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INTANGIBLE INVESTMENT AND MARKET VALUATION

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This study derives performance- and expenditure-based estimates of intangible capital and measures the extent to which intangible capital is captured by the equity market measures of firm value. Intangible capital is evaluated using occupational information available in the Finnish linked employer–employee data for the 1997–2011 period. The performance-based organizational investment in value added is approximately 3 percent; R&D and ICT investment shares are lower, at 1.5 percent, and all are clustered in intangible-intensive sectors that represent 40 percent of the private sector. Expenditure-based organizational capital also exists in clusters other than that intensively investing in managerial and marketing effort, and performance-based R&D capital is concentrated in the cluster with intensive R&D activity; both increase the market value of firms beyond the level that can be explained by standard economic analysis.

JEL Codes: J30, J42, M12, O30, O32

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1. Introduction

This paper analyzes the performance of own account production of intangible goods of the following types: organizational capital, research and development (R&D), and information and communications technology (ICT). The benchmark approach is the expenditure-based approach, which utilizes a measure of innovation input rather than innovation output. We evaluate not only R&D and ICT capital but also organizational capital, the value of which can be poorly reflected in book values. An increasing number of expenditures on management and marketing need to be recognized as intangible investments that increase productivity over a longer period. This type of organizational investment is more clearly firm specific and owned by the firm to a greater extent than other types of intangibles (Lev and Radhakrishnan, 2003, 2005; Youndt *et al.*, 2004).

R&D expenditures, in turn, were recently included in the U.S. GDP in addition to a category called entertainment, literary and artistic originals, and R&D expenditures were included in many EU countries' GDP in 2014. Investments in ICT complement R&D and organizational investment, as found in Ito and Krueger (1996) and Bresnahan and Greenstein (1999). Simply, R&D investment dominates in the early phase of creation of new products and services, while

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management and marketing abilities are needed when the product is put on sale. Due to the high degree of complementarity, intangible investments are analyzed in separate clusters that differ in the intensity of their use of the various intangibles. The organizational-capital-intensive cluster primarily consists of wholesale, retail, information, and transportation firms. Organizational capital, however, plays a less important role in certain fixed-capital-intensive firms listed on the Helsinki stock exchange. R&D-capital-intensive clusters are dominated by parts of construction, machinery and equipment, and electrical equipment but also include some large service-sector firms. Clusters also differ in how different types of intangibles complement each other.

The expenditure-based measure used in the INNODRIVE project and described by Görzig *et al.* (2010) utilizes the occupational structures of firms and assumes that a certain fraction of organizational, R&D, and ICT workers are engaged in the production of intangible goods irrespective of the industry/cluster.[1] The value of the necessary intermediate and capital costs in the own-account production of intangible capital goods is evaluated, which differs from the widely adopted approach developed by Corrado *et al.* (2005, 2009). The performance-based approach employs the Hellerstein *et al.* (1999) (HNT) methodology to infer a measure of the marginal products of intangible types of labor. Ilmakunnas and Maliranta (2005) and Ilmakunnas and Piekkola (2013) also consider these marginal products. The novelty in this paper is the evaluation of rents from intangible capital investment in conjunction with the output elasticities of the respective intangibles to form new performance-based estimates of intangible investments and capital. Most of the ICT literature analyzes either the marginal product (Morrison, 1997; Gera *et al.*, 1999) or the elasticity (Stiroh, 2005), but not both.

The output elasticity of R&D observed by Griliches (1979, 1984) ranges from 10 percent in the research-intensive sectors to 4 percent for the rest of U.S. manufacturing, which is similar to the figure we obtained in the R&D-intensive cluster when controlling for fixed effects. The output elasticities of R&D capital in Cuneo and Mairesse (1984) and Mairesse and Cuneo (1985) are higher, ranging between 9 and 33 percent in France, and the output elasticity is 15.3 percent in the U.K. (O'Mahony and Vecchi 2009). Ignoring organizational capital is likely to bias these estimates of R&D elasticity upwards, while a downward bias may emerge from either an overly broad definition of R&D effort or counting the labor used in the production of intangible assets in other areas. We avoid the bias resulting from omitting other intangibles by relying on occupational data. The latter biases are also mitigated because workers have only one profession, and hence R&D activity cannot overlap with other activities. Moreover, the performance-based approach also adjusts for the share of intangible work that is creating future intangible investment goods.

A Tobin's q valuation model, following Hall *et al.* (2007), is linked with a residual income valuation model that was further improved by Ohlson (1995). The intuition is that the financial markets assign a valuation to the bundle of firms' tangible and intangible assets, which is equal to the present discounted value of future cash flows. The research question is whether intangible capital yields

[1]See the INNODRIVE project website, at http://www.innodrive.org.

additional information that can explain the valuation of the firm beyond that explained by economic forecasts, which we find to be the case.

Section 2 of the paper discusses the composition of intangible capital and presents the data. The calculation of intangible capital and methodology in the expenditure-based approach and in the performance-based approach is provided in Sections 3 and 4, respectively. Section 5 incorporates intangible capital into a valuation model. Section 6 concludes.

2. Intangible Capital Components and Data

Organizational capital includes the competence of the top management and human resources, as well as that of marketing and sales efforts. The organizational structure of a firm's own-account production in Corrado *et al.* (2005) (CHS) is measured according to a predetermined share of management expenditures (20 percent) in total wage compensation. Market research activities, however, are not measured using expenditures on marketing personnel but by the size of the marketing industry in the System of National Accounts or by using private sources from media companies, as in Marrano and Haskel (2006).

This paper evaluates intangible investment from the perspective of occupational structure using linked employer–employee data that have been used extensively in the human capital formation literature, beginning with Abowd *et al.* (1999). These data are convenient for use in an analysis that relies on the valuation of different tasks and occupations. The labor data are from the Confederation of Finnish Industry and Employers with 9.6 million person-year and 68,754 firm-year observations for the years 1996–2011. The data include a rich set of variables covering compensation, education, and professions in the private sector. The non-production employees receive salaries, and the production workers, 36 percent of all workers, receive an hourly wage. Employee compensation is evaluated based on both hourly wages and annual earnings (which include performance-related pay and social security taxes).

The occupational codes in the Confederation of Finnish Industries labor data can be transformed into the International Standard Classification of Occupations by the International Labour Organization (ISCO-88). The occupations in manufacturing and services have different classifications; ultimately, we have 41 non-production worker occupations, which are listed in Appendix A. Organizational compensation is obtained from the occupations that are classified as relating to organizational capital—management (all executive level work), marketing, purchases, media, and financial administrative work performed—and dropping those employees with the lowest qualifications.[2] In R&D, the categorization of workers is broad and includes all with higher tertiary level technical education if the occupation code does not indicate another type of intangible (IC) work.[3]

[2]The fourth and lowest category is the implementation level; the others are the executive level, the senior expert level, and the expert level.

[3]The inclusion of all workers with higher technical education doubles the number of R&D workers in manufacturing and increases their share in services by 30 percent.

