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An Analysis of Regions in Finland

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Intangible capital agglomeration and economic growth: An Analysis of Regions in Finland

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Abstract

We use large linked employer-employee data to assess the importance of intangible capital - organizational, R&D and ICT capital – for the economic performance of firms and regions in Finland. Finland is one of the most R&D intensive economies in Europe. Intangible capital investment accounts for 6.7% of value added and intangible capital stock is 42% of the fixed non-residential capital stock of firms and evenly spread between small and large firms. In firm-level panel regressions for the years from 1998 to 2008 we find robust evidence of intangible capital to increase both productivity and profitability. Doubling the intangible capital intensity of firms increases the average productivity 7%. The regional spillovers on productivity are positive, while that on profitability are zero: firms in metropolies are not more profitable.

Keywords: Intangible capital, organisational capital, R&D capital, firm performance, linked employer-employee data

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1 Introduction

Intangible investment is crucial to continued economic development in Europe estimated in Finnish firms to account for 6.7% of new value added (Piekkola 2010). This figure is half of national measures with broader selection of intangibles but narrower definition of companies' own account intangible (Jona-Lasinio and Iommi 2011). Intangible investment is increasingly likely to become more important as greater emphasis is placed on 'smart' growth (Europe 2020). Investment in intangible assets has been shown to be an important factor in performance of European and US companies increasing Tobin's q (e.g. Piekkola 2010, Lev and Radhakrishnan 2005) and intangible capital type work is tied up with total factor productivity of Finnish firms (Ilmakunnas and Piekkola, 2010). Macro level studies have the same outcomes (Corrado, Hulten, Sichel 2006; Marrano, Haskel 2006; Roth and Thum 2010; Belhocine 2009). Ignoring intangibles in national accounts implies an underestimation of GDP by 5.5% in EU27 area and labor productivity growth by 10 to 20 percent.[2]

Intangible capital is becoming an essential factor input in the production decision and differs fundamentally from human capital since it is owned by the firm. The present paper claims that our understanding of the role of intangible capital can be enhanced by adopting a regional (or spatial) perspective. In terms of empirical analysis, three different aspects can be distinguished:

- Concentration of intangible capital to metropolitan areas
- Intangibles as firm-specific tacit knowledge but possibly with spillovers to other firms in the same industry in region
- Dynamics of the growth and innovation process

Organisational capital is inherently tacit knowledge – central in learning process in companies, see Nonaka and Takeuchi's (1995). R&D capital spillovers are also hard to occur from unplanned interactions. Intangible capital is thus expected to cause different knowledge spillovers than those bound to high density of people within cities, and that have led to models of urban growth based on agglomeration economies (Glaeser, 2008; Fujita and Thisse, 2002). It is generally known that wages and productivity are substantially higher in dense areas than in non-agglomerated regions (e.g. Glaeser, Maré 2001; Combes, Duranton, Gobillon 2004; Head and Mayer 2004; Rosenthal and Strange 2004). A regional

[2] See www.innodrive.org. Intangible investments included in the official systems of national accounts, software, licences and property rights and mineral exploration represent only a small fraction of all intangible assets accumulated in a firm or a whole economy (Corrado, Hulten, Sichel 2006, 40).

perspective on intangibles focuses on the sensitivity of this tacit knowledge to the spatial distribution of knowledge-intensive activities.

An interesting test of tacit knowledge is whether it is able to increase the profitability of the firms in contrast to knowledge capital in general. Human capital, in particular, may be owned by the employees and hence benefit them rather than entrepreneurial activity. We use the method introduced by Griliches (1967) and more recently popularized by Hellerstein, Neumark, and Troske (1999) to measure the value of three kinds of labor engaged in intangible-capital work: organisational (management and marketing), R&D and ICT work. This allows us to differentiate the productivity and wage gap. Specific attention is given to using the Olley–Pakes/Levinsohn-Petrin approach to account for the possibility that the measures of intangibles are correlated with productivity shocks. For example, ICT workers are recruited extensively in years of positive productivity growth (expectations) and sparsely in years with negative productivity growth.

Spillovers can be identified as either being technological including knowledge externalities or pecuniary (Moreno et al, 2006). Pecuniary externalities are regarded as factors that operate through a market such as the availability of qualified work force, primary and intermediate inputs. Knowledge spillovers of intangible capital to other – nearby – firms and workers relate to increasing returns on intellectual assets at regional and national levels (Audretsch, Feldman 1996, Jaffe et al., 1993, and Rodriguez-Pose and Crescenzi, R., 2008). Moreover, there appears to be a strong positive connection between the degree of urbanization and the income level of countries (Bertinelli, Strobl 2007; Glaeser, Gottlieb 2009, 1016). If urbanization together with having a shared pool of skilled labor is the externalities for enhanced growth then regional policy towards supporting *skill-intensive* regions is called for. But if intangible capital is tacit knowledge that is more global in character, and if firm-level accumulation of intangibles and the choice of occupational structure is the source of growth then regional policies may be better targeted for providing *sufficient* level of educational skills. Availability of skilled workforce forms bottlenecks rather than being the ultimate source of growth. Advantages of co-location in intangible capital type employment and sufficient availability of skilled workers induce these activities to agglomerate in space (Malecki 2010), but may call for supporting less skill-intensive regions but with potential for entrepreneurial activity in intangible capital creation.

In the present study we use a large micro dataset for Finland, first, to quantify intangible capital at the level of Finnish companies, second, to explore the role of intangible capital for the economic performance of firms and regions, third, to analyze whether there is indeed a connection between the productivity of individual companies and the amount of intangible capital in the regional economy. Our findings suggest that there are significant positive relationships between intangible capital and firm productivity and including regional spillovers in organisational capital and concentration of specific industries and higher.

The rest of the paper is organized as follows: Section 2 describes the data base, the measures of intangible capital, the regional concept and the approach chosen to evaluate the relation between establishments and their industrial environment. Section 3 presents descriptive results on the regional distribution of intangible assets, technology and innovative activities in Finland for the period from 1998 to 2007. Geographical correlations are used to illustrate connections between intangible capital and the economic performance of regions. Section 4 provides estimates of the determining factors of the wage levels of individual establishments and assesses agglomeration effects and localized spillovers. Section 5 summarizes.

2 Data, measurement and estimation

The database used for this analysis has been constructed as a combination of LEED data from the Confederation of Finnish Employers, Statistics Finland Regional Accounts and balance sheet data collected by private company (Suomen Asiakastieto). The dataset

- offers information on, e.g., employment, wages, tangible and intangible capital, output, value added,
- covers the period from 1995 to 2008,
- comprises around 1850 firms per year with turnover more than 1.5 million€ with around 390 000 employees,
- allocates establishment employment to two-digit manufacturing and three-digit service industries (NACE rev.1) and to 65 economic regions based on 74 NUTS4 regions in 2008 after merging mainly Northern Finland NUTS4 regions in greater units, merging the satellite municipalities around Greater Helsinki area[3] and separating Greater Helsinki area into Helsinki, Vantaa and Espoo.

Dataset is comprehensive in terms of coverage of economic region and variables. We use data on establishment employment to allocate the firm level variables across regions. Regional dummies of firms include the share of establishment employment in each region and sum up to one. We also use the detailed information on the educational or occupational structure of establishments. Intangible capital

[3] Satellite regions are Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Mäntsälä, Nurmijärvi, Pornainen

is calculated using both expenditure and performance-based approaches, where the latter evaluates performance at the firm level. Our period 11 years goes from a peak in 1998-99 to a trough of a business cycle in 2000-01 and relatively strong growth period 2002-2008. Our intangible capital set includes the core inputs: organisational, R&D and ICT capital.

The basic idea following Görzig, Piekkola and Riley (2010) is that each firm is producing three kinds of intangible goods: (I) organizational competencies (OC), (ii) information and, communications technology (ICT), and (iii) research and development (R&D). The production of these types of goods is directed primarily towards the firm's own uses.

2.1 Constructing intangible capital

Methodology follows INNODRIVE (European Commission FP7 project), described in full details by Görzig, Piekkola, Riley (2010). The methodology is briefly outlined here. We assume that a fraction of OC, R&D and ICT work is engaged in the production of intangible goods, whose fractions are set at 20% for OC, 70% for R&D, and 50% for ICT.[4] We further scale the relevant labor expenditures with the ratio of the intangible production costs to labor costs. To evaluate the value of intermediate and capital costs related to labor costs necessary in the production of intangible capital goods, the following industries within NACE category 7 have been chosen:

- Other business activities (Nace 74) as a proxy for OC goods,
- Research and development (Nace 73) as a proxy for R&D goods, and
- Computer and related activities (Nace 72) as a proxy for ICT goods.

We assume that the use of labor, intermediates, and capital in these industries can also be taken as an indicator for the cost structure in own-account production of these types of goods in all firms.[5] The combined multiplier M_{IC} in Table 1 is the product of the share of intangible-type work and the ratio of intangible production costs to labor costs.[6]

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[4] Occupational categories are harmonised in each country and listed in Piekkola (2010).

[5] The factor shares are taken as a weighted average using the EU KLEMS database for European countries Germany (40% weight), UK (30% weight), Finland (15% weight), Czech Republic and Slovenia (7.5% weights).

[6] Capital cost is the sum of the external rate of return 4% (representing the market interest rate) and depreciation multiplied by net capital stock.

Table 1. OC, R&D and ICT multipliers on total wage costs
and depreciation

	OC	R&D	ICT
Combined weighted multiplier M_{IC}	0.35	1.1	0.7
Depreciation rate δ_{IC}	0.25	0.2	0.33

Source: Görzig et al. (2011)

Organizational investment is 35% of wage costs when the use of intermediates and capital are added to the OC investment wage costs (that were 20% of all wage costs in organizational work). R&D and ICT investment costs are fairly close to all wage costs in R&D or ICT work since the respective multipliers 1.1 and 0.7 are close to one. We capitalize these investments according to the perpetual inventory model:

$$K_t = K_{t-1}(1-\delta) + I_t , \qquad (1)$$

with I_t for the capital formation of the current year and a constant depreciation rate δ that are typically higher than for tangible capital (investment deflated by the earnings index, which is assumed to represent the deflator for intangible assets). Micro data do not allow for a long history of intangible capital accumulation. We apply the following sum formula of a geometric row to estimate the initial stock, see Görzig et al. (2011).

