"Intangibles from innovative work – their valuation and technological change"

Hannu Piekkola

(University of Vaasa, Aarhus University)

Marina Rybalka

(Statistics Norway)

Tjaša Redek

(University of Ljubljana)

Paper prepared for the IARIW-ESCoE Conference
November 11-12, 2021
Session 2B
Time: Thursday, November 11, 2021 [14:00-15:30 GMT+1]

Intangibles from innovative work – their valuation and technological change[1]

by Hannu Piekkola
University of Vaasa, hannu.piekkola@uva.fi

Carter Bloch
Aarhus University

Marina Rybalka

Statistics Norway

Tjaša Derek
University of Ljubljana

Abstract

The purpose of this paper is to contribute to the development of the valuation of intangible assets and examine how it varies over time and evaluate its impact on technical change and markups and hence on firm performance. We explore a new measure of intangible assets (IA) based on expenditures on innovative labor and the creation of innovation-biased technical change. The analysis is conducted for four countries, Finland, Norway, Slovenia and Denmark, using linked employer-employee datasets and the EU 2020 Framework GLOBALINTO-project occupation-based approach for measuring intangible assets. All four countries show robust development of technical improvement over time that did not slow down or decline after financial crises. Intangibles and technical change have led to increases in contributions of both R&D and organizational labor. Markups have varied over time, but with an increasing trend in all countries.

JEL Codes: O33, O32, J30, J42, M10, M30

Keywords: Intangible capital, R&D, organizational change, technical change, markup

[1] This study was funded by EU Horizon 2020 GLOBALINTO project for the years 2019–2022 [grant number 822229]. The title is "Capturing the value of intangible assets (IAs) in micro data to promote the EU's growth and competitiveness". GLOBALINTO (www.globalinto.eu) is a continuation to the FP7 INNODRIVE project that developed the Innodrive-methodology in measuring intangible assets at the firm level.

1 Introduction

Intangible assets have become increasingly important over the last twenty years, with a corresponding shift in the composition of investments from tangible towards intangible assets. This raises interest in the contribution of intangibles to productivity, but also in how innovative work influences technical change and the size of markups. Increased intangible investments may enhance firms' ability to differentiate their products and gain market share. At the same time, new investments in intangibles may lead to improvements in the efficiency of existing intangible assets.

Intangibles are relevant also from the perspective of market power. Namely, intangibles generate high fixed costs, which as such can be a hindrance for competition giving market power to the firm. Competing firms have to invest in uncertain innovations and risk losing large amounts of money if they fail. Intangibles are indeed considered as firm-specific capital or structural capital that helps to differentiate the firm from others. It is hence also of considerable interest to examine their relation to markups over time, including facilitation of the finance of intangible resources. De Loecker and Warzynski (2012) suggests a production approach to proxy markups by the ratio of flexible factor input's output elasticity to the labor factor's expenditure share. The natural candidate for this measure is flexible labor, where we suggest to use all labor not engaged in intangible investment. The latter is possible since our broad definition of intangibles covers both R&D (in around 80% of firms with 5 employees or more), OC (in nearly same share of firms) and information and communication technology ICT work (in around half of firms). One argument for such a definition of flexible labor is that the intangibles and thereby innovations can generate not only fixed costs but also a large part of the markup (to finance fixed costs) and hence this input should be excluded from the flexible labor supply.

Goal. The purpose of this paper is to contribute to the development of the valuation of intangible assets and examine how it varies over time and evaluate its impact on firm performance. We explore a new measure of intangibles based on expenditures on innovative labor and the creation of innovation-biased technical change. Intangibles are then shown to be a key factor for profitability and higher markups. To do this, we apply two different approaches to consider the role of intangibles in augmenting technological change and markups generated by intangibles. The first concerns innovation-labor biased technical change (IBTC). Sustainable growth in the future will depend more and more on such intangibles and long-term growth associates with technological change rather than with the use of energy and exhaustible resources. Intangibles are the fruits of ICT, R&D, management and marketing work that also contributes to technological change. Such intangible work creates innovation-labor biased technical change (IBTC). Technical change is related to the improved productivity of innovative work rather than leading to better use of physical machines and equipment

(Piekkola, 2020). Second we measure markups based on returns to flexible work that we consider all work not related to createing intangible investments with potenatial high fixed costs. Such measure is welcome in the modern economy with more limited important of manufacturing blue-collar work that is ofter consided as the most flexible part of labor force. Such an approach does also apply to Nordic labor markets with highly unionized manufacturing labor, where the exporting indusries are usually considered as leaders in economy-wide wage setting.

Methodology. This analysis within the EU Horizon 2020 project Globalinto's focuses on evaluating the contribution of innovative work using a novel approach, partially based on 7th Framework Innodrive project, where intangible investment (organizational, R&D and ICT) is evaluated from innovative-work related occupations and the related wage costs, see Piekkola et al. (2011), the guidelines in OECD (2010) and Bloch et al. (2021). The obtained cost-data is used to generate intangible investment data and evaluate the contribution of intangible investment to different aspects of firm performance.