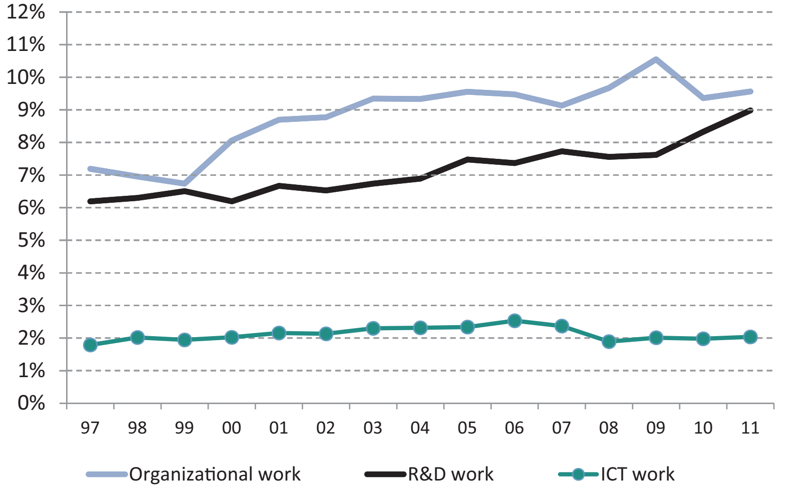

Figure 1. Share of Private-Sector Employees Engaged in Work Related to Intangible Capital in Finland (1996–2011)

Employee data are linked to the financial statistics data provided by the private company Suomen Asiakastieto[4] and include information on profits, value added, and capital intensity (fixed assets) for domestic firms. To eliminate firms with unreliable balance sheets, we only include firms that have real domestic sales exceeding €1.5 million (in 2000 consumer prices) in the analysis. The final linked employer–employee dataset of 6.66 million person-year observations annually covers an average of 2276 firms with 33,808 firm-year observations for the 1997–2011 period, and covers 53 percent of the turnover of Finnish companies in 2011. The employee data in the sample have an annual average of 447,000 employees (the original employee data covered 580,000 employees for the respective period), that is, one-third of the total private-sector workforce. Figure 1 presents the share of workers in occupations related to production and intangible capital in the linked employer–employee data (LEED). The micro data are aggregated to be representative at the business sector level. The figures are adjusted for the difference between the number of firms in the LEED data and that in the entire private sector from Statistics Finland in five turnover-size, one-digit industry classes.[5]

The shares of organizational occupations were generally approximately 8.8 percent. Management (3.4 percent) and marketing (5.4 percent) are the main categories for organizational work. The share of R&D workers is similar, at 7.1 percent (or 4.2 percent if those with higher tertiary technical education but not directly employed in an organizational, ICT, or R&D occupation are excluded).

[4]Suomen Asiakastieto is the leading business and credit information company in Finland.

[5]In the aggregation, the following categories are used in each one-digit industry: (1) turnover under 2 million Euros; (2) turnover between 2 and 10 million Euros; (3) turnover between 10 and 40 million Euros; (4) turnover between 40 and 200 million Euros; and (5) turnover over 200 million Euros (in year 2000 consumer prices).

TABLE 1
Summary of Variables

Variable	Mean	Std	Median	Obs
Value added factor prices (in 1000s)	21,992	104,169	4,118	33,488
Value added growth	3.6%	44.0%	0	26,452
Turnover (in 1000s)	59,906	279,557	9,862	33,808
Employment	197	795	45	33,808
Employees in organizational work	15	66	2	33,808
Organizational worker share	9.7%	15.0%	3.9%	33,808
Employees in R&D work	13	73	1	33,808
R&D worker share	6.3%	13.0%	0.9%	33,808
Employees in ICT work	4	29	0	33,808
ICT worker share	1.4%	6.8%	0.0%	33,808
Annual earnings (in 1000s)	30	10	30	33,808
Hourly wage	12	3	11	33,807
Organizational compensation (in 1000s)	740	3,151	109	33,808
Organizational compensation per value added	3.6%	0.4%	3.7%	33,731
R&D compensation (in 1000s)	547	3,185	30	33,808
R&D compensation per value added	2.7%	0.4%	2.5%	33,731
ICT compensation (in 1000s)	175	1,373	0	33,808
ICT compensation per value added	0.9%	0.1%	0.9%	33,731
Fixed capital (in 1000s)	43,084	401,235	1,685	33,808
Materials (in 1000s)	1,761	11,763	42	33,488

Notes: New value added, turnover, fixed capital, and materials are deflated at 2000 producer prices. New value added in the table is the sum of the operating margin, employment compensation, and an effective value added tax of 19.9% of the expenditure-based estimates of intangible capital. Annual earnings, hourly wages, and compensation for organizational, R&D, and ICT work are deflated using a wage index.

The total share of ICT workers is approximately 2.1 percent.[6] The increasing share of intangible-capital related workers is explained by the falling share of production workers, from approximately 50 to 28 percent. The 17.8 percent share of personnel in organizational, R&D, and ICT work in 2003 is comparable to the average share of 18 percent in the six European countries with LEED data in INNODRIVE. Management and marketing occupations are closely related, and the definitional distinctions between these occupations vary across countries. Management wage expenses alone, without accounting for marketing wage expenses—as in the procedure for calculating the national measures of intangible capital—may offer a less comparable basis for an analysis of organizational capital across countries. Table 1 presents a summary of the variables in the estimation sample.

The average value added is €26 million, and the growth in average value added is 3.6 percent (in 2000 producer prices). The average total organizational compensation of €740,000 exceeds the total of R&D and ICT compensation of €722,000. We observe intangible work occupations in 75 percent of all firms irrespective of size (organizational activity for 71 percent of the firms and R&D activity for 51 percent of the firms). These figures also capture small firms with only one or two workers engaged in intangible capital activities (the median is one

[6]Most ICT work is concentrated in the following industries: computers, software, and electronic equipment; finance; healthcare, medical equipment, and pharmaceuticals; and telecommunications, telephone, and TV transmission. The highest share of ICT workers in total intangible workers is in the fixed-capital- and organizational-capital-intensive cluster.

worker in R&D and ICT activities and two in organizational activities). This result indicates that R&D investments can be observed for many companies, whereas, for example in Sandner and Block (2011), R&D investments are only observed for 41 percent of the companies considered.

3. Methodology for the Expenditure-Based Approach

The methodology for the expenditure-based approach is also described in Görzig *et al.* (2010) (GPR). The basic concept is that each firm produces the following two types of intangible goods that are directed toward the firm's own use: organizational R&D, and ICT. Some share of the intangible employees is engaged in the production of intangible goods with a service life of over one year; the rest are engaged in current production (consumption). Alternatively, part of the working time is devoted to intangible production. To evaluate the values of the intermediate and capital costs related to the labor costs incurred in the production of intangible capital goods, the following industries in category 7 of the Classification of Economic Activities in the European Community (Nace Rev. 2) have been selected:

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

Expenditure-based calculations have been performed for each type of intangible expenditure IC = organizational capital (OC); R&D; ICT. Production of intangible goods (investment) of type IC, uses labor, capital, and intermediate input. The nominal value of intangible capital investment of type IC is given by

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

where labor costs are multiplied by M^{IC}, the combined multiplier, to assess the total investment expenditures on intangibles (as discussed below), and wL_{it}^{IC} denotes 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. The combined multiplier M^{IC} is the product of the shares of organizational, R&D, and ICT work that produce intangible goods and a factor multiplier depending on the intermediate and capital costs related to (one) unit of labor costs. We employ annual earnings instead of hourly wages because they include performance-related pay and the workers in managerial positions are not paid for overtime hours; their recorded hours are therefore lower than the actual value. The real stock R_t^{IC} of intangible capital of type IC for a firm *i* (or at cluster level *j*) is given by

$$(2) \qquad R_t^{IC} = R_{t-1}^{IC}(1-\delta_{IC}) + N_t^{IC}, \quad R^{IC}(0) = N^{IC}(0)/(\delta_{IC} + g_{IC}),$$

where $N^{IC}(0)$ is the initial investment, $R^{IC}(0)$ is the initial intangible capital stock, δ_{IC} is the depreciation rate, and g_{IC} is the growth of the intangible capital stock of type IC using the geometric sum formula. The initial intangible investment $N^{IC}(0)$ is operationalized as the average investment over the five-year period following the

TABLE 2

OC, R&D, and ICT 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%

first observation year. The average is used to assess the average investment rate over the business cycle. The growth rate g_{IC} is set at 2 percent, which follows the sample average growth rate (2 percent) of real wage costs for intangible-capital-related activities.