Our approach has broader coverage of own account production of intangible but narrower selection of intangibles than in country-level estimates such Jona-Lasinio and Iommi (2011) or Corrado, Hulten and Sichel (2006) including architectural and engineering design, (10% of intangibles NACE Rev. 2 74.20), new financial product (3.2% of intangibles) and training (11% of intangibles). Jona-Lasinio (2011) and Piekkola et al. (2011) show that in Finland we end up roughly at the same level of intangibles per new value added not recorded in System of National Accounts using either the firm-level or national level approaches.

2.2. Estimation methodology

Estimation follows closely Geppert and Neumann (2010) as also applied in Riley and Robinson (2011). The regional dimension of the analysis is based on the concept of 54 self-contained planning regions. Greater Helsinki area is divided into three main cities and the surrounding satellite municipalities are merged into a single area. Geppert and Neumann (2010) have 92 one or more NUTS-3 unit regions, whereas our approach is closer to the NUTS-4 level.

Table 1. Regional units of observation

Region type	Number of re-gions year 2010	Population 1000 Mean	Minimum	Max
Planning re-gions	54	97	8	583
NUTS4	74	75	6	1025
NUTS3	21	268	28	1424

On average, the Finnish regions have on average a population of 44 000 while in German study the 92 regions in Germany have an average population of 896 000. The distribution is spread from 82 000 to a maximum of 565 000 (Table 1). A possible alternative to this choice of areas of observation are NUTS-3 regions which would be closer to the Planning Regions in Germany. However, NUTS-3 regions typically include growth centers surrounded by less heavily populated rural areas.

A much discussed issue in the estimation of localized spillovers is the geographical extent of those externalities. If establishments in one region also benefit from activities in neighboring regions, our estimates on the economic environment of the own region are biased upwards. The potential relevance of such a bias depends on the definition of regions. With our concept of functional planning regions we can be still be confident that the bulk of spillovers are internal, since the regions in Finland are large areas in space. A stylized fact of empirical research in this field is that externalities are subject to a steep decay with distance. Most studies identify ranges of well below 100 kilometers (e.g. Rosenthal, Strange 2003; Henderson 2003; Duranton, Overman 2005; Graham 2008) and only a few find evidence for somewhat more extensive externalities (Rodriguez-Pose, Crescenzi 2008). It can be rather said that in Finland NUTS-3 areas the regional spillovers would be biased downwards due to the diversity of the area.

In order to control for the settlement structure of locations in the econometric analysis, we characterize the Planning regions by employment density (per sqkm) and classify them according to their settlement type:

- (1) large metro areas with core cities > 500 000 inhabitants

- (2) small metro areas with core cities of 100 000 – 500 000 inhabitants (four areas)
- (3) intermediate regions with population density >= 35 per sqkm
- (4) rural regions with population density < 35 per sqkm

The *localization* variable is specified as the number of other own-industry establishments in the region. In locational effect each unit, irrespective of its size, is a potential source of industry-specific externalities, e.g., the intentional or unintentional exchange of ideas or the sharing of inputs. [7] We also apply an index of diversity(Henderson, 2003):

$$D_j = 1/\sum_i \left(\frac{E_{ij}}{E_j} - \frac{E_i}{E}\right)^2 \quad (2)$$

where the summation is over the squared differences between the employment shares of industry *i* in region *j* and in the national economy. Higher figure shows that workers are more dispersed between industries than an average in the economy. This is a measure of industrial diversity equivalent to the inverse of Herfindahl index. *Urbanization* is first measured with employees per square kilometers or by the spatial productivity hierarchy dummies (from large metros down to rural regions). The first estimate shows the elasticity of productivity/wages with respect to density (employees per square kilometer). Finally regional intangible capital intensity is included excluding the intangible capital of the firm itself.

In our attempt to assess local externalities, we use labor productivity *LP* (or average wages) as dependent variable and firm, industry and regional characteristics as independent variables. We estimate the equation

$$\ln LP_{it} = b_{0i} + \alpha_i X_{it} + \beta_{jt} \ln R_{jt} + d_t[Year]*IND_{jt} + [F_{ij}] + e_{it} \quad (3)$$

where the X_i are establishment features (employment, intangible and tangible capital intensity, human capital), the R_{ij} describe the regional environment of establishments (regional intangible capital intensity, same-industry number of establishments, industrial diversity, employment density and settlement type of the region), *Ind* are two-digit industry dummies (three-digit in services) and F_{ij}, in the experiments with fixed-effects, are establishment-location fixed effects. Time-industry fixed effects $d_t[Year]*IND_{jt}$ control for national shocks to productivity and for deflation of all the variables. Re-

[7] Using own-industry employment instead of the number of establishments does not substantially change the results.

gional intangible capital intensity is measured excluding firm's own intangible capital also fairly uncorrelated to firm's own intangible capital (0.07).

3 Regional distribution of intangible capital and its components

In this section, we first describe the distribution of intangible capital across firms in private business. [8] Second, we show how intangible capital correlates with economic performance of regions. All of the other studies considers establishments as a separate entity, quite independent of the location of the headquarter or top management usually located in metropolies. This may cause an underestimate of the true technical productivity of establishments, if and as they have the same technology available as the whole enterprise. In the case of multi-plant firms, small subsidiaries can indeed often resort to the resources of larger units or to corporate headquarters (Duranton, Puga 2005; Aarland et al. 2006). We consider companies as entities and allocate the value added across establishment according to the employment distribution across regions.

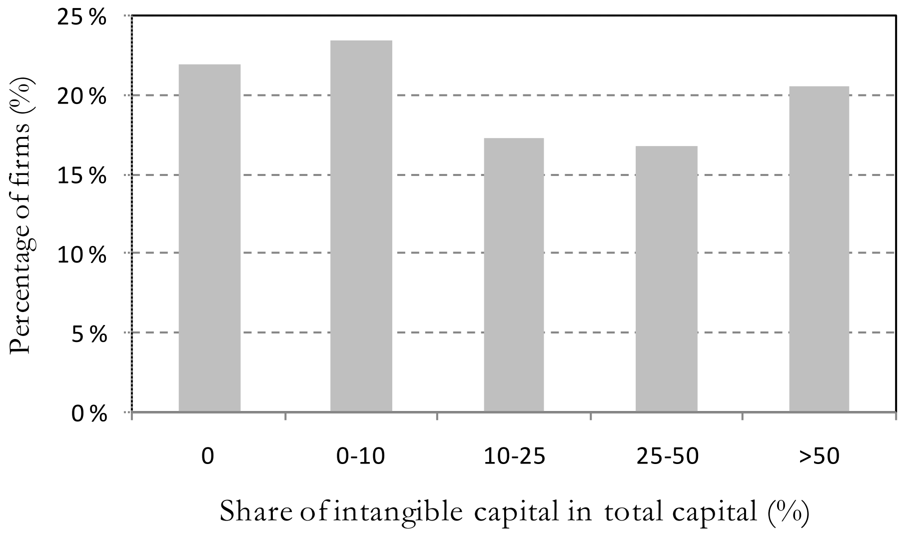
The estimating sample comprises around 1500 firms per year, which is considerably less than the 30 000 firm sample in Germany or in the UK. This data cover the largest firms in the private sector responsible for 40% of value added and 31% of employment in the respective non-farm private business. Regional intangible capital in the own industry and in the rest of the regional economy is measured in terms of intensities (per hour worked).

Firms

On average, the share of intangible capital in total capital of establishments was 14 percent in 2006. In line to German establishment the distribution is uneven. Nearly 20% of the establishments have no intangible capital at all, and 20% of the firms show shares more than 50% (Figure 1).