Globalinto examines intangibles in four countries: Finland, Denmark, Norway and Slovenia. Globalinto partners (University of Vaasa, University of Aarhus, Statistics Norway (Research department) and University of Ljubljana) in these countries have obtained access to data from registries of employees and companies via national statistical institutes (NSIs), that facilitated the formation of linked employer-employee datasets, where intangible investments are evaluated based on specific (innovative) occupation-related labour costs. Such labor costs are combined with other related factor inputs and used in further firm-level analysis.

Contributions. The paper makes several important contributions to the development in the field of measuring and evaluating the contribution of intangible capital to firm performance. **First**, the methodology proposes an innovative approach to measuring firm-level intangibles (which cannot be observed from firm-financial statements) based on wage-costs of relevant innovative occupations. Although the methodology to measure R&D, ICT and OC is based on the 7th framework Innodrive project, we simplify the method by using occupational data only rather than using educational background for imputing missing occupational data that was more common in earlier employee data. Second, another advantage of using the broad definition of intangibles is that we are able to analyze the whole economy rather than manufacturing only. It is indeed important to analyze intangibles for different technology types of firms. Many knowledge intensive services (KIS) are more intangible intensive than manufacturing, while R&D producing services are often units of company operating in manufacturing. Our analysis includes all industries with the exception of the public sector, health and education, agriculture, construction and financial services. It is important to see then which findings can be extended.

Third, Globalinto has applied joint testing of the specification of innovation work in the fields of R&D, ICT and OC in four different countries, which differ not only structurally, but are also different in terms of development. Significant attention was paid to the relevance of the methodology for all countries with the aim to develop a **framework that could have a wider applicability** (beyond these pilot four countries).

Fourth, an important contribution to future development is the new measurement applied for organizational capital related to management and marketing work. It is part of structural capital of firms including technology such as R&D (F-Jardón and Martos, 2009). Roos and Roos (1997, 42) defines organizational capital simply as what remains in the company when employees go home for the night. It not only covers the organization but also the proprietary software system.

Last, as intangible investments and capital represent large fixed costs, which as such can be a hindrance in firm-entry and can thus help increase market power of the firms, the empirical understanding of the extent of this contribution is important, and this paper provides both a methodological approach to estimate it as well as providing comparative estimates in four countries.

The paper is divided into 7 sections. Following this Introduction, Section 2 describes the Globalinto's methodology for measuring intangibles demonstrating the evolution of intangibles in Finland, Denmark, Norway and Slovenia. Section 3 describes returns to intangible work and section 4 method to measure markups. Section 5 analyses innovation-based technical change and explains productivity with related knowledge spillovers and intangibles. Section 6 reports the result for the production function estimation including IBTC and markups. Section 7 concludes and brings discussion on policy application of our results.

2 Measurement of intangibles

The measurement of intangibles in Globalinto project is based on several steps and follow several statistically important principles to be able to fit the analysis into the wider context of established statistical classifications. **First, methodologically**, the measurement of intangible investment is based on employee data, where in particular, as is explained, the occupations serve as the main criteria to identify "innovative labour". Individuals' wages aggregated at the level of core occupational groups (ICT, R&D and organizational and other work) allow the generation of intangible investments (details in continuing) once the employee-data are linked to employer data (firm-level analysis), which allows also detailed firm-level analysis with regards to productivity, IBTC and markups.

2.1 Measuring intangible investments: an occupation-based approach

A crucial issue in the Globalinto micro-based approach is how intangibles work utilizes tangibles and intermediate input together with intangibles labor in producing intangible investment. We extend the EU 7-th framework project Innodrive methodology, see (Piekkola, 2020, Bloch et al., 2021). Such an approach considers own house and purchased intangibles to be complements following the general guidelines in intangible capital (OECD, 2005). Own account production should also be accounted for as more firm-specific than purchased intangibles in improving the competitive advantage of the firm. Purchased intangibles as such may not always enter the structural capital since these are available also to rivals.

Occupation selection and innovative work

Purchased intermediate intangible input is considered rather mechanically by observing factor input relations in IA producing services. For each of the relevant intangible capital types, a list of relevant occupations was prepared. Following (Bloch et al., 2021) Box 1 lists the relevant occupations that engage in intangible investment according to our methodology in bold (**OC**=organizational occupation, **R&D**=R&D occupation and **ICT**= ICT occupation). Only part of working time goes to intangible investment. The share of labor cost dedicated to the production of intangible goods is 0.6 (0.5 in Innodrive) in ICT occupations, 0.7 in R&D occupations (0.7 in Innodrive) and 0.4 in OC related management and marketing occupations (0.4 in Piekkola (2016)).