GPR provide the value of a combined multiplier M^{IC} (the product of the shares of organizational, R&D, and ICT work that produce intangible goods and a factor multiplier). The factor multiplier from the intermediate and capital costs related to (one) unit of labor costs is a weighted average of the factor multipliers for Germany (40 percent weight), the U.K. (30 percent weight), Finland (15 percent weight), and the Czech Republic and Slovenia (both 7.5 percent weights).[7] The factor multiplier is thus set to be representative for the entire EU27 area. Purchased intangibles are included in intermediates, and hence the fixed factor multiplier assumes that the ratio of purchased to own account capital in the production of own-account intangible goods is identical across firms. We focused on the own-account production of intangible goods and excluded the purchased intangible capital apart from that employed as an input in the production of own-account intangibles. Purchased intangible capital represents half of all intangible capital in the EU27 countries according to the national estimates by Jona-Lasinio and Iommi (2011), but this figure will overlap with own-account intangibles when used as intermediate inputs.

The share of workers producing intangible goods is set at 40 percent for organizational occupations (double the share used in GPR), 70 percent for R&D occupations, and 50 percent for ICT occupations. The factor multipliers employed 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. If Finnish input–output tables had been used (instead of the weighted average over six countries), the factor multipliers would decline to 1.56 for organizational investment, 1.31 for R&D, and 1.37 for ICT investment. Table 2 summarizes the combined multiplier M^{IC} (the product of the share of work devoted to IC production and the factor multiplier) and the depreciation rates used.

Overall, organizational and ICT investments represent 70 percent of wage costs in the respective occupations (in ICT, the figure is an approximation of the combined multiplier of 0.74). In R&D activities, the total wage costs are similar to approximations of total investments, with a combined multiplier of 110 percent.

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

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 percent than the 20 percent figure used in CHS. The depreciation rate for organizational investments is set at 20 percent in production, while the higher depreciation rate of 25 percent employed by CHS is retained in services. This higher rate is used because the life cycle of an organizational investment is longer in production (2.9–5.4 years) than in services (2.6–4 years), and branding and reputational efforts are higher in services and are relatively short lived. ICT investments face a 33 percent depreciation rate.

4. Methodology in the Performance-Based Approach

The performance-based approach analyzed here assumes a constant returns-to-scale (CRTS) production function using the expenditure-based estimate as a starting point. Following the approach used by Griliches (1967) and HNT, the effective labor input is quality adjusted for the productivity (rent) of organizational, R&D, and ICT workers. Estimating production provides information on marginal productivity of IC workers and the output elasticities. Estimation is done by clusters and therefore releases the assumption of a common technology which would lead to biased estimates. Another reason is the correlation between intangible assets—in particular in those with few intangibles—and therefore in some clusters intangible capital inputs are used as a whole in the production function estimation. Clusters are determined depending on organizational, R&D, ICT, and fixed capital investment as a share of factor inputs employed (which also include labor costs). The partition cluster method divides firms into non-overlapping groups using the deviation of median values from the average. Each observation is assigned to the group with the closest median and, based on that grouping, new group means are determined. The procedure continues until no observations change groups. The clusters are thus characterized by varying factor input intensities.

Some service and production industries are first treated as a separate heterogeneous group that is not included in the clustering 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 the remaining firms results in four optimal clusters with other industries as the fifth cluster (see Table A.2 in Appendix A).[8] The clusters are: (i) fixed capital intensive with a mean 90 percent factor input share of fixed investment and a 17 percent share of private-sector value added; (ii) fixed capital and organizational capital intensive, where the respective factor input shares are 57 percent for fixed investment and 26.5 percent for organizational investment, and with a 27 percent share of private-sector value added; (iii) R&D intensive with a mean 57.2 percent factor input share and 25 percent private-sector value added share; (iv) organizational capital (OC) intensive with a mean 68.4 percent factor input share and 14 percent private-sector value added share; and (v) the industries that were not clustered with a 17 percent private-sector value added share. The value added shares of the clusters thus range

[8]Four clusters were optimal according to the Calinski and Harabasz (1974) criterion.

from 14 percent for the OC-incentive cluster to 27 percent for the fixed-capital and OC-incentive cluster. The OC-intensive cluster is dominated by (wholesale) trade, information, and transportation, and the R&D-intensive cluster by construction, machinery and equipment, electrical equipment, and scientific R&D.

The explanatory variable is value added and includes investments in all types of intangibles $Y_{it} = VALADD_{it} + \sum_{IC} N_{it}^{IC}$ for firm i in year t. 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

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

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), and *eit* is an error term. Following the analysis of the productivity of intangible workers as in HNT, quality-adjusted labor is

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

where q_{it} denotes the quality adjustment due to marginal productivity in occupations of type IC. The relative rent (marginal productivity) of IC occupations differs from that of the other workers in cluster j by a factor $a_j^{IC,NON-IC}$, which should be compared with the wage ratio for IC occupations relative to non-IC occupations in cluster $w_j^{IC,NON-IC}$. We can approximately write in log form $\log q_{it} = \log\left[1 + \sum_{IC} (a_j^{IC,NON-IC} - 1) L_{it}^{IC} / L_{it}\right] \approx \sum_{IC} (a_j^{IC,NON-IC} - 1) L_{it}^{IC} / L_{it}$, as 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

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

where $b_{LICj} = b_{Lj}(a_j^{IC,NON-IT} - 1)$. One approach is to assume that the relative wages align with the relative marginal productivity $a_j^{IC,NON-IT} = w_j^{IC,NON-IT}$. This assumption assumes that the labor market (or factor input market for intangibles) is competitive. In other words, employees receive no rents from production. Note that L_{it}^{IC} is used in the construction of R_{it}^{IC}, but this would not affect the outcome because workers capture no rents. We assume that the factor input markets in the production of intangibles may not be competitive. In particular, firms may have some monopsony power in the labor market and capture some rents. We measure rents using

(6) $$z_{jt}^{IC} = \frac{a_j^{IC,NON-IT}}{w_{jt}^{IC,NON-IT}},$$

where $a_j^{IC,NON-IT} = b_{LICj}/b_{Lj} + 1$. If $z_{jt}^{IC} > 1$ the relative marginal productivity of an intangible worker of type IC to non-intangible workers is higher than the hourly wages of IC workers relative to non-intangible workers in year *t*. Ilmakunnas and Piekkola (2013) found this to be the case, especially for high-productivity firms. The productivity-wage gap is thus explained by firm-specific intangible and human capital that cannot be purchased from the market. In contrast, when the intangibles are more general and characterized by human capital the labor market is closer to perfect competition, and the rent multiplier z_{ICjt} should be closer to unity. Note that the monopsony power of firms in the intangible work labor market ensures that employees capture no rents and hence rents z^{IC} can be separately determined from intangible investment R_{it}^{IC}, as labor costs are unaffected.