Figure 1. Share of intangible capital in total capital 2006

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

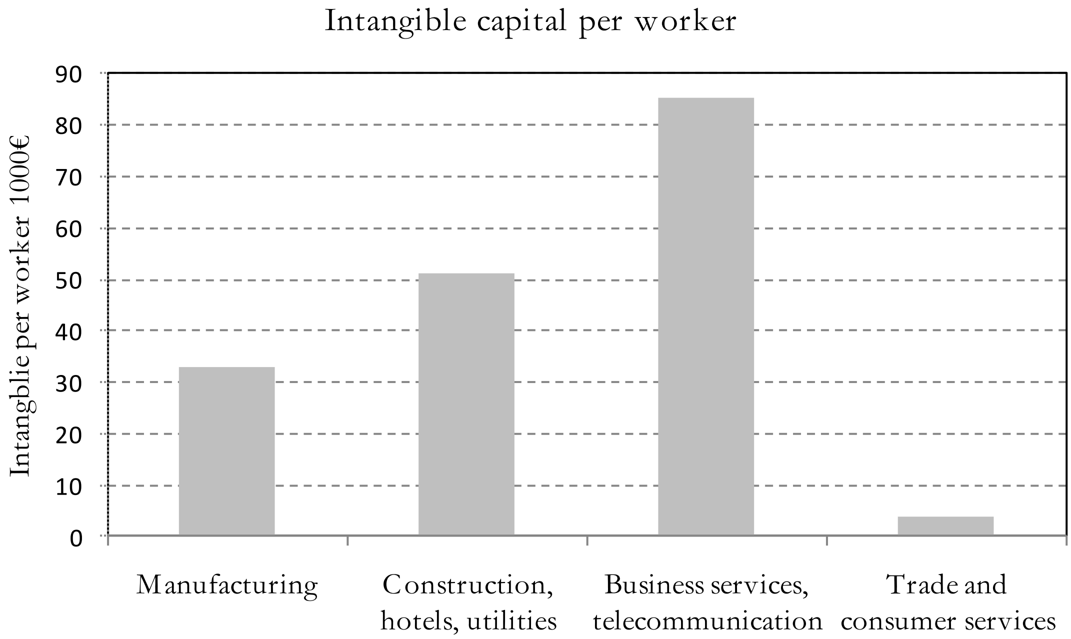


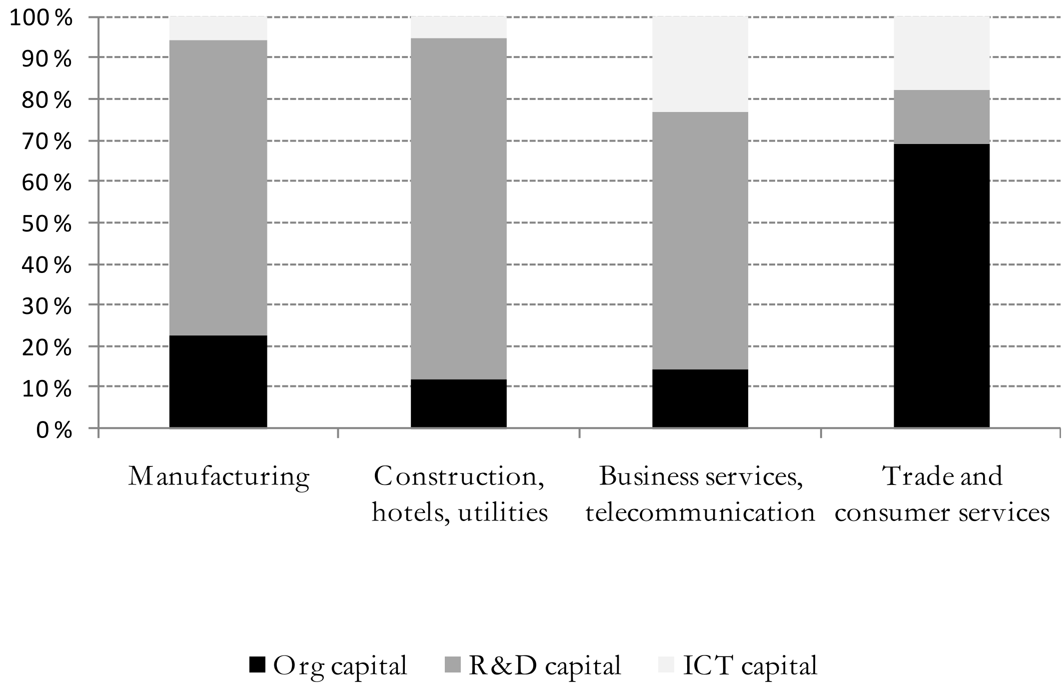
Variation in intangible intensity is substantial. It is surprising that there is roughly equal number of firms in the intangible capital intensity categories (four in the range between zero and 50% and the rest). The share of intangible capital from total capital is highest in firms with an average number of employees between 90 and 700, while it is generally well known that large firms tend to be more intensive in tangible capital. The share of R&D capital from total capital is most equally distributed across all firm-size categories. This is despite the fact that small firms do not typically have their own department for research in contrast to large manufacturing firms. Finland has more equal distribution of intangible capital across firms of different type than Germany.

Industries

The role of intangibles differs substantially between the various sectors of the economy. Industries are (i) *manufacturing*, (ii) *construction, hotels, utilities* (iii) *business service* sector (business services, telecommunication, finance and private health) and (iv) *trade and consumer* services (wholesale and retail trade, other service activities) With 80000 € per intangible type work, the intangible capital intensity is highest in business services followed by construction and utilities with much lower intensity 48000 € (Figure 2). Manufacturing has considerably lower intangible capital intensity 31000 €, which differs from Germany with the goods-producing sector being most intensive in intangible capital. High share in business services is explained by the ICT activity. Quite a number of industries in communication and business services are highly innovative, e.g., telecommunications, software development, engineering. The same applies to consultancy firms that develop and sell new organisational and ICT solutions. Construction and utilities have highest R&D activity.[9] Other services are scarce in R&D activity and organisational capital is 70% of the very value of intangible capital of just 3000 €.

Figure 2. Sectoral distribution of intangible capital and its components 2006





[9] Real estate activities are excluded from the analysis.

The low intangible capital intensity in the sector *trade and consumer services* (wholesale and retail trade, hotels and restaurants, health and social work, other service activities) is also recorded in Germany. Some industries in trade and consumer services provide organisational or ICT advice to customers which we cannot clearly separate from own-account investment in ORG or ICT capital in these industries. Examples are business and membership organizations.

Regions

Intangible capital per employee is highest in metropolitan areas 46000 € in contrast to less than 30000 € in other areas or rural areas with 20000 € per intangible worker at the bottom.

Figure 3. Intangible capital per worker by settlement type 2006

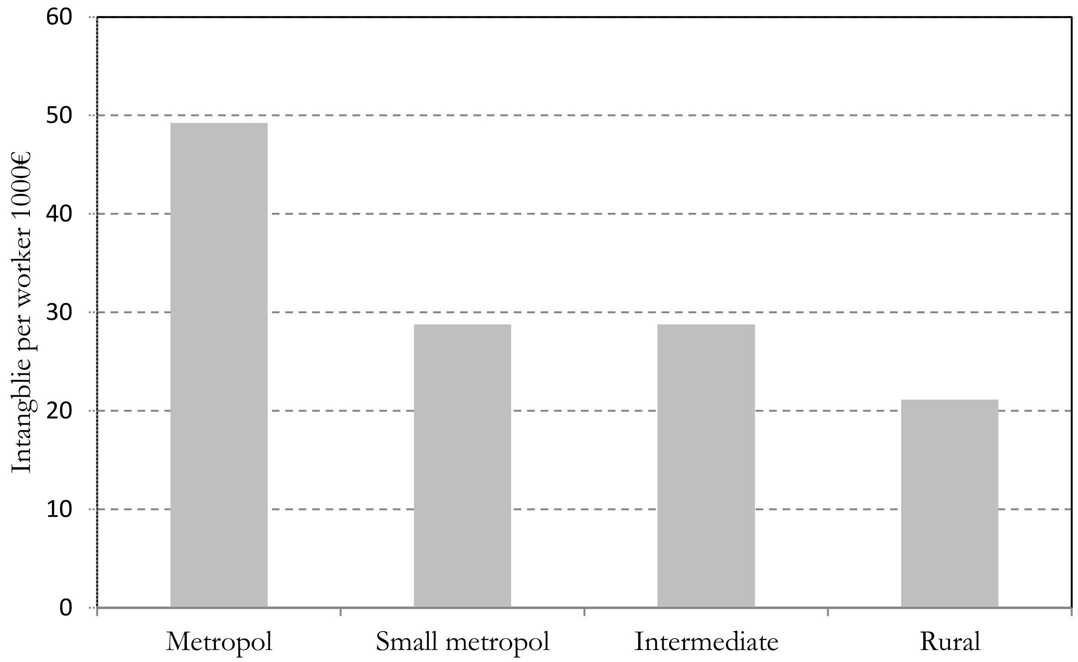
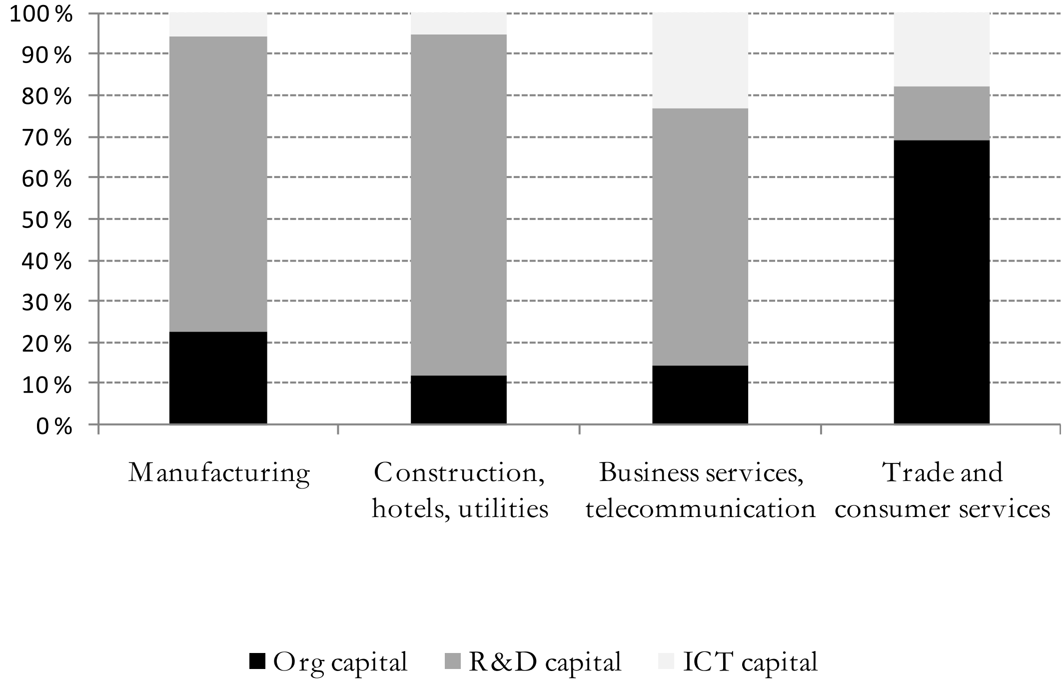