Box 1 Globalinto Intangibles Assets occupations (based on ISCO08 Occupation classification)

1 Managers **112 OC** Managing Directors and Chief Executives **12 OC** Administrative and Commercial Managers **121 OC** Business Services and Administration Managers 122 Sales, Marketing and Development Managers **1221 OC** Sales and Marketing Managers **1222 OC** Advertising and Public Relations Managers **1223 R&D** Research and Development Managers 13 Production and Specialized Services Managers **131 OC** Production Managers in Agriculture, Forestry and Fisheries **132 OC** Manufacturing, Mining, Construction and Distribution Managers	**216 R&D** Architects, Planners, Surveyors and Designers 22 Health Professionals **221 R&D** Medical Doctors **222 R&D** Nursing and Midwifery Professionals 223 Trad. and Complementary Medicine Professionals; 224 Paramedical Practitioners **226 R&D** Other Health Professionals 23 Teaching Professionals 24 Business and Administration Professionals **241 OC** Finance Professionals **242 OC** Administration Professionals 243 Sales, Marketing and Public Relations Professionals **25 ICT** Information and Communications Technology Professionals 26 Legal, Social and Cultural Professionals

133 ICT Information and Communications Technology Services Managers **134 OC** Professional Services Managers 14 Hospitality, Retail and Other Services Managers 2 Professionals 21 Science and Engineering Professionals **211 R&D** Physical and Earth Science Professionals **212 R&D** Mathematicians, Actuaries and Statisticians **213 R&D** Life Science Professionals **214 R&D** Engineering Professionals (excluding Electrotechnology) **215 R&D** Electrotechnology Engineers 2151 Electrical Engineers **2152 R&D** Electronics Engineers R&D **2153 ICT** Telecommunications Engineers	3 Technicians and Associate Professionals 31 Science and Engineering Associate Professionals **311 R&D** Physical and Engineering Science Technicians 312 Mining, Manufacturing and Construction Supervisors; 313 Process Control Technicians **314 R&D** Life Science Technicians and Related Associate Professionals 315 Ship and Aircraft Controllers and Technicians 32 Health Associate Professionals **321** R&D Medical and Pharmaceutical Technicians 33 Business and Adm. Associate Professionals; 34 Legal, Social, Cultural Associate Professionals; **35 ICT** Information and Communications Technicians

2.2 Generating intangible investment and the challenge of factor multipliers

Factor multipliers are used to account for other factors of production, tangibles and intermediate input, that are used in producing intangibles. Globalinto estimates these multipliers from Eurostat national accounts based on production activities in certain knowledge intensive industries (KIS) on how value added is divided into labor costs, capital and intermediate inputs. Factor multipliers are calculated as the average over EU countries. In Table 1, the figures are multipliers for one unit of the innovating labor (labor costs in the innovative KIS sector). The total multiplier for own account IA is the factor multiplier multiplied by the labor share (share of labor cost dedicated to the production of intangible goods in each profession fixed to be the same in all industries).

The factor multipliers vary by type of KIS sector (OC, R&D or ICT intensive).

Table 1. Factor multipliers for one unit of labor costs in micro data

	OC	**R&D (M72)**	**ICT**
Factor multiplier	1.76	1.55	1.48
Labor share	0.4	0.7	0.6
Total multiplier	0.70	1.1	0.9

The method described above is analogous for measuring “overheads” in OECD (2010)); a method applied to evaluate ICT from related labor costs in most NSIs, proxying in most countries software and database expenditures. The Office for National Statistics (ONS) in the UK in their satellite accounting of investment in intangible assets also applied the method to evaluate ICT exploiting data for the 72.2. industry (Research and experimental development on social sciences and humanities). In the more detailed approach intermediates exclude road transport, computer services, advertising and marketing costs, depreciation of vehicles and intermediates used for resale without further processing. Intermediates are added by total taxes and levies and total depreciation. Estimates of the rate of return on capital are excluded. ONS ended up with a non-labor cost share of 80%, which is close to the 90% here (Chamberlin et al., 2007). Furthermore, our ICT labor costs are evaluated from all ICT related occupations multiplied by 0.6, thus bringing ICT labor costs close to labor costs in more selective ICT occupations in ONS.

The nominal value of intangible capital investment of type IA=OC, R&D and ICT for a firm *i* in year *t* is given by

$$P_{it}^{N} N_{it}^{IC} = A^{IC} M_{it}^{IC}, \text{ for } \mathrm{IA} = \mathrm{R\&D, OC, ICT} , \tag{1}$$

where labor costs, M_{it}^{IC}, are multiplied by a total multiplier, A^{IC} from Table 1, to obtain total investment expenditures on intangibles. It demonstrates the innovative share of IA occupations and the use of capital and intermediate inputs for one unit of IA occupation labor costs. The parameter, P_{it}^{N}, is the price of each of the three types of intangibles. To estimate fixed values, we use the investment deflator for R&D, the innovation property investment deflator (includes R&D and software and database) for ICT and the labor costs weighted average of producer price deflator over business services (Nace 69, Nace 70, Nace 71, Nace 72, Nace 73) for OC. The real stock, R_{it}^{IA}, of intangible capital is given by

$$R_{it}^{IA} = R_{it-1}^{IA}(1-\delta_{IC}) + N_{it}^{IA},\ R_{i}^{IA}(0) = N_{i}^{IA}(0)/(\delta_{IA} + g_{IA}) , \tag{2}$$

where $N_{i}^{IA}(0)$ is the initial investment, $R_{i}^{IA}(0)$ is the initial intangible capital stock, δ_{IA} is the depreciation rate and g_{IA} is the growth of the intangible capital stock of type IA (R&D, OC and ICT) using the geometric sum formula. The initial investment, $N_{i}^{IA}(0)$ is the first three-year average for the corresponding type of investment and the growth rate of all intangibles, g_{IC}, is set at 2%, which follows the average labor costs growth. In subsequent years IA costs/all labor costs ratio must be within 1st and 99th percentile of the overall distribution and IA investments are adjusted accordingly. The depreciation rate for organizational investments δ_{OC} is set at 20% following the survey by Lev et al. (2016) and paper by Squicciarini and Le Mouel (2012). Surveys by Whittard et al. (2009) and Awano et al. (2010) find that the life cycle of an organizational investment is in production 2.9-5.4 years and in services 2.6-4 years. Recent estimates of R&D depreciation rates are closer to 15% taken here than to the 20% figure used in Corrado et al. (2014). ICT investments are assigned a 33% depreciation rate.