The output elasticities $\hat{b}_{ICjt}$ of IC capital reflect annual capital income shares under perfect competition and constant returns to scale

$$\hat{b}_{ICjt} = \frac{P_{jt}^R r_j^{IC} R_{jt}^{IC}}{P_{jt}^Y Y_{jt}}, \tag{7}$$

where the rental rate r_j^{IC} equals depreciation and the external rate of return of 4 percent, 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 $\hat{b}_{ICjt}$ is a constant for the time and industry under consideration. The perpetual inventory method from (2) implies that $N_{jt}^{IC} = (g_{jt}^{IC}(1-\delta_{IC}) + \delta_{IC})R_{jt}^{IC}$, where $g_{jt}^{IC} = (R_{jt}^{IC} - R_{jt-t}^{IC})/R_{jt}^{IC}$ is the growth rate of intangible capital observed in industry *j*. Solving this equation for R_{jt}^{IC} and substituting in (7) provides

$$\hat{b}_{ICjt} = \frac{P_t^R N_{jt}^{IC}}{P_{jt}^Y Y_{jt}} \frac{r_{ICj}}{g_{jt}^{IC}(1-\delta_{IC}) + \delta_{IC}}. \tag{8}$$

The nominal value of an intangible capital investment of type IC using the performance-based approach is given by

$$P_t^N N_{jt}^{IC} \equiv z_{jt}^{IC} M_{jt}^{IC} w L_{jt}^{IC}, \tag{9}$$

where $z_{jt}^{IC} M_{jt}^{IC}$ is the product of rents z_{jt}^{IC} and the combined multiplier M_{jt}^{IC}. Equations (8) and (9) yield

$$z_{jt}^{IC} M_{jt}^{IC} = \bar{b}_{ICj} \frac{P_{jt}^Y Y_{jt}}{(P_t^R/P_t^N) w L_{jt}^{IC}} \frac{g_{jt}^{IC}(1-\delta_{IC}) + \delta_{IC}}{r_j^{IC}}. \tag{10}$$

Here, output elasticity $\hat{b}_{ICjt}$ is proxied by the estimate for the entire period $\bar{b}_{ICj}$ (from (5) as given by the estimation of (11) below), and the intangible capital growth of type IC g_{jt}^{IC} at any period is approximated by the growth implied by the expenditure-based estimates. The rent multiplier z_{jt}^{IC} from (6) and (10) also provides an estimate of the total multiplier $M^{*}_{ICjt} = z^{IC}_{jt} M^{IC}_{jt} / z^{*}_{ICjt}$. A higher intangible capital growth g^{IC}_{jt} and a lower user cost of capital r^{IC}_{j} at a given level of intangible labor costs must be explained by an increase in either the rent z^{IC}_{jt} or the combined multiplier M^{IC}_{jt}. As in the expenditure-based approach, the combined multiplier depends on the share of workers engaged in the production of intangible capital of type IC and the use of other inputs (intermediates and capital); the performance-based approach does not directly indicate which of the two is subject to change.

The estimation for each industry j and year t from (5) is provided by[9]

$$(11)\quad \ln Y_{it} = b_0 + b_{Lj} \ln L_{it} + \sum_{IC} b_{LICj} \frac{L_{ICit}}{L_{it}} + \sum_{IC} b_{ICj} \ln K_{ICit} + b_{Kj} \ln K_{it} + b_z' X_{jt} + e_{it},$$

where X_{jt} is the vector of control dummy variables (years and, in pooled estimates, their interaction terms with clusters), $b_{LICj} = b_{Lj}(a^{IC}_{j} - 1)$ and e_{it} is the residual error. The value added Y_{it} is in real factor prices using producer prices as a deflator. The parameter Y_{it} also includes the real investment in intangibles that are deflated by the investment deflator in business services. We prefer the fixed effects models to estimate (11) for all firms and at the cluster level while assuming time invariant rents and output elasticities, but we also present the random effect results. The Hausman specification test also reveals that fixed effects estimates should be preferred to random effect estimates in all clusters.

Table 3 reports the pooled and cluster-level estimation results. The general finding is that organizational capital is productive in the organizational-capital-intensive cluster and R&D capital is productive in R&D-intensive clusters. In all other clusters, organizational capital has a particularly high correlation with ICT capital (approximately 0.65 in both the fixed-capital and OC-intensive cluster and in the R&D-intensive cluster) and organizational and ICT capital are estimated jointly. Table 3 indicates that the combined elasticities are reasonably high in the fixed- and OC-capital-intensive cluster. Additionally, all intangibles (including R&D) are considered as a whole in the other industries and in the fixed-capital-intensive clusters, where joint elasticities are low.

The output elasticities of intangible capital vary substantially from one cluster to another, and therefore a single combined multiplier irrespective of the type of cluster, as assumed in the expenditure-based approach, does not hold. An example is the low output elasticities in the fixed-capital-intensive and other industry clusters. These clusters have relatively few intangibles, which are unproductive.

Note also that all estimates yield decreasing returns to scale if the quality of labor q is fixed. Increasing factor inputs and labor quality by the same amount and dropping the no-intangible-capital dummies would instead lead to estimates closer to constant returns to scale. It is well known that more aggregated national data typically provide higher output elasticity estimates (Stiroh, 2005).

In Table 4, the three columns in each cluster report the output elasticity based on Table 3, the rent multiplier z^{IC}_{j}, which is estimated as relative rents divided by

[9]Caves and Barton (1990) and Jorgenson *et al.* (1986) provide details regarding the estimation of firm production functions with fixed effects. It must be acknowledged that b_{ICj} and therefore the rent multiplier z^{IC}_{jt} and the combined multiplier M^{IC}_{jt} are also dependent on specification and measurement errors.