Figure 4. Components of intangible capital by region 2006



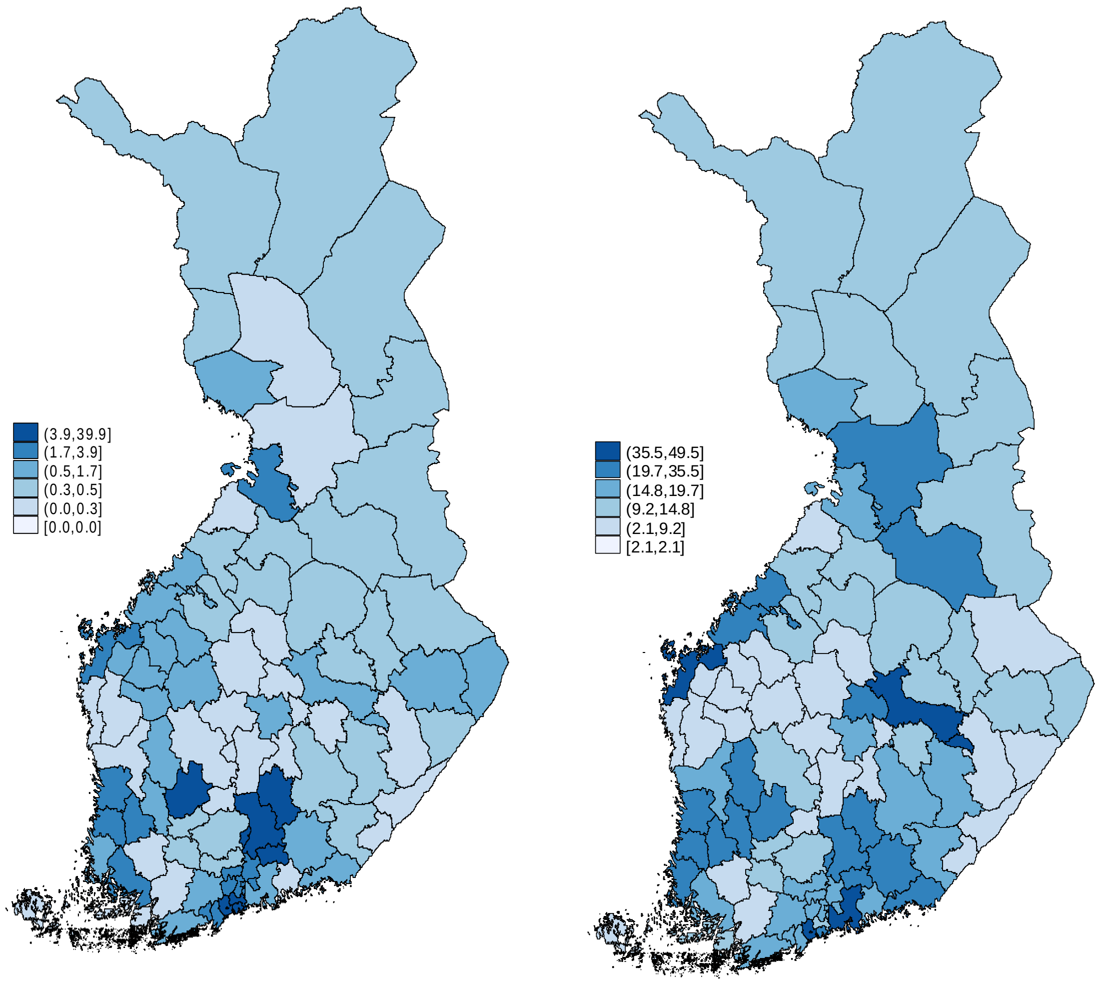
In all areas R&D capital is the dominating type of intangible capital with a share around 65% of all intangible capital. Metropolitan areas separate out as with the highest share 13% in ICT capital and rural areas with the highest share 30% of organisational capital.

Following maps show intangible capital as share of all intangible capital in Finland (Map 1) and intangible capital per employee (Map 2). Regions with high absolute stocks of intangible capital (Map 1) also tend to show high intangible capital intensities, but the spatial hierarchy of intensities is less clear (Map 2). Greater Helsinki area has 54% of all intangible capital and the second most heavily populated Tampere area 5.6% lags far behind. Many small metro areas and intermediate regions have been able to attract relatively high amounts of ICT and R&D capital. Most of these regions feature at least one of the following characteristics: headquarters and large-scale production in technology-based manufacturing, a high-level technical university and good accessibility. Overall, there exists a considerable positive relation between intangible capital intensity and employment density of regions (with R^2=0.38).

One of the characteristics of the spatial distribution of intangible capital in Finland is the gap between the southern and western Finland to eastern and northern Finland. Almost all eastern regions lag far behind the western regions in terms of intangible capital intensity. The exception in the eastern area is Varkaus, but since 2006 the dominating paper and pulp industry has closed down all important establishments there. Many firms in eastern and northern Finland are mere assembling operations or subsidiaries that typically do not use intensively intangible capital. Germany is more evenly spread in intangible capital with ten big regions accounting for half of total intangibles, but also the East Germany lagging behind in growth.

Map 1

Shares of regions in national intangible capital (left figure) and intangible capital per employee (right figure) (Euro) 2006 (%)



Geographical correlations

The regional distributions of the different kinds of intangible capital are not independent of each other. Regions that attract one component of intangible capital tend to concomitantly attract other components. This geographical correlation of ORG capital intensity to ICT capital intensity and R&D capital intensity is close the same ($R^2 \approx 0.34$), while R&D capital intensity and ICT intensity are least related ($R^2 = 0.25$).[10] The interlinkages between the different categories of intangible capital at the regional level are also not the result of industrial specialization of regions, i.e., industries that are intensive in all intangibles do not account for high employment shares in specific types of regions.

Both tangible and intangible capital are concentrated in specific regions and the concentration is highest for ICT capital. In contrast to Germany intangible capital is not more concentrated than tangible capital.[11] These results, together with the geographical correlation described above, suggest that establishments with specialization in OC and ICT capital tend to co-locate - and possibly cooperate, while R&D and ICT are somewhat more loosely related locally.

We show next the overall intangible capital of regions and their economic performance. We first cross tabulate it with respect to the productivity and the hourly wages across regions. In the calculation of labor productivity the valued added includes intangible investment not hitherto included in regional or national GDP estimates and employment in the numerator is the employment at the end of year (with relatively few part-time workers). In comparison of wage and productivity levels and intangibles we find a close positive correlation of intangible capital intensity with hourly wages (R^2=0.60) and positive but weaker correlation with productivity (R^2=0.16) (Figures 5 and 6). The lower correlation to productivity than in Germany (R^2=0.80) possible arise from the very low correlation observed in the least intangible capital intensive regions that are here shown at Nuts-4 level but absent in German planning regions closer to Nuts-3 level.. It can be seen from the figure that the correlation would be much higher for the most intangible capital intensive regions. Finally, our sample is also less representative or the regional value added than what is the case in Germany. We find stronger positive relation between regional GDP per employee and intangible capital intensity (R^2=0.20 not shown). The apparent reason is that

[10] R^2s from single regressions with logarithms.

[11] Spatial concentration is measured as the sum of squared shares of regions in the respective national values. If all activities were concentrated in only one region, the index would be 1; if the activities were distributed evenly across regions, the index would be close to 0 (1/92=0.01). The average index over the years takes the values of 0.257 for tangible capital, 0.268 for total intangible capital, 0.264 for OC capital, 0.250 for R&D capital and 0.412 for ICT capital.

our data is biased towards large high productivity firms that exhibit high variation in intangible capital intensity.

Figure 5 **Intangible capital and average hourly wages in regions**

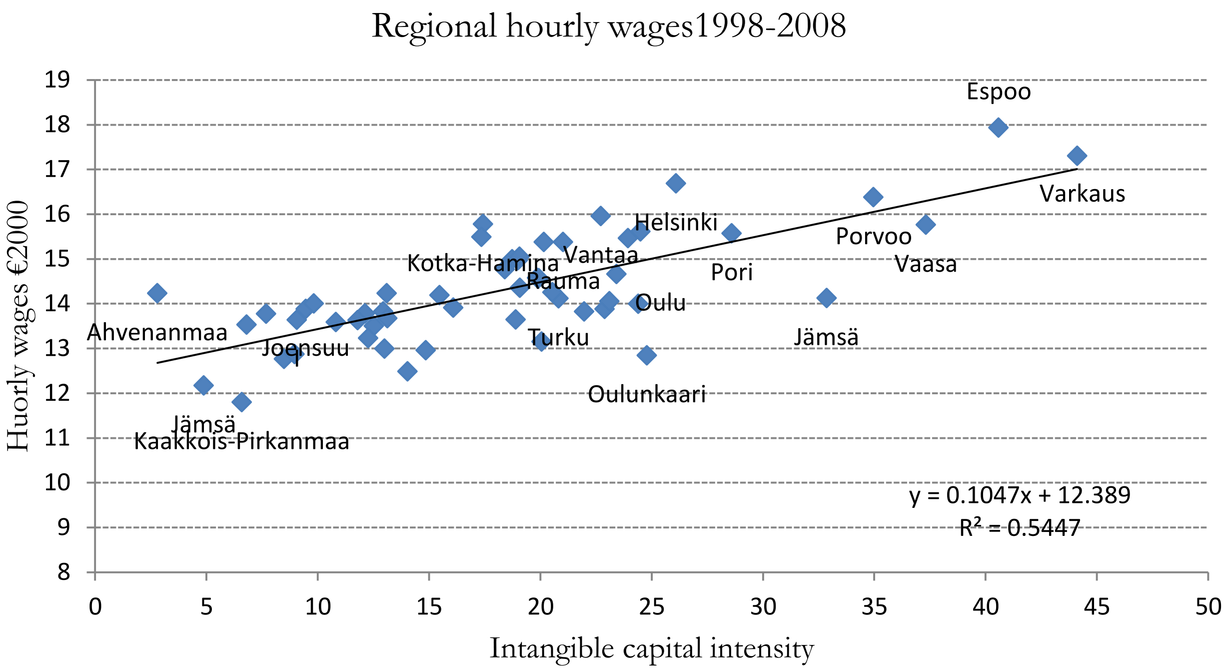
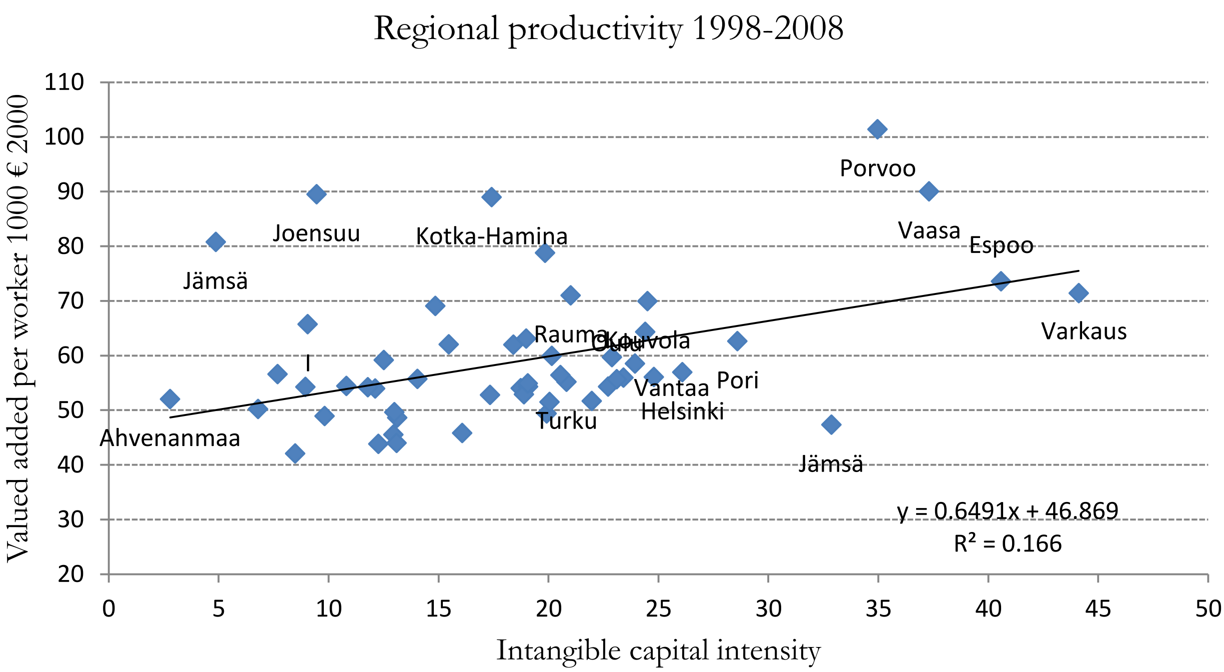