2.3 Empirical approach: sample and descriptive statistics

We limit our sample to firms with at least 5 employees on average divided into nine groups differing by technology level. In addition, we exclude agriculture (Nace A), forestry, mining (Nace B), financial intermediation and insurance (Nace K), water supply etc (Nace E), construction (F), health (Nace Q), education (Nace P) and public administration (Nace O) and non-profit sectors (Nace Q, S, T, U, X). Table 2 shows the evolution of IA work over time after assuming the innovative work share to be 40% for OC, 70% for R&D and 50% for ICT.

Table 2: Intangibles work share of all work by intangible type, %

Year	OC	R&D	ICT	All	OC	R&D	ICT	All
		Finland				**Denmark**		
2000	1.75	7.82	1.64	11.20	2.00	7.07	1.92	10.99
2002	1.77	8.27	1.72	11.75	1.84	6.79	1.86	10.49
2004	1.57	7.64	1.72	10.93	1.88	6.58	2.04	10.50
2006	1.75	7.14	1.69	10.59	2.00	7.00	2.04	11.04
2008	1.80	7.22	1.65	10.67	2.00	6.37	2.10	10.47
2010	1.33	7.22	2.41	10.97	2.64	8.33	3.24	14.21
2012	1.30	7.19	2.47	10.95	2.48	8.19	3.30	13.97
2014	1.27	7.14	2.40	10.82	2.44	8.05	3.24	13.73
2016	1.25	7.13	2.31	10.69	2.64	8.68	3.36	14.68
2018	1.54	7.40	2.01	10.95				0.00
		Norway				**Slovenia***		
2008	2.82	5.78	2.62	11.21	5.42	5.86	2.71	13.99
2010	2.98	6.58	2.59	12.15	6.29	5.90	2.71	14.90
2012	3.20	7.57	2.87	13.64	6.54	5.79	2.79	15.12
2014	3.18	8.07	2.90	14.15	6.83	5.99	3.00	15.82
2016	3.33	7.70	2.99	14.01	6.64	6.22	3.04	15.90
2018*	3.20	7.47	3.10	13.78	6.54	6.36	3.09	15.99

*2017 for Slovenia

Shares for organizational work from all work reported in table 2 are lower than in Innodrive due to a narrower choice of management and marketing occupations. The shares of organizational work have been increasing over time for Denmark and Norway, while they have fluctuated up and down for Finland and also in Slovenia. In the latest years, 2016-2018, shares are in decreasing order Slovenia 6.5, Norway 3.2 , Denmark 2.6 , and Finland 1.5 . R&D employee shares are around the same in Nordic countries. In the latest years, 2016-2018, shares are in decreasing order in Denmark 8.7 , Norway 7.5 , Finland 7.1 , and Slovenia 6.4 . There is a downward trend in R&D shares in Finland, while the shares have been on rise in Denmark and Slovenia and have inverse U-shape in

Norway. ICT shares have been increasing and are in latest years at around 3 in Norway, Slovenia and Denmark, while they are a bit lower at around 2 in Finland. Together, these numbers mean that shares of intangible work from all work is in 2016-2018 Denmark 14.7 , Norway 13.8 , Finland 11.4 and Slovenia 16 .

Further, table 3 shows intangibles (intangible capital stock) per employee. These have been accumulated with depreciation rates of 15 for R&D, 20 for OC and 33 for ICT.

Table 3: Intangibles per employee across country

Year	OC/L	R&D/L	ICT/L	All	OC/L	R&D/L	ICT/L	All
		Finland				Denmark		
2000	16.6	43.8	5.1	65.6	8.0	50.1	2.1	60.2
2002	16.4	42.6	5.0	63.9	9.1	48.6	2.2	60.0
2004	16.1	44.3	5.4	65.8	9.6	51.1	2.4	63.1
2006	16.0	43.9	5.6	65.5	10.5	52.7	2.3	65.6
2008	16.0	45.5	5.3	66.8	11.3	54.1	2.2	67.6
2010	14.8	47.0	6.8	68.6	11.1	52.4	5.0	68.5
2012	13.4	47.0	7.6	67.9	10.6	47.8	7.2	65.7
2014	13.0	48.3	7.9	69.2	10.5	46.7	8.3	65.5
2016	12.1	47.4	7.9	67.4	9.7	43.4	8.3	61.5
2018	10.8	45.9	7.7	64.3				
		Norway				Slovenia		
2008	20.2	54.2	10.9	85.2	5.0	18.4	2.4	25.8
2010	22.3	64.5	10.5	97.3	5.6	20.8	2.6	29.0
2012	25.3	71.2	11.7	108.2	6.1	22.3	2.8	31.2
2014	27.1	74.8	12.2	114.0	6.5	24.2	3.0	33.7
2016	28.1	77.4	12.8	118.3	6.6	24.5	3.0	34.1
2018	26.8	76.2	12.8	115.8				

R&D per employee figures in Norway are highest and are about 76.2 thousand 2015€ in 2018. Other countries have had about the same R&D per employee, around 43-45 thousand 2015€ (Danish and Norwegian figures are calculated with average exchange rates over the period).