TABLE 3

PRODUCTION FUNCTION FIXED EFFECT AND RANDOM EFFECT ESTIMATIONS: ALL AND BY CLUSTERS

	All		Fixed-Capital Intensive		Fixed- and OC-Capital Intensive		R&D-Intensive		OC-Capital-Intensive		Other Industries	
	Fixed	Random	Fixed	Random	Fixed	Random	Fixed	Random	Fixed	Random	Fixed	Random
Employment	0.312***	0.361***	0.183***	0.258***	0.306***	0.354***	0.420***	0.450***	0.371***	0.402***	0.185***	0.251***
	(45.09)	(56.53)	(14.82)	(23.38)	(20.57)	(25.56)	(24.55)	(28.61)	(20.34)	(24.14)	(10.86)	(18.56)
Relative rent OC	0.341***	0.427***	–	–	–	–	–	–	0.240***	0.216**	–	–
	(8.35)	(10.95)	–	–	–	–	–	–	(3.43)	(3.23)	–	–
Relative rent OC	–	–	–	–	0.535***	0.691***	0.427***	0.334***	–	–	–	–
and ICT	–	–	–	–	(5.85)	(7.86)	(4.11)	(3.48)	–	–	–	–
Relative rent	0.587***	0.543***	–	–	0.613***	0.619***	0.654***	0.422***	0.393	0.382	–	–
R&D	(11.3)	(11.32)	–	–	(5.64)	(5.81)	(7.95)	(5.69)	(1.94)	(1.93)	–	–
Relative rent ICT	0.262*	0.517***	–	–	–	–	–	–	0.602**	0.540**	–	–
	(2.53)	(5.43)	–	–	–	–	–	–	(2.68)	(2.62)	–	–
Intangible capital	–	–	0.000408	0.0762***	–	–	–	–	–	–	0.00712	0.191***
	–	–	(0.03)	(6.14)	–	–	–	–	–	–	(0.36)	(13.68)
Organizational	0.0396***	0.102***	–	–	–	–	–	–	0.0849***	0.187***	–	–
capital	(4.25)	(11.93)	–	–	–	–	–	–	(3.62)	(9.21)	–	–
Organizational	–	–	–	–	0.0656***	0.0961***	–0.00178	0.0484**	–	–	–	–
and ICT capital	–	–	–	–	(3.99)	(6.23)	(0.09)	(2.59)	–	–	–	–
R&D capital	0.00235	0.0422***	–	–	0.00171	0.0283	0.0448	0.114***	0.0233	0.0364	–	–
	(0.25)	(5.08)	–	–	(0.09)	(1.72)	(1.88)	(5.92)	(1.03)	(1.75)	–	–
ICT capital	–0.000202	0.0508***	–	–	–	–	–	–	–0.0244	0.0186	–	–
	(0.02)	(4.47)	–	–	–	–	–	–	(0.96)	(0.79)	–	–
Net plant,	0.150***	0.171***	0.229***	0.283***	0.174***	0.203***	0.0997***	0.115***	0.115***	0.119***	0.221***	0.221***
property,	(39.28)	(51.3)	(22.12)	(36.52)	(18.17)	(24.85)	(12.39)	(15.99)	(16.53)	(18.32)	(20.23)	(27.95)
equipment												
Intangible asset	–	–	0.0206	0.418***	–	–	–	–	–	–	0.0447	0.976***
dummy	–	–	(0.26)	(5.75)	–	–	–	–	–	–	(0.37)	(10.74)
OC (and ICT)	0.234***	0.588***	–	–	0.424***	0.631***	0.015	0.312**	0.444**	1.082***	–	–
asset dummy	(4.3)	(11.8)	–	–	(4.38)	(6.95)	(0.12)	(2.87)	(3.17)	(9)	–	–
R&D asset	0.0156	0.247***	–	–	–0.0299	0.139	0.414**	0.893***	0.1	0.183	–	–
dummy	(0.28)	(4.92)	–	–	(0.28)	(1.41)	(2.61)	(7.05)	(0.74)	(1.46)	–	–
ICT asset dummy	0.01	0.265***	–	–	–	–	–	–	–0.116	0.0859	–	–
	(0.16)	(4.67)	–	–	–	–	–	–	(0.91)	(0.73)	–	–
Observations	34,346	34,346	7,605	7,605	9,541	9,541	6,410	6,410	5,904	5,904	4,846	4,846
R squared within	0.201	0.195	0.190	0.183	0.149	0.148	0.218	0.213	0.258	0.254	0.209	0.182
sigma_e	0.469	0.469	0.389	0.389	0.505	0.505	0.479	0.479	0.419	0.419	0.461	0.461
sigma_u	0.872	0.694	0.769	0.599	0.870	0.772	0.764	0.652	0.787	0.686	1.004	0.735
rho	0.776	0.687	0.796	0.703	0.748	0.700	0.718	0.649	0.779	0.728	0.826	0.717

Notes: All values except intangible worker shares are in logs. Year, industry dummies, and their interactions and dummies for no organizational, R&D, and ICT capital are included. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TABLE 4

Output Elasticities, Rents $z^{IC} = a^{IC,NON-IT}/w^{IC,NON-IT}$ and Combined Multipliers M^{IC} in Fixed Effects Estimation

Industry	Annual Value Added in Billion €, 2000 Prices	Organizational			R&D			ICT		
		Output Elasticity	Rent Multiplier z	Combined Multiplier M	Output Elasticity	Rent Multiplier z	Combined Multiplier M	Output Elasticity	Rent Multiplier z	Combined Multiplier M
Fixed-capital intensive	9,256									
Industry fixed		0.04%	6.04	0.002	0.04%	6.23	0.002	0.0%	6.18	0.00
Fixed- and OC-intensive	14,000									
Industry fixed		6.6%	1.22	1.41	0.2%	1.96	0.04	6.6%	1.63	2.50
R&D-intensive	14,200									
Industry fixed		0.00%	0.94	0.000	4.5%	1.63	0.44	0.0%	1.13	0.00
OC-intensive	7,468									
Industry fixed		8.5%	0.70	2.05	2.3%	1.61	1.04	0.0%	1.81	0.00
Other industries	8,541									
Industry fixed		0.7%	5.88	0.03	0.7%	6.08	0.04	0.7%	6.03	0.07
All										
Average		3.0%	2.65	0.66	1.7%	3.22	0.28	1.8%	3.01	0.67
Average total multiplier		0.68			0.48			1.14		

Notes: Rent is the relative rent divided by the relative wages. The organizational relative rent and wages in the fixed effects estimates are 10.55 and 2.32 in cluster 1, 3.26 and 0.48 in cluster 2, 1.8 and 2.12 in cluster 3, 1.58 and 2.34 in cluster 4, 12.68 and 2.16 in cluster 5. The R&D relative rent and wages in the fixed effects estimates are 8.17 and 1.56 in cluster 1, 3.02 and 0.63 in cluster 2, 2 and 1.56 in cluster 3, 2.03 and 1.26 in cluster 4, 9.11 and 1.5 in cluster 5. The ICT relative rent and wages in fixed effects estimates are 8.7 and 1.71 in cluster 1, 3.26 and 0.65 in cluster 2, 1.8 and 1.76 in cluster 3, 2.46 and 1.46 in cluster 4, 9.84 and 1.63 in cluster 5.

TABLE 5
Summary of Intangible Capital

Variable	Mean	Standard Deviation	Median	Businesses Mean	Businesses Median
Value added (VA) at factor prices excluding intangibles	21,992	104,169	4,118		
Book value of assets	27,105	377,390	1,148		
Organizational capital expenditure-based	3,630	12,245	1,047		
Organizational capital	5,583	14,708	1,577		
R&D capital experience-based	7,094	29,773	1,231		
R&D capital	4,409	19,408	554		
ICT capital experience-based	1,355	5,599	256		
ICT capital	6,575	36,364	840		
Organizational capital/VA expenditure-based	10.2%	1.4%	10.3%	10.5%	10.5%
Organizational capital/VA	12.1%	0.5%	12.1%	35.9%	34.7%
R&D capital/VA expenditure-based	16.5%	2.4%	15.8%	16.2%	16.6%
R&D capital/VA	9.7%	1.1%	9.2%	29.4%	28.1%
ICT capital/VA expenditure-based	1.7%	0.3%	1.8%	1.7%	1.7%
ICT capital/VA	4.1%	0.4%	4.4%	12.1%	12.3%
Fixed capital/VA	176%	9.5%	176%	138%	135%
Organizational investment/VA expenditure-based	2.6%	0.4%	2.7%	2.6%	2.7%
Organizational investment/VA	3.0%	0.4%	2.8%	8.9%	8.4%
R&D investment/VA expenditure-based	3.1%	0.6%	2.9%	2.8%	2.8%
R&D investment/VA	1.6%	0.3%	1.5%	5.0%	4.7%
ICT investment/VA expenditure-based	0.6%	0.1%	0.6%	0.6%	0.6%
ICT investment/VA	1.4%	0.3%	1.4%	4.0%	4.1%

Note: Performance-based measures of intangibles are used unless otherwise noted.

relative wages (see (6) and the note in Table 4) and the combined multiplier M_j^{IC} (from (6) and (10)) using the preferred fixed effects estimates. The last row in the table reports the average figures (using value added shares as weights).

The 3 percent average of the output elasticities/coefficients of organizational capital over the years in the fixed effects estimation is close to the overall coefficient of 4 percent in Table 3, column 1. The average total multiplier of 0.68 exceeds the expenditure-based combined multiplier of 0.4 (which equals the total multiplier because the rent multiplier is one). The mean and median values of organizational capital are thus approximately 50 percent higher when using the performance- rather than expenditure-based approach (see summary Table 5) and concentrated in the organizational-capital-intensive and fixed- and organizational-capital-intensive clusters (representing 40 percent of total value added).