Figure 6 **Intangible capital and economic performance of regions**



4 Productivity and agglomeration effects

We now turn to the analysis of the effects of intangible capital on the productivity and wages of firms, controlling for other firm characteristics and the regional economic environment of each establishment. Economies of agglomeration can arise from spatial clustering of specific industries, leading to localization economies or from urbanization economies. Non-production jobs and highly qualified employees tend to concentrate in space, constituting a hierarchy of knowledge - and thus intangible capital - with large cites and metropolitan areas at the top and rural regions at the bottom (Duranton, Puga 2005; Markusen, Schrock 2006). The spatial concentration of intangible capital is consistent with such a hierarchical pattern. In the following cross-sectional regressions we try to find indications for potential effects of localisation, urbanization and regional intangible capital on the wage level of individual establishments.

Panel regressions using expenditure approach

We apply random effect estimates from 1998 to 2008 and also Olley-Pakes estimates that control for productivity shocks. The dependant variable in this analysis is labor productivity or the average hourly wage of establishments. On the right hand side we include variables that capture the well known facts that larger establishments pay higher wages than small ones, capital intensive establishments pay higher wages than labor intensive ones, and establishments in dense urban areas pay higher wages than those in rural regions. In detail, the explanatory variables are five firm-size categories (less than 30 employees, 30-90 employees, 90-350 employees, 350-700 employees and more than 750 employees), intangible capital intensity, human capital, tangible capital intensity, 3-digit industry classification, settlement type/employment density of locations and the number of own-industry establishments. The human capital is controlled by the firm averages of person effects from individual-level wage equations. Iranzo, Schvandi, and Tosetti (2007) argued that this cleans some of the institutional constraints stemming from the union wage determination as firm fixed effect is separately estimated encompassing these institutional elements, too. In additional regressions, the productivity growth is explained and also the productivity and wage gap is analyzed as the source of profitability.

One potential source of bias in our results is intangible capital investment explained by productivity shocks. This endogeneity bias is controlled using the Olley and Pakes (1996) approach, which accounts for the possibility that the measures of intangibles are correlated with these shocks. [12] The intangibles

[12] The estimation procedure is adapted from Yasar, Raciborski, and Poi (2008).

are the state variables that adjust slowly. The firm can manage intangibles by hiring new employees for tasks related to organizational work. The hiring rate would thus be a proxy variable for the productivity shocks in the same way as Olley and Pakes (OP) use investments. We also control for the selectivity caused by the exit of firms. Following OP, the likelihood of exit is modeled with a probit model, and the predicted probability is used as an additional variable in the second step.

The results of the pooled regressions using random effects and OP estimates are shown in Table 5 and analyzing separately organisational, R&D and ICT capital in Table 6 using the preferred OP estimates.

Table 5. Productivity and intangible capital

	1 Produc-tivity	2 Produc-tivity	3 Hourly wage	4 OP Produc-tivity	5 OP Product. growth 3 yrs
Proximity to productivity frontier	-	-	-	-	-1.717***
					(23.02)
Intangible capital intensity	0.0902***	0.0899***	0.0459***	0.0732***	0.00501*
	(18.13)	(18.09)	(25.93)	(4.43)	(2.12)
Human capital	0.377***	0.369***	0.632***	0.559***	0.153***
	(9.85)	(9.57)	(36.83)	(21.36)	(4.8)
Tangible capital intensity	0.108***	0.108***	0.00965***	0.113***	-0.0666***
	(22.82)	(22.77)	(8.8)	(49.21)	(20.92)
Employees/km2 in the region	0.0104***	-	-	-	-
	(3.57)				
Intangible capital intensity region	-	-0.00093	0.00227	0.0157*	0.0111
		(0.13)	(0.98)	(2.13)	(1.2)
Share of innovative firms	-	0.0282	0.00281	0.0537	-0.0000317
		(0.98)	(0.28)	(1.58)	(0)
Industrial diversity region	-	-0.01	-0.00319	-0.0308***	-0.0196
		(1.27)	(1.02)	(3.57)	(1.83)
Own-sector firm share in the region	-	-0.00917	0.000328	-0.00366	0.00148
		(1.63)	(0.17)	(0.82)	(0.28)
Metropoli	-	0.101***	0.0563***	0.0992***	0.0541**
		(4.33)	(6.64)	(6.87)	(3.16)
Small metro	-	0.0325	0.00659	0.0425***	0.0233
		(1.6)	(0.83)	(3.73)	(1.73)
Intermediate	-	0.0462*	0.0263***	0.0301**	0.0177
		(2.37)	(3.52)	(3.04)	(1.52)

Observations	16883	16852	16852	15417	8807
R Squared overall	0.52	0.52	0.68	0.55	0.23
R Squared within	0.24	0.24	0.71		
R Squared between	0.56	0.57	0.66		

All except dummies and hiring in OP in logs. Year and industry dummies and their interactions are included. OP with state variables: firm-level intangible capital and proximity to production frontier. Proxies are hiring and material. All up to fourth potency, interactions of intangible capital with hiring and material. Non-linear estimation excludes lagged proximity. The number of repetitions in bootstrap is 30.

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

Table 6. Productivity and intangible capital components

	1 OP Productivity	2 OP Product. growth 3 yrs
Proximity to productivity frontier	-	-1.773***
		(20.15)
Organisational capital intensity	0.0346*	0.0205***
	(2.24)	(4.9)
R&D capital intensity	0.0824***	-0.0188***
	(4.88)	(4.99)
ICT capital intensity	-0.105*	0.0024
	(2.19)	(0.56)
OC capital intensity region	0.0024	0.0172
	(0.18)	(1.09)
RND capital intensity region	0.0009	0.000178
	(0.12)	(0.02)
ICT capital intensity region	0.0119*	0.00759
	(2.54)	(1.37)
Observations	13363	7612
R Squared overall	0.56	0.38
R Squared within		
R Squared between		

See table 5 column 2-4. * p < 0.05, ** p < 0.01, *** p < 0.001

All coefficients except some of the regional variables are significant. Hausman tests show that random effect estimates are not significantly different from fixed effects estimates, and they are also close to OLS estimates.[13] One reason is that we have large set of controls and disaggregated regional dummies

[13] Hausmant test show that random effect is not significatn from fixed effect estimates, in column 1 at 12% level and in column 2 at 31% level.

that allow for enough within region variation over time. The average wage and productivity levels of firms are much influenced by their industrial affiliation. In table 52-digit industry dummies and their interaction to year dummies explain 33% of variation of productivity and 44% of total variation of log hourly wages. The variation explained rises up to 52% in productivity and up to 60% in wage estimation when firm and regional characteristics are accounted for. Doubling the intangible capital intensity of establishments from the average of 25000 € per employee to 50000 € per employees – one fourth of standard deviation increase – increases the average productivity by 9% percent in random effects estimates (column 2) while the hourly wage effect is half of that 4.6% (column 3). The elasticity with respect to tangible investment is around 10% for both productivity and wages.

Olley-Pakes (OP) estimation controls two productivity shocks using two instruments hiring and materials (column 4 in Table 5). It is expected that hiring policy is quick to adjust to general economic growth, whereas the use of material may be related more to industry-specific shocks.[14] Random effects results reported appear to be biased upwards. In OP estimates a 100% increase in intangible capital intensity increases productivity by 7% instead of 9% in random effects estimates. We rely on OP estimates in what follows. Using OP the productivity elasticity estimate is 3.5% for organisational capital and 8% for R&D capital, while negative -10% for ICT capital (Table 6). Turning to agglomeration regional intangible capital is positively related to productivity (Table 5) but this finding only holds for regional spillovers by organisational capital (Table 6). R&D capital creates negative spillovers. Some of the positive spillovers by organisational capital may relate to the purchase of advertising and market research services on the market, as part of "thick" local markets and networks (Bellandi 1989; Markusen 1996). However, these may not be tacit knowledge than cannot be purchased elsewhere.