Finland has a higher OC intensity than Denmark or Slovenia despite a lower share of OC workers, but in Norway, OC per employee is highest at around 27 thousand 2015€ in 2018. The sum of the OC and ICT intensity is approximately 25 thousand 2015€ and 2/3 of this is OC. Our approach excludes purchased OC as well as branding such as advertising.

Organizational or firm-specific human capital and ICT are the largest subcategories of intangible investment in many other studies (Bloom and Van Reenen, 2010, Piekkola, 2016). In Finland, the trend of OC intensity is decreasing down to 10.5 thousand 2015€ by 2018, but equivalently ICT per employee has been on the rise. Norway stands out as the ICT intensive country with around 12.7 thousand 2015€.

We have already observed in Table 2 the decreasing share of R&D workers in Finland. Thereby large structural changes in Finland have created shockwaves, where a large part of intangibles have been misallocated to wrong sectors. The occupation classification has been also less consistent over the years in Finland since Isco08 was not fully revised to cover earlier periods as was the case in Denmark. The decrease in organizational workers (and OC per employee) may have led to a relative shift to ICT work away from OC work.

Denmark has an increasing share of high-tech and high-middle tech manufacturing so that R&D per employee was by 1.5 percentage-point higher than in Finland by 2016, see table 2. In 2000 the shares were opposite in favor for Finland.

In Finland, ICT per employee has doubled in the time period. As discussed, Denmark and Norway still have about 1-percentage point higher ICT worker shares than Finland, which also leads to 30% higher ICT intensity. ICT per employee varies across technological type similarly in both countries, although the returns are 70% higher in Danish relative to Finnish KIS ICT services.

3 The returns to intangible work

The production function–based approach can provide information on the relative returns to intangible work and output elasticities to employee or intangible capital, R_{it}^{IA}, for industry *i* in year *t*. Output elasticities of flexible labor are needed to estimate markups proxied for output of flexible labor. Relative returns and output elasticities to employee are needed to evaluate IBTC. The production function that accounts for intangible assets (IA) is given by

$$Y_{it} = b_0 \left(A(L_{OC}, L_{RD}) L_{it} \right)^{b_L} \prod_{IA} \left(R_{it}^{IA} \right)^{b_{IA}} K_{it}^{b_K} \exp(e_{it}) \ , \qquad (3)$$

where labor excludes the part of IA occupation workers going to IA investment. We exclude it also in evaluation of IBTC, since omitting intangibles work from flexible work also has some econometric merits. Schankerman (1981), Hall and Mairesse (1995) show that intangibles work should be excluded from the employment figures to avoid double counting which can lead to downward biased estimates of the output elasticity of R&D. For this reason, value added also excludes income accruing to broad intangibles and a large part of this is already incorporated in formal R&D and ICT including value added in the data. $A(L_{OC}, L_{RD})$ measures the relative quality of intangible work (set at one for IBTC), R_{it}^{IA} refers to the capital stocks of intangible assets of type IA=OC, R&D and ICT and K_{it} is tangible capital which considered as total fixed capital in markup and IBTC estimation), and e_{it} is an error term. The production function is also assessed separately by main technology sectors j (high-tech manufacturing, low-tech production, KIS and other services, see Appendix A).

The estimation for each firm i and year t from (3) in log form is provided by

$$\ln Y_{it} = \ln b_{0j} + b_L AL_{it} + b_{IA+K} \ln\left(\sum_{IA} R_{it}^{IA} + K_{it}\right) + b_Z^{'} \ln Z_{it} + \ln e_{it} \ , \qquad (4)$$

where Z_{it} is the vector of controls: dummy variables (at Nace at two-digit level and year). Markup estimations set the quality of labor homogeneous A=1. Piekkola (2020) analyses innovation-labor biased technical change (IBTC) which is analogous to skill upgrading, better known as skill-biased technical change. Ilmakunnas and Piekkola (2014) evaluate relative productivity of intangibles by measuring the employment shares of intangible workers. It can be shown that this share is an appropriate proxy for measuring the quality of intangible workers relative to other workers, when the shares are small and hence non-linear estimation need not be done:

$$A(L_{OC}, L_{RD})L_Y = \left(\left(\frac{a_{RD}L_{RD}}{\bar{a}_L L} + \frac{a_{OC}L_{OC}}{\bar{a}_L L}\right) + \frac{L_Y}{L}\right)L \text{, where} \qquad (5)$$

$$\frac{a_{Rt}L_{Rt}}{\bar{a}_{Lt}L_t} + \frac{a_{Ot}L_{Ot}}{\bar{a}_{Lt}L_t} + \frac{L_{Yt}}{L_t} = \left(\frac{a_{Rt}}{\bar{a}_{Lt}} - 1\right)\frac{L_{Rt}}{L_t} + \left(\frac{a_{Ot}}{\bar{a}_{Lt}} - 1\right)\frac{L_{Ot}}{L_t} + 1$$