The average of the output elasticities of R&D is low, at 1.7 (Table 4). The average total multiplier of 0.48 is two times lower than the unit value in the expenditure-based approach. Of R&D investment, 63 percent occurs in the R&D-intensive cluster (engineering in construction, machinery and equipment, and electrical equipment, as indicated by Table 1), and the total multiplier of 0.71 in this cluster is also less than the combined multiplier of 1 used in the expenditure-based approach. The organizational-capital-intensive cluster is the other cluster with notable R&D investment, where the total multiplier is high at 1.7.

ICT investments are concentrated in the fixed-capital-intensive and R&D-intensive clusters according to the expenditure-based figures. The performance-based estimates instead highlight the clusters that intensively invest in fixed and organizational capital and other industries. The average total multiplier of 1.14 would exceed the 0.7 figure assumed for all clusters in the expenditure-based approach.

Table 5 presents a summary of our results, including the intangibles per unit of value added (value added includes investments in intangibles).

Using performance-based, fixed effects estimates, the overall intangible capital investment is 6 percent (organizational investment 3% + R&D investment 1.6% + ICT investment 1.4%), and the intangible capital stock represents 26 percent of the business sector value added (organizational investment 12.1% + R&D investment 9.7% + ICT investment 4%). The overall intangible investment is the same using the expenditure-based approach. However, the results of the decomposition are very different. The experience-based estimates reveal extensive intangible investments in all clusters. It should also be noted that applying a different set of expenditure-based multipliers, such as combined multipliers for all types that are two times lower, would not change the rent multipliers or output elasticities in the pooled performance-based estimation but, naturally, the cluster decomposition would be different. The performance-based value of intangible assets is thus relatively robust to the assumptions made in the creation of the expenditure-based estimates.

Figure 2 depicts the evolution of the intangible investment over the new value added, which also includes these types of investments. The figures are representative of the business sector (similar to Figure 1).

The R&D investment rate of value added is on average 1.5 percent, while expenditure-based estimates had increased to 4 percent by 2011. Note here that Nokia has been dropped from the figures, and hence part of the recent increase is explained by Nokia firing employees that are subsequently re-employed elsewhere. The organization capital investment rate had increased to 3.5 percent by 2011, irrespective of the approach considered. ICT investments decreased when using the performance-based estimates, and hence also in the clusters that intensively invest in fixed and organizational capital and other industries.

Finally, in our study, labor productivity is 20 percentage-points higher using the performance-based approach, and labor productivity growth is similar to the value observed when not accounting for intangible capital. Marrano *et al*. (2009), using the CHS methodology, found labor productivity growth to be 0.3–0.4 percent stronger when accounting for intangible capital in the U.K. They also

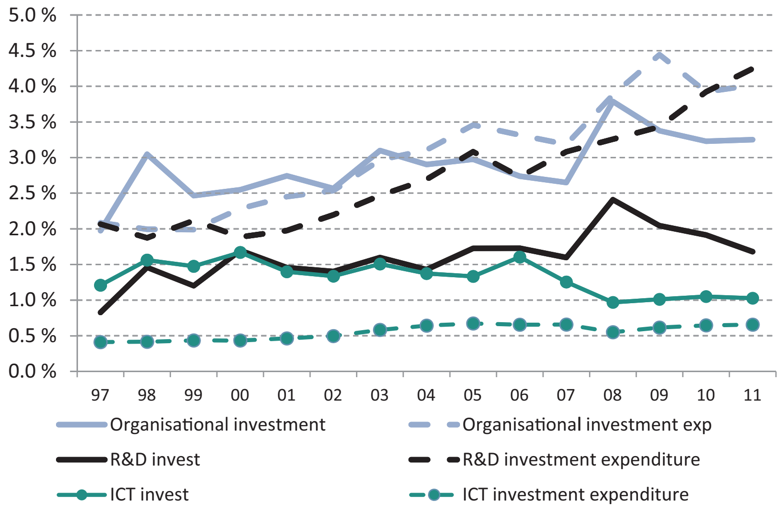

Figure 2. Intangible Investment per Unit of Value Added (1998–2011)

attributed half of the higher value added to economic competences such as organizational capital and training provided by employers.

5. Intangible Capital and Market Value

This section examines how intangibles affect forward-looking market values. The results of numerous studies (e.g., Brynjolfsson *et al.*, 2002; Van Bekkum, 2008) appear to indicate that the value of intangibles materializes over a longer period, especially in such areas as business organization, finance, and healthcare. Intangible capital can explain the weak relationship found between value changes and accounting information in many studies, beginning with Lev (1989). Lev and Radhakrishnan (2003, 2005) use intangibles-related work as an instrument to explain sales growth in yearly industry-level estimates using the two-stage least squares (2SLS) method. These researchers find that the annual measures of organizational/intangible capital predict the market value of the firm well in advance. Their proxy for organizational capital (selling, general and administration expenditures) would here have a high correlation of 0.96 with sales in our setting. Our model incorporates economic analysts' forecasts using a residual income valuation model extended by Ohlson (1995). We thus account for the company's already well-known prospects by including market forecasts in the analysis. The market value is equal to the present value of future dividends

$$MV_{it} = \sum_{\tau=1}^{\infty} \frac{E_t(DIV_{it+\tau})}{(1+r_i)^{\tau}} \tag{12}$$

where MV_{it} is the market value of equity at time t, DIV_{it} are the dividends received at the end of period t, r_i is the discount rate, and E_t is the expectation operator based on the information set at date t. Let BV_{it} = the sum of the balance-sheet value of assets net of liabilities and intangibles $\sum K_{ICit}$, IC = OC, R&D, ICT. The clean surplus relationship reads as

$$BV_{it} = BV_{it-1} + FE_{it} - DIV_{it}, \quad (13)$$

where FE_{it} are the earnings for the period ending on date t, which are proxied by the analysts' forecasts one year ahead (made in March for the upcoming year). We next use equations (12) and (13) and write the market value as a function of the book value and discounted expected abnormal earnings

$$MV_{it} = BV_{it} + RE_{it}, \quad (14)$$

where $RE_{it} = \sum_{\tau=1}^{\infty}(1+r_i)^{-\tau}[FE_{it} - r_i BV_{it-1}]$ is the present value of abnormal earnings at the end of year t, extrapolated to infinity. With the assumption that the total capital stock grows at a rate of less than $1 + r_i$, such that $(1 + r)^{-\tau}E_{r+\tau}(B_{it+\tau}) \to 0$, the residual earnings can be written as

$$RE_{it} = (1+r_{it})^{-1}[FE_{it+1} - r_i BV_{it}] + (r_i - g_{it})^{-1}(1+r_i)^{-2}[FE_{it+2} - r_i BV_{it+1}], \quad (15)$$

where g_{it} is the growth rate of abnormal earnings, which is set at r_{it} minus 3 percent. The abnormal earnings capture how well standard analysis can predict the future evolution of capital formation. In empirical estimates, the discount rate r_{it} is obtained from the Capital Asset Pricing Model (CAPM) as the sum of the return on government bonds for the shortest period available (five years) and market returns using the systematic risk beta as the weight. The beta in the risk premium is estimated using the capital asset pricing model for the companies listed on the Finnish stock market. Thus, the beta for each year is estimated using observations from the preceding 60 months. The data employed include all of the companies listed on the Helsinki stock market during the period.