Overall, it is seen that the elasticities are of the same magnitude as found in Germany in Geppert and Neumann (2010) but less than in the UK in Riley and Robinson (2011). Regional spillovers were evident for all intangibles irrespective of their type in Germany, while similarly to Finland in the UK only organisational spillovers matter.

Human capital is equally important for productivity, but here we find the wage effects to be twice stronger. As a consequence, human capital benefits workers in terms of higher wages but may not be a source for improved profitability. Ilmakunnas and Piekkola (2010) similarly find that intangibles should

[14] Ilmakunnas and Piekkola (2010) use these instruments combined as the benchmark approach although the difference in using just one instrument (hiring) is not very distinct.

be clearly separated from general human capital, for which ownership does not satisfy the traditional definition of assets used in the SNA.

The usual summary measure of urbanization is density (regional employment per square kilometer). Theory and numerous empirical analyses suggest that productivity and wages are positively related to density, and most studies find elasticities of wages with respect to density between 2% and 6% (Gebbert and Neumann, 2011, Riley and Robinson, 2011, Ciccone 2002; Rice, Venables 2004; Combes et al. 2008; Puga 2010). Our estimates are at this bond of range being 2.5% using OLS and ignoring human capital as control. Random effects approach reported gives 1.0% (Table 5 column 1). This relationship might also be non-linear (Brülhart, Sbergami 2009). We find that firms in large metropolitan areas are 10% more productive for unexplained reasons than those located in rural regions and about 5% more productivity than establishments in small metropolitan areas (Table 5 column 4). It should be noted that metropolitan effect would be over 6%-points higher if human capital is not controlled. This shows that significant part of all urbanization effects relate to agglomeration of skilled workers. Urbanization effect also follows from intense clustering in metropolitan area, as also found in the UK and Germany. People in metropolitan areas have higher skills and are better paid.

In order to describe in more detail the agglomeration effects and to explore the potential role of intangible capital in these processes, we have further complemented our regressions by specific underlying features of the spatial concentration of economic activities (columns 2 onwards in Table 5 not reported in Table 6 giving qualitatively the same results). Other regional effects besides metropolitan dummy and intangible capital spillovers relate to industrial diversity. Regions that have wider spectrum of industries perform worse. Productivity is thus higher when workers are less dispersed between industries than an average in the economy, a finding which was evident also in the UK and Germany. This result is sensitive to productivity shocks as random effect estimates are insignificant. We instead find no clear relation between the share of innovative firms in the region and productivity, which may also arise from our proxy being inaccurate. The other localization effect own-sector firm share has instead no clear effect on productivity or wages.

Finally, we have not reported firm-size effects that show no clear pattern except for the small firms having an average higher productivity after all the controls used in the analysis. Large firms instead pay clearly higher wages. This again shows no firm-size effect as was found also in the distribution of intangible across firms of different size.

Our next step is to analyze longer-term productivity growth. The growth-enhancing impact of skilled labor should increase with a firm's proximity to the frontier, where proximity is measured by the ratio between the total factor productivity and the total factor productivity in the same two-digit industry. There are significant learning effects in the adaptation of intangible investment. Because of this we explain productivity in three years (Table 5 column 5, Table 6 column 2). Since proximity to frontier is likely to persistent but correlated with the errors, we apply Olley-Pakes estimate and consider it to be "state variable". We thereby include it in the final step of non-linear estimation of the productivity effect of state variables (after eliminating in first step the contribution of the controls that are immediately adjusted).[15] As expected proximity to economic frontier has a significant negative effect on productivity growth. It is seen in Table 5 that intangible capital intensity has a positive but insignificant effect on long run growth of productivity. Table 6 shows that organisational capital has a clear positive effect on productivity growth and the overall ambiguous effect in Table 5 is explained by the opposite negative effect of R&D capital. Doubling level the level of organisational capital leads to 2%-point higher growth in three years. The presence of technology intensive firms with R&D is also insignificant.

Robustness checks

Intangible capital has been observed to have strong effect on productivity. Fairly little of this high elasticity is explained by unobserved differences in the internal structure of establishments and settlement type. It has also been shown that not only intangible capital but also workers with high observed and unobserved skills tend to gravitate to metropolitan areas, raising the wage levels there (Borjas et al. 1992).[16]

We further apply other fixed effect estimates to check robustness of our results. We are also interested in how the large metropolitan effect divides into the three cities Helsinki, Vantaa and Espoo and also in comparison with the fourth and fifth largest cities Tampere and Turku (columns 5 and 6, the reference is the rural areas). We also interact intangible capital with human capital, where the latter is measured as deviation from the grand average labeled as human capital difference. We are thus able to analyze how percentual increase in human capital from the average associates with positive productivity effects given the firm's intangible capital. Our final robustness check is to use a fixed effect model through differencing.

[15] We also ignore its lagged effects on the polynomial of the shocks.

[16] For spatial sorting on regional wages, see also Combes et al. 2008.

Table 7. Human capital and fixed effect models

	Productivity		Hourly wages			Productivity	
	Random effect	Fixed effect	Random effect	Fixed effect		Random effect	Random effect
Intangible capital intensity	0.0859***	0.0971***	0.0421***	0.0472***		0.0834***	0.0421***
	(16.11)	(7.85)	(23.35)	(12.37)		(16.68)	(23.96)
Human cap. difference	0.163***	-0.07	0.487***	0.499***		0.151**	0.505***
	(3.43)	(0.78)	(22.97)	(12.62)		(3.21)	(24.16)
Intangible cap. int., human cap. difference	0.112***	0.131***	0.0585***	0.0612***		0.122***	0.0708***
	(5.46)	(3.84)	(7.96)	(4.53)		(6.48)	(10.42)
Tangible capital intensity	0.110***	0.0945***	0.00991***	0.00996***		0.108***	0.00954***
	(22.92)	(11.59)	(8.46)	(5.39)		(22.85)	(8.74)
Intangible capital intensity region	0.0000	0.0000	0.0000	0.0000		-0.0050	0.0012
	(0)	(0)	(0)	(0)		(0.7)	(0.49)
Metropoli	0.0969***	0.02	0.0625***	0.03	Helsinki	0.0802**	0.0653***
	(3.93)	(0.27)	(7.01)	(1.48)		(3.12)	(6.91)
Small metro	0.0458*	-0.02	0.01	0.03	Vantaa	0.116***	0.0461***
	(2.12)	(0.27)	(1.55)	(1.3)		(3.83)	(4.64)
Intermediate	0.0478*	0.04	0.0338***	0.04	Espoo	0.117***	0.0577***
	(2.31)	(0.67)	(4.36)	(1.55)		(3.4)	(4.6)
					Turku	0.04	0.02
						(1.41)	(1.22)
Observations	14691	14691	14691	14691	Tampere	0.0626*	0.0269*
R Squared overall	0.522	0.409	0.692	0.574		(2.2)	(2.45)
R Squared within	0.233	0.236	0.695	0.696	Observations	16852	16852
R Squared between	0.57	0.421	0.679	0.549	R Squared overall	0.524	0.691

The productivity effect of intangible capital is positively related to human capital. Productivity is highest in intangible capital intensive firms with high-skill workers. The interaction is weakest in wage estimation. One standard deviation increase in human capital from the average (0.16) improves productivity effect of intangible capital by 1.7%. Fixed effects results in column 2 are not significantly different, which again shows that random effect estimates are appropriate together with the hausman test showing that random and fixed effects are not significant at 9% level. We can find considerable within firm variation in the time period. Regions are enough disaggregated allowing for diverging regional development within regions so that fixed effect estimates yield roughly the same results are random effect estimates.

Metropolitan area consists of three cities Helsinki, Espoo and Vantaa. The firms are most productive and pay the highest wages in Espoo and Vantaa. The unexplained part of productivity is highest yielding 11% higher productivity than in rural areas. The region closest to Metropolitan area in unexplained productivity is the second biggest city Tampere.

Intangible and profitability

We, finally, analyze productivity-wage gap to see how much intangible capital, human capital and regional effects improve profitability. The difference between the coefficient of the respective variables in the productivity equation and in the wage equation is defined as the productivity–wage gap of intangible capital (see Ilmakunnas and Maliranta, 2005). We first show the productivity (reproduction of Table 6) and wage estimations. Wages are measured as log of annual earnings per employee since this definition is appropriate to compared with productivity (value added per employee). Improved efficiency leads to decline in labor utilizations and hours worked, while hourly wages may even increase (as shown). Annual earnings also include payments from overtime hours and performance-related pay being the relevant measure for overall compensations for work. We also report log of hourly wages as dependent variable.

Table 8. Productivity - wage cap and intangible capital

	OP Productivity	OP Annual earnings	OP Hourly wages
Organizational capital intensity	0.0346*	-0.0897***	0.0278***

	(2.24)	(3.45)	(6.6)
R&D capital intensity	0.0824***	-0.177***	0.0539***
	(4.88)	(6.65)	(14.34)
ICT capital intensity	-0.105*	-0.26	0.00128
	(2.19)	(1.4)	(0.14)
Human capital	0.564***	0.394***	0.504***
	(20.53)	(10.47)	(51.19)
Tangible capital intensity	0.114***	0.0181***	0.00638***
	(45.97)	(5.36)	(7.2)
Organizational capital intensity region	0.0024	-0.0105	-0.00621
	(0.18)	(0.59)	(1.33)
R&D capital intensity region	0.0009	0.0141	0.0023
	(0.12)	(1.37)	(0.85)
ICT capital intensity region	0.0119*	-0.00492	0.00463**
	(2.54)	(0.77)	(2.76)
Share of innovative firms	0.049	0.054	0.0379*
	(1.18)	(0.95)	(2.54)
Regional intangible worker diversity	-0.0538***	0.0442**	-0.00402
	(5.47)	(3.28)	(1.14)
Own-sector firm share in the region	0.00271	0.0138*	0.000863
	(0.56)	(2.09)	(0.5)
Metropoli	0.0910***	0.128***	0.0740***
	(5.75)	(5.89)	(13.06)
Small metro	0.0586***	0.000172	0.00341
	(4.66)	(0.01)	(0.76)
Intermediate	0.0209	0.0245	0.0218***
	(1.9)	(1.63)	(5.53)
Observations	13363	13363	13363
R Squared	0.56	0.857	0.73

All except dummies and hiring in logs, five firm-size dummies, year and industry dummies and their interactions are included. OP with proxies: hiring and material up to fourth potency, intangible capital intensity up to fourth potency and interactions to hiring and material. State variable is intangible capital intensity and the number of repetitions in bootstrap is 30.