where a_{RD} , a_{OC} are the quality of intangible workers relative to the average quality $\bar{a}_{Lt}$ of all workers in the firm (sub-index for firm *i* is not shown here) and $L = L_Y + L_{RD} + L_{OC}$ is the total labor force including the time spent on intangibles. The logarithmic approximation of the first term is $ln\left((a_{Rt} / \bar{a}_{Lt} - 1)L_{Rt} / L_t + (a_{Ot} / \bar{a}_{Lt} - 1)L_{Ot} / L_t + 1\right) \approx \quad (a_{Rt} / a_{Lt} - 1)L_{Rt} / L_t + (a_{Ot} / a_{Lt} - 1)L_{Ot} / L_t$ given that the first two terms are not too far from zero. In Piekkola (2020), the main idea is that the relative qualities of intangible workers are first approximated by the relative wages of intangible work to the average. Production function estimation is then used to revise the initial figure. From $b_{IBTC,IA}(w_{IAit} / \bar{w}_{Lit} - 1) = b_L(\hat{a}_{IAit} / \hat{\bar{a}}_{Lit} - 1)$ where $b_{IBTC,IA}$ is the coefficient on relative wages $w_{IAit} / \bar{w}_{Lit} - 1$ and b_L on flexible work a lower coefficient of total labor b_L than the coefficient for the quality estimate (that should be the same) implies that relative productivity of intangible work must be revised up giving $\hat{a}_{IAit} / \hat{\bar{a}}_{Lit}$.

Markup estimations use instrumental variable GMM regression, where instruments are lagged values of the explaining variable and productivity shocks are controlled by tangible investment lagged up to period. The estimations are made separately on about 90 Nace 2-digit industries. IBTC estimation uses simple OLS over about 200 Nace 3-digit industries. These estimations include year dummies but not industry dummies. Here we show random effect estimations for all and in main technological sectors. We also include human capital measured as education years in order to show the distinct effects that it has on productivity. We report also separate output elasticity of R&D, OC and ICT although we consider them together with tangible capital in IBTC and markup estimations.

In contrast to Piekkola (2020) we use random rather than fixed effect estimates given that technological level and human capital (average years of education) are controlled Table A.1 in appendix shows the industries by technology type following OECD classification and typology of KIS (knowledge intensive services) by Eurostat, where the industries in each grey area are considered together in the production function estimation.Jointly estimated technology type sectors are thus: high technology manufacturing, low technology production, KIS and other services. Random effect estimations are reported later in Table 5.

An analogy applies between skill-biased technical change as described in Acemoglu (1998) and IBTC. A large increase in the supply of innovation workers (like skilled workers in Acemoglu) first moves the economy along a short-run (constant technology) relative demand curve, reducing the innovation premium. The relative supply change also increases the size of the market for technologies complementary to innovativeness, and induces a change in the direction of technical progress and a shift of the relative demand curve. Hence, innovation-labor biased technical change could benefit the economy with some lag as there is a greater number of technologies that benefit from innovation workers. The first direct effect on markups can be negative so that better returns from overall shifts in the economy are reaped in the longer term. There is hence complementarity between intangibles and ibtc because of which the returns to intangibles show up here as higher.

Output elasticity of labor is also lower because it formerly accounted for the markups that are now separately controlled at industry level.

4 Markups

4.1 Estimation approach

Intangibles generate high fixed costs and depreciate by varying rates across time and industries. Furthermore, the intangibles work that intangibles investments entail may allow firms to differentiate products and processes from competitors. Markups may reflect to which degree intangibles indeed are firm-specific capital that gives profit opportunities to the firms. To the degree that intangibles cause fixed costs and allow for differentiation, they also increase the potential for increasing returns to scale, which as such is part of the markup, as discussed below.

Performance-based estimates above show that expenditures and performance match fairly well, although not necessarily in the high-tech industries where formal R&D should be used to evaluate the complex set of R&D activity. For overall consistency it is then important to check what the implied markups are, how they vary over time and what their effects are on output elasticities of intangibles.

We follow the production function method by De Loecker and Warzynski (2012) and De Loecker et al. (2020). The main idea there is that the gap between productivity and employment costs of flexible workers gives a better estimate of markups than any estimate for innovative work, where fixed costs are prominent and returns may gradually materialize over a longer period. The advantage of our approach is that we can specify flexible work by separating from work that generates intangible assets, which is prominent among management, marketing, R&D and ICT work. Intangibles work requires firm-specific learning and is therefore not freely available in the labor market. Alternatively, new intangible workers bring new knowledge to the firm from their previous job relationships, again lowering the flexible nature of their work. De Loecker and Warzynski (2012) instead use labor costs as flexible input and De Loecker et al. (2020) total variable costs (labor, intermediate inputs, electricity, and others) because labor costs are not available.