We follow the typical linear market value model applied by Hall *et al.* (2007), among others. The firm's assets enter additively, and hence we can write the estimable function under constant returns to scale $\sigma = 1$ as

$$\begin{aligned} MV_{it} &= q_t^e(1+F_{it})\left[\gamma_{RE}RE_{it} + K_{it} + \sum_{IC}\gamma_{IC}R_{it}^{IC}\right]^{\sigma} \\ &= q_t^e(1+F_{it})K_{it}\left(1 + \gamma_{RE}RE_{it}/K_{it} + \sum_{IC}\gamma_{IC}R_{it}^{IC}/K_{it}\right), \end{aligned} \quad (16)$$

where K_{it} is physical capital, R_{it}^{IC} is intangible capital of type IC, and F_{it} is the share of employment abroad. Note that the investment decision for period t depends on the expected evolution of abnormal earnings RE_{it}, and this information also has a direct bearing on market values. The expected share price q_t^e is the average Tobin's q or the ratio of market value to the replacement cost of abnormal earnings and tangible capital stock. The parameters γ_{RE}, γ_{IC} are the respective marginal values of physical capital at a given point and the extent to which economic forecasts have not fully accounted for the marginal value of intangibles. A second novelty here is to account for the division of activities at home and abroad, and F_{it} denotes the foreign employment share. Employment at domestic plants remained at approximately half a million in our data, while employment abroad expanded from 137,000 in 1996 to nearly 400,000 by 2006 according to data from the Bank of Finland regarding foreign direct investment. The listed firms that are included in our analysis were responsible for most of this internationalization. The share of foreign activities measures the degree of globalization, while all financial data are from unconsolidated balance sheets.

Following the usual analysis, we define Tobin's q with respect to physical capital. Our estimates are in logarithmic form, but similar to Hall *et al.* (2007), and in contrast to several earlier approaches, we do not use the approximation $\log(1_{it} + \gamma R_{it}^{IC}/K_{it}) \approx \gamma R_{it}^{IC}/K_{it}$, as intangibles are a notable share of total capital. The same strategy applies to the share of employment abroad, as the ratio increased from less than 10 percent to approximately 90 percent for the firms listed on the Helsinki stock market. Rearranging and taking the log yields

$$(17) \qquad \ln Q_{it} = \ln q + \ln\left[1 + \gamma_{RE}\frac{RE_{it}}{K_{it}} + \sum\nolimits_{IC}\gamma_{IC}\frac{R_{it}^{IC}}{K_{it}}\right] + \ln[1 + F_{it}],$$

where $Q_{it} \equiv MV_{it}/K_{it}$. The intercept ln q represents the average logarithm of Tobin's q for the current total capital stock when the future evolution of assets, as expected by the standard economic analysis, is captured by abnormal profits (zero for a Tobin's q equal to one). The parameter $q\gamma_{IC}$ represents the absolute hedonic price of the respective intangible capital component. The estimable equation is

$$(18) \qquad \ln Q_{it} = \ln q + \ln\left[1 + \gamma_{RE}\frac{RE_{it}}{K_{it}} + \sum_{IC}\gamma_{IC}\frac{R_{it}^{IC}}{K_{it}}\right] + \log[1 + F_{it}] + D_{jt} + e_{it},$$

where D_{jt} includes year and three industry dummies and their interaction terms. We can now test the extent to which the financial analysts account for the value and profit implications of intangible capital in their analyses and consequent earnings forecasts. Table 6 is a summary table. Companies typically operate on a global scale. We use unconsolidated balance sheet data from the domestic forms linked to domestic worker characteristics, but half of the firms' employees are located abroad. In the table, the unconsolidated balance sheets and intangible capital figures from domestic operations were revised upwards by multiplying them by the inverse of the share of employees in domestic plants. The assumption is thus that the balance sheet structure is identical at home and abroad.

Abnormal earnings are on average positive, indicating that companies experienced positive growth. Performance-based estimates reveal that intangible capital represents 5.9 percent of total assets reported in balance sheets (the sum of fixed capital and current assets), of which organizational and R&D capital reflect equal shares of approximately 2.5 percent. The expenditure-based figures would be twice as large, indicating that organizational- (and to some extent R&D-) intensive firms are underrepresented among listed firms. The median value of Tobin's q is 1.8, such that the fixed assets are overpriced when excluding intangibles (the denominator here is total assets and not the typical book value of assets). Including intangible capital such that the denominator is the sum of

TABLE 6

Summary of Variables: Market Value and Balance Sheets of Listed Companies

Variable	Mean	Standard Deviation	Median Value	Obs
Market value (€ million)	2,953	2,816	1,839	753
Analyst forecast profits (€ million)	408	665	142	635
Abnormal earnings	3,341	6,303	534	753
Book value (net of liabilities) (€ million)	1,067	1,178	619	753
Total assets	14,097	15,295	7,231	753
Fixed assets less liabilities	2,585	2,644	1,450	753
Tobin's q	1.80	0.78	1.70	753
Tobin's q including intangibles	1.70	0.72	1.60	753
Organizational capital expenditure-based	195	153	176	753
Organizational capital	96	172	8	753
R&D capital expenditure-based	365	478	227	753
R&D capital	159	320	12	753
ICT capital expenditure-based	27	23	22	753
ICT capital	26	44	3	753
Organizational capital per total assets	2.7%	5.2%	0.0%	753
R&D capital per total assets	2.5%	7.6%	0.1%	753
ICT capital per total assets	0.7%	1.3%	0.0%	753
Employment abroad share	46.0%	21.0%	48.0%	753

intangible capital and total assets lowers the Tobin's q to 1.7 because of the low average intangible intensity. The estimates of Tobin's q that are closer to unity are consistent with theory and are captured by the hedonic prices $q\gamma_{IC}$ in the estimations. Note that Nokia, which experienced a dramatic shift in market value from €11.4 billion in 1997 to €295 billion in 2000 and then declined to €23.3 billion by 2011, is excluded from these estimates. However, dropping Nokia from the analysis does not change our results because firm-size weights are not used in the regressions.

Intangible assets are not included in market value when performing the estimations to avoid multicollinearity. We use non-linear estimates and control for firm size (four size categories) and industry (four industries). The intangible capital elasticities with respect to Tobin's q are provided by

$$\frac{\partial \ln q_{it}}{\partial \ln R_{it}^{IC}} = \frac{\gamma_x \frac{R_{it}^{IC}}{K_{it}}}{1+\gamma_{RE}\frac{RE_{it}}{K_{it}}+\sum_{IC}\gamma_{IC}\frac{R_{it}^{IC}}{K_{it}}}. \tag{19}$$

Table 7 reports the regression results and the corresponding elasticities between Tobin's q and the intangibles (and abnormal earnings). The model explains approximately 40 percent of the variation in net profits. A 100 percent increase in abnormal earnings increases Tobin's q by approximately 8 percent, hence explaining approximately 3–4 percent of the variation in Tobin's q. Intangibles also clearly have strong independent predictive power for market value in excess of that explained by standard economic theory. The market value elasticity of organizational capital is 7 percent in the expenditure-based approach but 3 percent lower in