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

Work related to intangibles improves productivity while having a dampening effect on annual earnings (Tables 6 and 8). Especially organizational and R&D capital improve the profitability. We instead find similarity in productivity (column 1) and hourly wage effects (column 3). The negative effect of intangible investment on annual earnings shows that improved productivity leads to more efficiently use of labor with less working hours. Note that this may well be combined with better labor utilization and hence with an improved employment. It is of interest to compare the productivity–wage gap explained by the intangible capital intensity and including some of our regional measures over time. Figure 7 shows the aggregate productivity–wage gap. This is evaluated as the mean of the productivity–wage gap observed in years 2002-2008 that is explained by intangible capital intensity of the firm. We also analyze human capital effect and separately regional intangible spillovers and combined other regional spillovers (same-industry number of establishments, industrial diversity and settlement type of the region).

Figure 7. Productivity – wage gap explained by intangible capital intensity, human capital and regional effects.

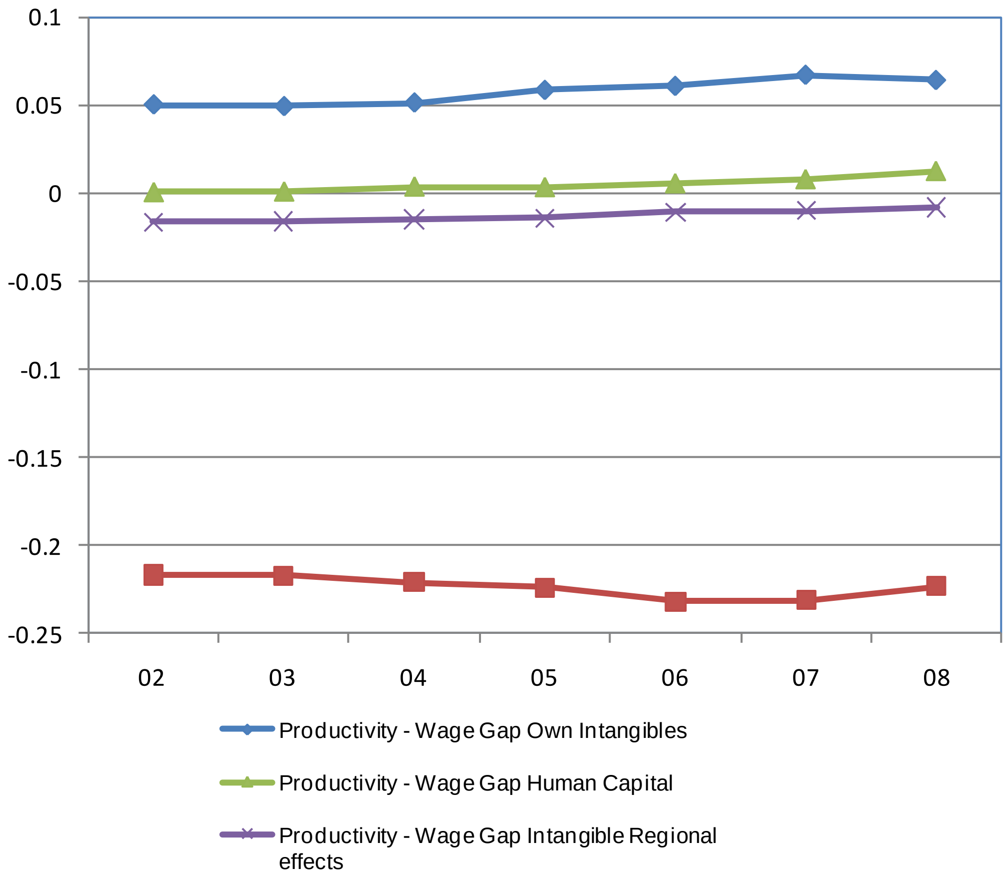


Figure 7 shows that the productivity–wage gap created by intangible capital is on average 0.05. Human capital effects are instead almost fully absorbed in wages so that profitability is not improved. High wages in agglomerated areas even lead to negative regional effects on profitability. We can thus see that a 100% increase in intangible capital intensity has a positive effect on profitability increasing it by around 5%. We can also see that the profitability effect has been steady or increasing in the most recent years. This is explained by the increasing share of intangible-type workers over the years.

Regional effects had negative effect on profitability. Part of the higher wage costs in metropolitan areas are most likely due to higher living costs and these together with human capital intensity may not raise the profitability of the firms. In Table 5 in columns 2 and 3 the large metropolitan dummy was also of the same size in productivity and wage estimates leaving thus the profitability effect to be rather moderate. It can be said that many of the unobserved characteristics have no effect on profitability. These results are consistent with other estimates on the "urban wage premium" (Glaeser, Maré 2001; Yankow 2006).

5 Conclusions

We use a large micro-dataset to assess the importance of intangible capital - organization, R&D and ICT capital – for the economic performance of establishments and regions in Finland. Intangible capital accounted for around 20% of the total capital stock of Finnish firms but the variation is large: 20% of firms have no intangible capital and in 20% of firms the share of intangible capital from total capital exceeds 50%. The middle-sized firms with 90-700 employees have highest shares of intangibles 35%. R&D capital is also evenly spread in small and large firms, which differs from the concentration of it in large manufacturing firms in Germany.

We find that 100% higher intangible intensity - half standard deviation increase from the average 25 000 Euros per employee – to increase productivity by 6-7%. As a result the profitability increases by 5%. Tangible capital intensity has not similar kind of effects in increasing productivity more than wages. Human capital is also fully absorbed in wages and cannot be considered as tacit knowledge owned by the firm, although complements intangible capital investment.

Countries should focus more in their economic policy on intangible investment and especially on accumulating organizational capital. We have analyzed the long run productivity growth and controlling for the proximity to the productivity frontier in the same industry, where organisational capital drives the long run growth. The accumulated investment into organizational capital has a positive effect on long run productivity growth. The negative effects of R&D capital as for Germany can be a sign of overinvestment. Ilmakunnas and Piekkola (2010) also find the organisational capital to be the type of intangible that improves total factor productivity. Finland is one of the most R&D intensive economies in Europe so that growth oriented policy should rely more on organizational capital. Two-thirds of the intangible capital is already R&D capital. The high proportion is evenly spread between small and large firms.

Intangibles are clearly concentrated geographically and over half of intangible capital is located in greater Helsinki area with the employment share of 28%. Greater Helsinki area is also intensive in human capital and unexplained productivity is 9% higher than in rural areas. Finland is too small country to have other metropolitan areas. Indeed nearly all of the large Finnish firms have their headquarters in greater Helsinki area. We can see that intangible investment is the source for growth supported by regional concentration of organisational capital, low industry diversity and location in metropolitan area. Intangible capital can be tacit knowledge with benefits from concentration of industries. In this respect our results are in conformity with localization economies in other types of assets as found in manufacturing (Moomaw 1998; Henderson 2003).

However, it appears that earlier studies have over emphasized this when concentrating on human capital agglomeration. We do not find positive spillovers of human capital accumulation on profitability. Most of the positive productivity effects of intangible capital investments are also created within firms and positive regional effects on profitability are absent. The regional intangible capital spillovers on productivity are modest, and again also for the UK and Germany. This leaves space for intangible investment outside metropolies. Large firms may easily reallocate their economic activity for sake of costs savings given the over 10% higher costs in operating in Greater Helsinki region. The 500 largest firms in Finland are responsible for 70% of exports and indeed have major plants outside the metropolitan area.

Ilmakunnas and Piekkola (2010) similarly show the productivity growth generated by organizational workers to be largely explained by within firm growth. We can say that regional policies can be targeted for subsidizing innovative activity also outside metropolitan area. Regional policies may still be targeted for providing *sufficient* level of educational skills as intangible and human capital are clear complements at firm-level. Availability of skilled workforce forms bottlenecks rather than being the ultimate source of growth.

Aarland, K., Davis, J., Henderson, J. V., Ono, Y. (2006): Spatial Organisation of Firms. Federal Reserve Bank of Chicago, Working Paper 2003-30

Acemoglu, D. (1996): A Microfoundation for Social Returns in Human Capital Accumulation. Quarterly Journal of Economics, 111, S. 779-804

Audretsch, D. B., Feldman, M. P. (1996): R&D Spillovers and the Geography of Innovation and Production. American Economic Review, 86, 630-640

Belhocine, N. (2009): Treating Intangible Inputs as Investment Goods: The Impact on Canadian GDP. IMF Working Paper WP/09/240.

