limited space than in a city area such as the within 6 km distance found by Van Soest et al. (2006).

[22] Employment density is log of workers per square kilometer of land.

Countries should design their economic policies to support intangible-capital-intensive firms of all types, efforts which have largely been neglected to date. Technology and service companies oriented business centers should also measure adequately the growth potential in intangible capital of the businesses, which would also help the appropriate valuation of the technology companies in merges and acquisitions. Intangible capital as measured here has a strong additional explanatory power with respect to improvements in not only productivity but also profitability. Piekkola (2010) find also intangible capital to explain market values of listed companies well beyond that explained by economic forecasts.

In contrast, human capital increases earnings to a greater extent than productivity and hence may decrease the market value of the companies. Regional human capital also contributed to regional wages while having a more limited effect on productivity. This is not to say that intangible-intensive firms would not demand skilled workers. Regional policies can be designed to provide a *sufficient* level of educational skills, which as such primarily improve intangible capital accumulation. Much of the wage effects were explained by employment density and, likely, institutional factors related to strong unions.

Moreover, industrial diversity has not improved productivity, at least at level of aggregation measured here and when considering intangible as a whole when analyzing the spillovers. High-productivity firms do benefit from urbanization and thus from links to city regions and areas with higher employment densities, and these accumulation effects are stronger for productivity than for wages. Beugelsdijk (2007) lists a range of explanations for these results that are rooted in economic geography, from labor pools to branding for high visibility in cities, which allows firms to be taken seriously by customers. Another potential explanation is that competition is more intense in urban areas, which drives down margins– also in the use of intermediate inputs – and finally leads to the creative destruction of low-productivity firms.

Firms may also choose to locate in metropolitan areas because managers are attracted to cities with a wide range of consumption opportunities. Certain cultural opportunities (e.g., opera) are often only available in large cities. In the latest corporate survey by the Finnish Chambers of Commerce in 2011, the security and attractiveness of the region was the third-most important factor for location decisions of new establishments.

Intangible capital is thus an essential tool to maintain productivity growth and will be all the more important when manufacturing and hence fixed capital investments are declining. Future work should also exploit LEED data in combination of the type of R&D using company patenting patterns which was found important for R&D spillovers in Deltas and Karkalakos (2013).

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APPENDIX A Summary and robustness check estimations

Table A.1 Summary and correlations

Variable	Mean	Stand. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Log of labor productivity after all inputs	4.0	0.94																
2 Log of hourly wage	2.5	0.26	0.35															
3 Performance-based organizational capital per hour	17.0	25.0	0.14	0.23														
4 Organizational capital per worker	12.0	12.0	0.27	0.55	0.56													
5 R&D capital per worker	19.0	31.0	0.08	0.37	-0.12	0.32												
6 ICT capital per worker	2.6	6.4	0.18	0.35	0.07	0.18	0.12											
7 Tangible capital per worker	130.00	1224.00	0.20	0.10	0.05	0.24	0.03	0.10										
8 Firm-level regional intangible capital per worker	19.00	6.90	0.12	0.41	0.08	0.26	0.19	0.13	0.04									
9 General human capital (education, years)	-0.01	0.14	0.28	0.65	0.21	0.57	0.40	0.33	0.13	0.21								
10 Educational capital	12.00	1.100	0.26	0.61	0.05	0.53	0.50	0.26	0.16	0.34	0.70							
11 Experience capital	0.29	0.03	0.13	0.20	0.15	0.17	-0.03	0.06	0.06	0.03	0.09	-0.02						
12 Unobserved human capital	-6.60	0.20	0.03	0.10	0.14	0.17	0.10	0.10	0.03	-0.11	0.45	-0.14	-0.10					
13 Regional general human capital per worker	-0.04	0.06	0.10	0.26	0.11	0.22	0.10	0.12	0.00	0.45	0.36	0.27	-0.04	0.15				
14 Regional industrial diversity	2.00	0.63	0.06	0.17	0.11	0.17	0.07	0.08	0.00	0.22	0.23	0.21	-0.05	0.06	0.48			
15 Metropolis	0.35	0.46	0.14	0.32	0.15	0.28	0.08	0.14	0.03	0.32	0.42	0.30	-0.04	0.17	0.65	0.46		
16 Small metropolis	0.21	0.39	-0.10	-0.09	-0.06	-0.08	0.02	-0.07	-0.04	-0.04	-0.13	-0.05	-0.03	-0.05	-0.11	-0.39		
17 Small city	0.17	0.36	0.05	-0.08	-0.03	-0.07	-0.01	-0.05	0.00	0.06	-0.11	-0.08	0.06	-0.07	-0.24	-0.40	-0.19	

Labor productivity and intangible assets in thousands of € at 2000 producer prices and hourly wages in thousands of € at 2000 wage index prices. In labor productivity, the value added includes intangible investment. Organizational, R&D and ICT capital investment and capital are reported for non-zero values.