TABLE 7

Non-Linear Estimates Explaining Market Value

	Expenditure-Based		Performance-Based		Manufacturing	Services
Constant (average log Tobin's q)	0.0786	0.111	0.189*	0.243**	0.184	0.202
	(0.96)	(1.28)	(2.39)	(2.88)	(1.91)	(1.47)
Abnormal earnings/fixed capital	0.0784*	–	0.0776*	–	0.0506	0.169*
	(2.25)		(2.49)		(1.5)	(2)
OC capital/fixed capital	1.453***	1.563***	0.421**	0.482**	0.475	0.36
	(4.59)	(5.01)	(2.67)	(3)	(1.75)	(1.35)
R&D capital/ fixed capital	0.0283	0.0236	0.372***	0.406***	0.751***	0.537***
	(0.49)	(0.4)	(5.05)	(5.57)	(3.38)	(3.7)
ICT capital/fixed capital	7.661	9.732*	–0.739	–0.964	–1.668	1.29
	(1.84)	(2.24)	(0.96)	(1.2)	(1.85)	(0.87)
Employment abroad share	1.793***	1.627***	1.693***	1.499***	1.629***	1.436***
	(8.68)	(7.47)	(8.33)	(7.05)	(7.71)	(3.95)
Observations	753	753	753	753	457	249
R squared total	0.41	0.38	0.39	0.35	0.39	0.42
Average elasticity and standard errors using "delta" method						
Abnormal earnings/fixed capital	0.022	–	0.023	–	0.018	0.030
	(3.18)		(3.56)		(1.86)	(4.27)
OC capital/fixed capital	0.074	0.080	0.027	0.031	0.027	0.028
	(4.94)	(5.38)	(2.86)	(3.24)	(1.85)	(1.47)
R&D capital/ fixed capital	0.004	0.003	0.035	0.039	0.037	0.072
	(0.49)	(0.4)	(6.12)	(6.87)	(3.93)	(5.18)
ICT capital/fixed capital	0.031	0.039	–0.008	–0.011	–0.020	0.012
	(1.94)	(2.38)	(16.28)	(1.15)	(1.76)	(0.92)
Employment abroad share	0.453	0.431	0.440	0.412	0.423	0.416
	(17.41)	(14.34)	(16.28)	(13.06)	(14.53)	(7.43)

Notes: Non-linear estimates by industry and year with robust t-statistics in parentheses. Estimation includes four firm size dummies, year and four industry dummies. *p < 0.05, **p < 0.01, ***p < 0.001.

the performance-based approach. In the expenditure-based approach, R&D capital has no market valuation effect, while the elasticity of ICT capital is 3 percent. In the performance-based approach, the opposite is true and R&D capital has a more significant elasticity of 3.5 percent, which is higher than that of organizational capital elasticity (2.7 percent). Rahko (2014) analyzed the reported R&D investments in a consolidated database and found the R&D elasticities to be somewhat higher, in the 5–9 percent range.

Hall *et al*. (2007) found that the mean elasticities of knowledge stocks are more significant: the elasticity of R&D capital is approximately 20 percent, and the elasticity of the patents/R&D ratio varies from 1 to 5 percent. Here, the total elasticity of intangible capital is less than one-half of that found by Hall *et al*. However, Cummins (2005) did not find that appreciable intangibles are associated with R&D capital.

Our analysis suggests that the performance-based approach is able to capture R&D that has real market value. In industry-specific estimates using the performance-based approach, R&D capital also had a more positive significant effect on market values in services than in manufacturing (columns 5–6 in Table 7). The performance-based approach underestimates organizational capital. The reason is that performance-based organizational capital is concentrated in the organizational-capital-intensive cluster, and among the listed firms, this cluster only represents 2 percent of total value added and 8 percent of firm-year observations (in contrast to being 14 percent of all value added and 17 percent of firm-year observations among all non-listed and listed firms). ICT capital is also not significant in the performance-based estimates, which may be again explained by the entirely different cluster decomposition relative to the expenditure-based estimates. Finally, the share of employment abroad has a significant and positive effect on market value. Doubling employment abroad increases Tobin's q by 50 percent.

We can conclude that while the actual R&D investment level can be lower than the total organizational investment, this activity has a significant effect on the market valuation of listed firms. Expenditure-based organizational investment is also a better proxy for organizational investment among listed firms, as organizational-capital-intensive clusters are largely absent.

6. Conclusions

Intangible capital investment is similar to fixed capital income investment in machinery and equipment during the last years of the period (2009–11), in part because the factor income share attributable to fixed capital was halved, from approximately 22–24 percent to 13 percent. Therefore, intangibles are becoming the dominant type of capital investment. However, industries are heterogeneous in their use of intangible investments and how various types of intangible investments complement one another. Thus, we employ a clustering method to evaluate firm production functions.

Several studies, such as Stiroh (2005), have stressed the omitted variable problem resulting from failing to include organizational capital (improved workplace practices and firm re-engineering) to explain the large returns obtained in the production function estimates of ICT and R&D. On the other hand, conventional expenditure-based approaches appear to yield excessively uniform values to organizational and R&D capital stocks, irrespective of the type of cluster considered. Performance-based estimates indicate that the productivity of intangible investments is cluster specific. Management and marketing and R&D employees provide high future benefits for firms in the organizational-intensive cluster and among R&D-intensive firms. These clusters are relatively large, representing 40 percent of private sector value added. However, the organizational-capital-intensive cluster is underrepresented among listed firms.

The total combined multiplier for R&D investment of 0.48 suggests that R&D effort also includes a greater amount of maintenance work that does not produce new investments. Assuming a uniform factor multiplier of 1.55 for intermediates and physical capital in R&D capital goods production—as in the expenditure-based approach—and a rent multiplier of 1.5 would indicate that only approximately one-third of R&D work (0.48/1.55 = 0.31) is related to the production of R&D investment goods (or half in the R&D intensive sector). The share of workers in R&D in our study is 7 percent, while according to Statistics Finland, there were 41,000 R&D workers in 2011 or 2.8 percent of private sector employment. The limited share of R&D workers representing R&D investment may hence be explained by the broad definition of R&D work (that included all non-intangible workers with lower or higher tertiary technical education). However, including those with technical education in the R&D staff is important in the service sector, as R&D occupations are not generally well defined.

The average total multiplier in organizational investment of 0.68 suggests that a large component of organizational work relates to the production of organizational investment goods. Assuming a factor multiplier of 1.76 for intermediates and physical capital and a rent multiplier of 1 (as in the expenditure-based approach) indicates that approximately 40 percent ($0.68/1.76 = 0.39$) of such work is allocated to organizational occupations, which was also assumed in the expenditure-based approach. The performance-based approach thus justifies our initial assumption that 40 percent of working time is devoted to creating organizational capital goods, and not 20 percent as assumed in CHS. The share is, however, cluster specific as the performance-based approach revealed a significant concentration of organizational and R&D investment in clusters that intensively invest in these intangibles.

Intangible capital is shown to be an important missing factor in q-theory. Intangible capital stocks explain the variations in the market values of firms listed on the Helsinki stock exchange during the 1998–2008 period. The forward-looking estimates of future profitability that include intangible capital thus play an important role. A 100 percent increase in intangible capital increases the firm's market value by approximately 7 percent beyond that explained by the economic forecast. Performance-based R&D capital outperforms organizational capital in terms of its effect on market value. The listed firms thus better capture the significance of R&D investment than that of organizational investment. Listed firms are dominated by manufacturing firms that engage in relatively little organizational investment. However, organizational capital was also found to be significant using the broad, expenditure-based measure. Future research should further develop performance-based methodologies and market valuation models that are better adapted to the firm-level evaluation of intangibles and cluster composition. Our estimates also exclude purchased intangible assets and, especially, architectural design, mining exploration, and financial innovations.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix A.1: The occupational classification of workers
Table A.2: Clusters and the factor input share of the typical factor input, in parenthesis, for the most common industries