Bellandi, M. (1989): The industrial district in Marshall. In: Goodman, E., Bamford, J. (eds.): Small firms and industrial districts in Italy, 136-152

Bertinelli, L., Strobl, E. (2007): Urbanisation, Urban Concentration and Economic Development. Urban Studies, 44 (13), 2499-2510

Borjas, G. J., Bronars, S. G., Trejo, S. J. (1992): Self-selection and Internal Migration in the United States. Journal of Urban Economics 32, 159-185

Brülhart, M., Sbergami, F. (2009): Agglomeration and growth: Cross-country evidence. Journal of Urban Economics, 65, 48-63

Ciccone, A. (2002): Agglomeration effects in Europe. European Economic Review 46: 213-227

Combes, P.-P., Duranton, G., Gobillon, L. (2008): Spatial Wage Disparities: Sorting Matters! Journal of Urban Economics, 63, 723-742

Corrado, C., Hulten, C., Sichel, D. (2005): Measuring Capital and Technology: An Expanded Framework. In Corrado, C., Haltiwanger, J., Sichel, D. (eds.): Measuring Capital in the New Economy. National Bureau of Economic Research, Studies in Income and Wealth, 65, 11-45. The University of Chicago Press, Chicago and London

Corrado, C., Hulten, C., Sichel, D. (2006): Intangible Capital and Economic Growth. NBER Working Paper 11948

Dekle, R. (2002): Industrial Concentration and Regional Growth: Evidence from the Prefectures. The Review of Economics and Statistics, 84 (2), 310-315

Duranton, G., Overman, H. G. (2005): Testing for Localization Using Micro-Geographic Data. Review of Economic Studies, 72 (4), 1077-1106

Duranton, G., Puga, D. (2001): Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. American Economic Review, 91, 1454-1477

Duranton, G., Puga, D. (2005): From Sectoral to Functional Urban Specialisation. Journal of Urban Economics, 57, 343-370

Fujita, Masahisa and Jacques-François Thisse. (2002): Economics of Agglomeration: Cities: Industrial Location, and Regional Growth, Cambridge: Cambridge University Press.

Glaeser, E. L. Maré, D. C. (2001): Cities and Skills. Journal of Labor Economics, 19, 316-342

Glaeser, E. L., Gottlieb, J. D. (2009): The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States. Journal of Economic Literature, 47 (4), 983-1028

Griliches, Z. (1967), "Production Functions in Manufacturing: Some Preliminary Results", in M. Brown (ed.), The Theory and Empirical Analysis of Production, New York: Columbia University Press.

Görzig, B., Piekkola, H., Riley, R. (2010): Production of own-account intangible investment and growth: Methodology in Innodrive project, Innodrive Working Paper No. 1.

Graham, D. J. (2008): Identifying urbanisation and localisation externalities in manufacturing and service industries. Papers in Regional Science, 88 (1), 63-84

Head, K., Mayer, T. (2004): The Empirics of Agglomeration and Trade. In: Henderson, J. V., Thisse, J-F. (Eds.): Handbook of Urban and Regional Economics, Volume 4, 2609-2669. Amsterdam: Elsevier

Hellerstein, J.K., D. Neumark, and K.R. Troske (1999), "Wages, Productivity, and Worker Characteristics: Evidence from Plant-Level Production Functions and Wage Equations", Journal of Labor Economics, Vol. 17, No. 3, 409-446.

Henderson, J. V. (2003): Marshall's Scale Economies. Journal of Urban Economics, 53, 1-28

Ilmakunnas, P. and M. Maliranta. 2005. Technology, Worker Characteristics, and Wage-Productivity Gaps. Oxford Bulletin of Economics and Statistics 67, no. 5: 623-645.

Iranzo, S., F. Schivardi, and E. Tosetti (2007): Skill Dispersion and Productivity: An Analysis with Matched Data, Journal of Labor Economics, Vol. 26, No. 1, pp. 247-285.

Jaffe, A. B., Trajtenberg, M., Henderson, R. (1993): Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citation. Quarterly Journal of Economics, 108, 577-598

Jona-Lasinio, C. and M. Iommi (2011): Intangible Capital and Productivity Growth in EU area. Innodrive working paper No. 10.

Jona-Lasinio, C. , Iommi M. and Roth, F. (2011): National Measures of Intangible Capital in EU27 and Norway in Innodrive Manual – Data and Some Results (ed. Hannu Piekkola), www.innodrive.org and University of Vaasa Reports.

Geppert, K. and A. Neumann (2010): Regional Patterns of Intangible Capital, Agglomeration Effects and Localised Spillovers in Germany, INNODRIVE Working Paper 9.

Lev, B., Radhakrishnan, S. (2005): The Valuation of Organizational Capital. In Corrado, C., Haltiwanger, J., Sichel, D. (eds.): Measuring Capital in the New Economy. National Bureau of Economic Research, Studies in Income and Wealth, 65, 73-110. The University of Chicago Press, Chicago and London

Levinsohn, J. and A. Petrin (2003), "Estimating Production Functions using Inputs to Control for Unobservables", *Review of Economic Studies*, Vol. 70, No. 2, pp. 317-342.

Malecki, E. J. (2010): Everywhere? The Geography of Knowledge. Journal of Regional Science, 50 (1), 493-513

Markusen, A. (1996): Sticky Places in Slippery Space: A Typology of Industrial Districts. Economic Geography, 72, 293-313

Markusen, A., Schrock, G. (2006): The Distinctive City: Divergent Patterns in Growth, Hierarchy and Specialisation. Urban Studies, 43, 1301-1323

Marrano, M. G., Haskel, J. (2006): How Much Does the UK Invest in Intangible Assets? Queen Mary, University of London, Working Paper 578

Moomaw, R., L. (1998): Agglomeration Economies: Are They Exaggerated by Industrial Aggregation? Regional Science and Urban Economics, 28, 199-211

Moreno. R.. R. Paci and S. Usai (2006): Spatial Spillovers and Innovation activity in European Regions. Environment and Planning A, 37, 1793-1812.

Moretti, E. (2004): Human Capital Externalities in Cities. In: Henderson, J. V., Thisse, J-F. (eds.): Handbook of Urban and Regional Economics, Volume 4, 2243-2291. Amsterdam: Elsevier

Nonaka, I. and H. Takeuchi (1995): The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation, Oxford: Oxford University Press.

Olley, G.S. and A. Pakes. (1996): The Dynamics of Productivity in the Telecommunications Equipment Industry. Econometrica 64, no. 6: 1263-1298.

Piekkola, H. (2010): Intangibles: Can They Explain the Unexplained? Innodrive working paper No. 2.

Piekkola H., Geppert K., Görzig B., Henningsen M., Jurajda S., Lintamo M., Neumann A., Riley, R., Robinson K., Skjerpen T., Stancik J., Verbic M. (2011): Firm-level Intangible Capital in Six Countries: Finland, Norway, The UK, Germany, The Czech Republic and Slovenia in Innodrive Manual – Data and Some Results (ed. Hannu Piekkola), www.innodrive.org and University of Vaasa Reports.

Puga, D. (2010): The Magnitude and Causes of Agglomeration Economies. Journal of Regional Science, 50 (1), 203-219

Rice, P., Venables, A. J. (2004): Spatial Determinants of Productivity: Analysis for the Regions of Great Britain. CEP Discussion Paper 642

Rigby, D. L., Essletzbichler, J. (2002): Agglomeration Economies and Productivity Differences in US Cities. Journal of Economic Geography, 2, 407-432

Riley, R. and Robinson, C. (2011): Agglomeration Spillovers from Intangible Capital: An Analysis of UK City Regions. INNODRIVE Working Paper No 15.

Rodriguez-Pose, A., Crescenzi, R. (2008): Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe. Regional Studies, 42 (1), 51-67

Rosenthal, S. S., Strange, W. (2003): Geography, Industrial Organization, and Agglomeration. Review of Economics and Statistics, 85 (2), 377-393

Rosenthal, S. S., Strange, W. (2004): Evidence on the Nature and Sources of Agglomeration Economies. Handbook of Regional and Urban Economics. V. Henderson and J.-F. Thisse. Amsterdam, North-Holland. 4: 2119–2171

Rosenthal, S. S., Strange, W. (2004): Evidence on the Nature and Sources of Agglomeration Economies. Handbook of Regional and Urban Economics. V. Henderson and J.-F. Thisse. Amsterdam, North-Holland. 4: 2119–2171

Roth, F. and A.-E. Thum (2010): Does intangible capital affect economic growth. Innodrive working paper No. 3.

Vandenbussche, J., Aghion P. and C. Meghir (2004): Growth, Distance to Frontier and Composition of Human Capital. xxx

Van Soest, D. P., Gerking, S., van Oort, F. G. (2006): Spatial Impacts of Agglomeration Externalities. Journal of Regional Science, 46, 881-899

Yankow, J. J. (2006): Why Do Cities Pay More? An Empirical Examination of Some Competing Theories of the Urban Wage Premium. Journal of Urban Economics, 60, 139-161

Appendix

Table A.1 Summaries

Variable	Mean	Standard Deviation	Median
Labour productivity	66	59	52
Productivity growth in 3 years	0.11	0.36	0.096
Hourly wages €	17	4.3	16
Intangible capital per employee	24	82	7
Human capital	0.004	0.160	-0.003
Tangible capital per employee	133	818	27
Intangible capital per employee region	29	15	28
Share of innovative firms	35.0 %	11.0 %	37.0 %
Employees/km2 in the region	351	523	22
Industrial diversity	8.8	3.8	8.4
Own-sector firm share in the region	7.1	11.0	3.0
Employment share in metropoli	29.0 %	44.0 %	0.0 %
Employment share in small metropolies	20.0 %	38.0 %	0.0 %
Employment share in intermediate	21.0 %	39.0 %	0.0 %
Value added market prices	17437	84476	3761
Value added incl. intangibles market prices	20705	99167	4322
Organizational capital/value added	5.9 %	0.9 %	6.2 %
R&D capital/value added	26.0 %	3.1 %	27.0 %
ICT capital /value added	2.9 %	0.6 %	3.2 %
Intangible capital/value added	34.0 %	4.5 %	35.0 %
Organizational investment/value added	1.6 %	0.2 %	1.7 %
R&D investment/value added	5.7 %	0.6 %	5.9 %
ICT investment/value added	1.0 %	0.2 %	1.2 %
Tangible capital/value added	85.0 %	9.8 %	82.0 %

In thousands € fixed 2000 prices. In the ratios value added includes intangible investment.