De Loecker et al. (2020) finds that the sales-weighted average markup in the United States climbed from about 1.2 in 1980 to 1.6 in 2014. This is explained by increasing skewness in the across-firm distribution of markups over that period, so that markup growth comes from a shift in revenue shares toward higher-markup firms. However, the median markup remained about the same. Syverson (2019) shows that markups essentially depend on the multiplication of pure profits from value added and the scale elasticity. Syverson (2019) suggests that the latter must have increased for the results to be consistent with the actual share of pure profits from value added. De Loecker et al. (2020) indeed finds an increase in returns to factor inputs from 1.03 to 1.08 during 1980-2014. Another assumption also in interpretation of our results is that firms' observed markups are not caused by monopsony power in the market for flexible work.

We present two alternative dimensions of markups. The first one is revenues weighted markups and the second one is mean markups. We argue that one apparent difference between the two is that the former gives much higher weight to large firms. As discussed, the alternative explanation is that firms with higher markups have been able to further improve their profitability and have also become larger in size. Without sales weights, the markup better represents the development of markups among SMEs.

Following De Loecker and Warzynski (2012), the markup is given by

$$\gamma_{it} = \frac{\beta}{\left(\frac{P_{it}^{L} L_{it}}{P_{it} Y_{it}}\right)} \tag{6}$$

Where β denotes the output elasticity of non-innovative labor input and not total labor as in markup analysis using real values and $P_{it}^{L}L_{it}/P_{it}Y_{it}$ is the nominal share of expenditures on non-innovative labor input in value added (i.e. labor costs net of those for innovative work in current production per value added). The elasticity is allowed to vary by nine technology types of industries and over time. The elasticity of labor is calculated using a moving average of time over seven periods. The expenditures share of labor varies by firm.

4.2 Markups results

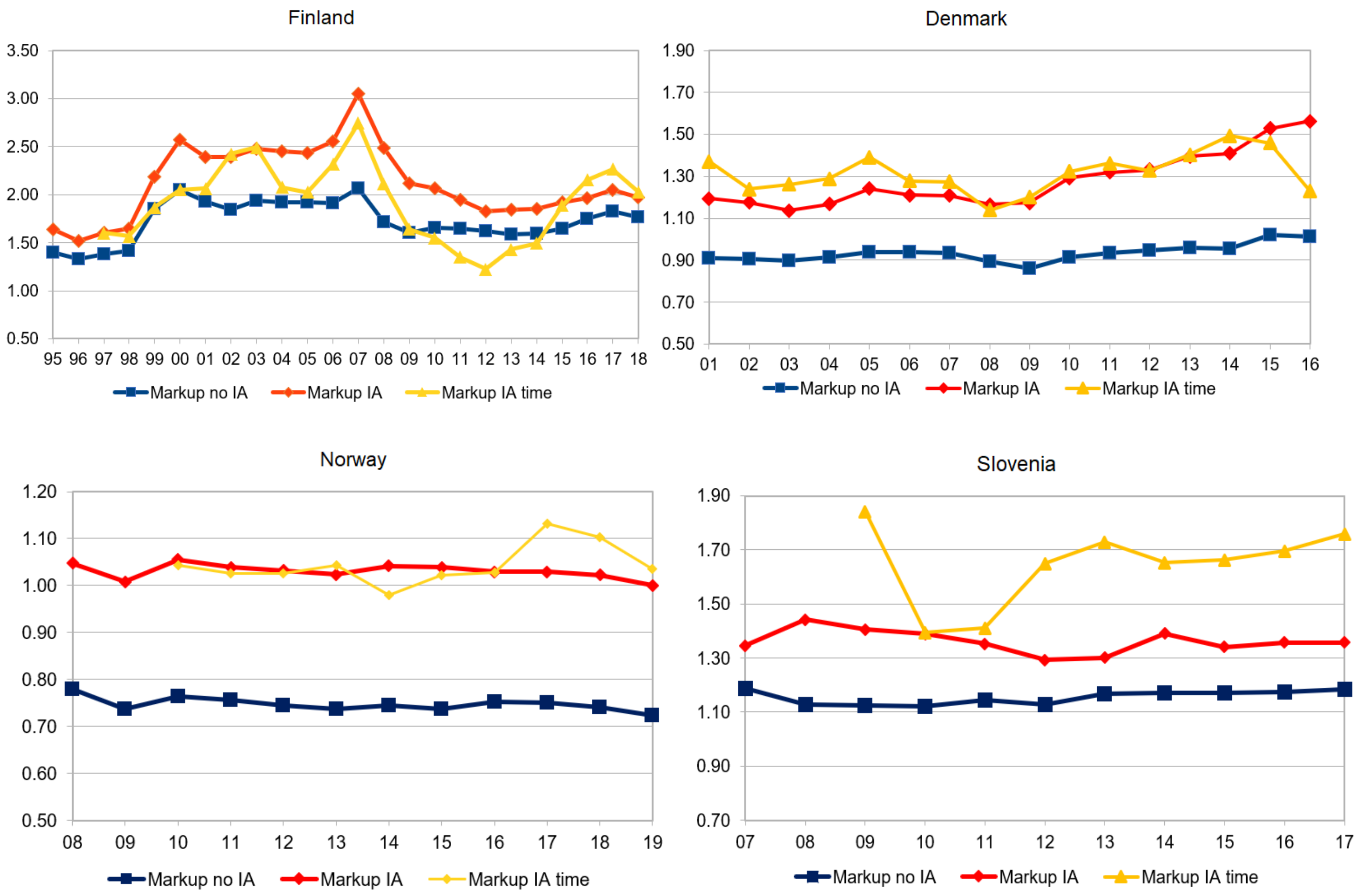
Figure 1 shows the development of markups over time, where the time period differs somewhat across countries. "Markup IA" is markups for intangibles labor while "Markup noIC" is markups for not excluding any IA labor costs from total costs and not including unmeasured IA investment in value added and it total fixed capital. "Markup IA time" has annually varying output elasticity of flexible work, while in the former two output elasticity is non-time varying as estimated for the whole period. We rely primary on the markups with flexible output elasticity of labor overtime. Finland has the longest observation period beginning from 1995, while the observations for the rest are from 1999-2000 in Denmark and Slovenia and from 2008 in Norway. In the empirical estimation, we would find that both market shares and intangibles increase markups. Thereby it is clear that market forces, scaling opportunities and profits from firm-specific intangibles explain markups. While this finding is clear when comparing firms to each other, the situation appears more mixed over time.