Table A.2 Productivity and wage effects of intangible capital, fixed effect estimation

	Labor productivity				Hourly wages			
	Experience-based organizational	Basic	Performance-based intangibles	Basic with experience and unobserved human capital	Experience-based organizational	Basic	Performance-based intangibles	Basic with experience and unobserved human capital
Organizational capital per hour	0.0539***	0.0335***	0.0521***	0.0463***	0.0186***	0.0390***	0.00201***	0.0111***
	(12.18)	(5.93)	(23.53)	(10.42)	(20.97)	(34.9)	(4.43)	(13.46)
R&D capital per hour worked	0.0404***	0.0388***	0.0721***	0.0328***	0.0146***	0.00993***	0.0103***	0.00446***
	(8.63)	(8.16)	(13.01)	(6.92)	(15.54)	(10.59)	(9.01)	(5.1)
ICT capital per hour worked	0.109***	0.115***	0.0352***	0.0979***	0.0292***	0.0287***	0.0111***	0.0179***
	(12.43)	(13.14)	(6.59)	(11.18)	(16.55)	(16.53)	(10.09)	(11.01)
Regional intangible capital	0.0335	0.0373*	0.0395*	0.0374*	0.0424***	0.0438***	0.0454***	0.0540***
	(1.85)	(2.06)	(2.2)	(2.07)	(11.63)	(12.18)	(12.27)	(16.08)
Tangible capital per hour worked	0.244***	0.247***	0.235***	0.243***	0.00460***	0.00486***	0.00612***	0.00274***
	(63.51)	(64.11)	(61.12)	(63.22)	(6.05)	(6.49)	(7.89)	(3.92)
Educational capital	0.0825***	0.0811***	0.112***	0.121***	0.0883***	0.0765***	0.101***	0.143***
	(11.07)	(10.46)	(15.92)	(13.77)	(58.78)	(49.73)	(69.04)	(87.29)
Experience capital	-	-	-	2.304***	-	-	-	1.460***
				(12.85)				(43.96)
Unobserved human capital	-	-	-	0.199***	-	-	-	0.323***
				(6.46)				(56.35)
Regional general human capital per hour worked	-0.00274	-0.00249	-0.0033	-0.00221	0.000567	0.000873	0.000639	0.00138
	(0.42)	(0.38)	(0.51)	(0.34)	(0.43)	(0.67)	(0.48)	(1.14)
Metropolis	0.0259	0.0281	0.0309	0.0102	0.0471***	0.0444***	0.0546***	0.0196*
	(0.59)	(0.64)	(0.71)	(0.23)	(5.34)	(5.1)	(6.1)	(2.41)
Small metropolis	0.0403	0.0409	0.0272	0.0287	0.0346***	0.0344***	0.0357***	0.0195*
	(0.84)	(0.86)	(0.58)	(0.6)	(3.61)	(3.64)	(3.66)	(2.21)

Small city	-0.00995	-0.0138	-0.0172	-0.018	0.0116	0.0091	0.0108	-0.00293
	(0.21)	(0.29)	(0.37)	(0.38)	(1.23)	(0.98)	(1.12)	(0.34)
Constant	2.104***	2.101***	1.932***	2.300***	1.258***	1.364***	1.123***	2.314***
	(20.22)	(19.83)	(19.21)	(12.22)	(59.99)	(64.88)	(54.22)	(66.19)
Observations	0.469	0.47	0.465	0.468	0.0948	0.0935	0.0963	0.087
R Squared within	0.742	0.741	0.737	0.741	0.789	0.777	0.801	0.759
Sigma_u	0.795	0.795	0.775	0.78	0.184	0.175	0.158	0.159
Sigma_e	0.469	0.47	0.464	0.465	0.0946	0.0933	0.087	0.0871
Rho	0.741	0.741	0.736	0.737	0.79	0.778	0.766	0.768

Notes. All of the figures except for human capital variables and the dummies are in logs. The year and industry dummies and their interactions are included.

p values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.3 Productivity and wage effects of intangible capital, OLS estimation

	Labor productivity		Hourly wages	
Organizational capital per hour	0.0282***	0.0130**	0.0297***	0.0179***
	(6.49)	(2.98)	(35.05)	(24.39)
R&D capital per hour worked	0.0309***	0.00521	0.0415***	0.0203***
	(5.53)	(0.89)	(40.17)	(21.26)
ICT capital per hour worked	0.213***	0.188***	0.0568***	0.0384***
	(24.35)	(21.22)	(30.9)	(22.07)
Regional intangible capital	0.00171	0.0574**	0.0425***	0.0462***
	(0.08)	(2.96)	(10.22)	(14.34)
Tangible capital per hour worked	0.165***	0.161***	0.0128***	0.00810***
	(40.61)	(39.29)	(18.74)	(13.47)
Educational capital	0.0638***	0.126***	0.0737***	0.119***
	(10.94)	(18.56)	(63.55)	(88.1)
Experience capital	-	1.264***	-	1.657***
		(8.42)		(61.1)
Unobserved human capital	-	0.605***	-	0.428***
		(21.71)		(69.42)
Regional general human capital per hour worked	0.0544	-0.272*	0.0411	-0.0336
	(0.44)	(2.17)	(1.73)	(1.54)
Regional industrial diversity	-0.0102	-0.011	- 0.00667***	-0.00432**
	(1.01)	(1.16)	(3.51)	(2.65)
Employees/land km2 in the region	-	0.0317***	-	0.00272**
		(6.4)		(3.2)
Metropolis	0.185***	-0.0528**	0.111***	0.0579***
	(8.27)	(2.7)	(26.36)	(17.2)
Small metropolis	-	-	0.0133***	-
	(6.02)		(3.81)	
Small city	0.120***		0.000849	-
	(6.64)	-	(0.25)	
Constant	2.548***	5.302***	1.349***	3.198***
	(26.78)	(30.12)	(73.59)	(89.3)
Observations	31585	31585	31737	31737
R Squared	0.165	0.177	0.585	0.68

Notes. All figures except for general human capital, its components and the dummies are in logs. The year and industry dummies and their interactions are included.

p values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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