In Finland, results available already from 1995 show that the output elasticity of labor first decreased from 64% to around 40% after the financial crises in the low growth period 2009-2014 and then jumped back to 65% as of 2016. The nominal labor cost/valued added ratio has varied even more, so that markups accounting for intangibles first increased from 1.6 in 1997 to around 2.7 in 2007 after rapidly decreasing to around 1.4 in the low-growth period 2010-2014and to return back to over 2 in by 2016. The volatility of markups in the Finnish economy is higher than in other Nordic coutnries. De Loecker et al. (2012) uses instead total labor costs and non-time varying output elasticities which is consistent to our approach though with no account for IA or deducting it from value added when calculating labor costs/value added ratio in (10). It is seen using this method that the markups would be the level observed in the US in De Loecker et al. (2020) 1.1-1.5 over the period in Finland and Slovenia, but below 1 in Denmark and Norway. In all countries, the true markup would likely be much higher when excluding intangible work from flexible work labor costs and when unmeasured IA investment in included value added and excluding from flexible labor costs.

The curves of markups with and without IA are still similar in shape. Brynjolfsson et al. (2021) finds that as firms adopt new technology, capital and labor are used to accumulate unmeasured intangible capital stocks, creating fixed costs. Hence, productivity growth will initially be underestimated. However, unmeasured intangibles yield capital service flows over longer time so that the hidden intangible stocks generate measurable output at later periods. At the aggregate level here, we do not observe such shifts over time, so the phenomenon observed at the micro level does not show up in statistics at the macro level, also because the increase in the level of IA intensity over time in other countries than Finland has been gradual, see table 3.

It is seen that in Norway markups would stay about 0.75 throughout during 2008-2019 if intangibles are ignored. In Denmark, markups would also remain relatively flat over time and below 1. Finland and Slovenia are the only countries with markups above 1 if unmeasured intangibles are not considered and intangible work is also included in flexible work (as part of total wage costs). In all countries markups accounting for IC are above 1. Unmeasured intangibles and all intangibles work should be appropriately taken into account in order to see that firms are profitable. In what follows, we concentrate on reporting markups with intangibles.

Figure 1 Markups and its component Finland, Denmark, Norway and Slovenia



Markups (with revenues weights) vary over time with time-varying output elasticity, with an average around those with fixed output elasticity (except Slovenia). In Norway, Markup IC time is below fixed values in 2014 and above in 2017-19. Decrease in profitability is seen as a temporary cut in output elasticity of flexible labor in 2014. In Denmark Markup IC time is below Markup IC in 2016-2017, as the output elasticity fell from the previous about 66% to 58% . Overall, Markup IC time reflects well changes in profitability. Norwegian firms have low markups just over 1, values that are significantly lower than in Finland (hovering around 2) and Slovenia (hovering around 1.4).

In Finland, it is the large firms that suffered in the low-growth period 2011-2014 but markups were still reasonable (about 1.2) even at this period. It is evident that time-varying output elasticity of labor gives a better view of the profitability of firms over time. Fixed values would give too positive development of markups over time especially in Finland that had a long period of low growth after the financial crises in 2011-2014. Slovenia is the other country with relatively high markups and high volatility among the large firms with time-varying markups. In Slovenia, as well as in Finland, the markups with the time-varying output elasticity again better shows the fluctuations of the economy and profitability. In Slovenia markups for intangibles go down to around 1.4 in 2010-2011, but returned to around 1.7 since 2012. Denmark have also reasonably high and stable markup around 1.3, but has experienced a drop in markups from 1.4 in 2014 to 1.2 by 2016.

In KIS industries, markups have been increasing over time in all countries and are notably high in Finland. In High-tech manufacturing, markups have instead been more moderate in the latest years 2018-2019 after being very high in Finland earlier. Slovenia is the only country where markups have been improving in high-tech manufacturing since 2012.

Overall, the financial crises in 2009 was associated with strong decreases in markups in Finland until 2014 and in Slovenia in 2010-11. However, markups were not below the pre-crises level in Denmark and Norway had just slight decrease in 2009 with immediate comeback a year after. High markups before financial crises in Finland likely relates to the Nokia phenomenon and the relatively strong performance of the Finnish paper and pulp industry in 2000's. Piekkola (2018) argues that in the 2000's creative destruction has led to an increase in tangible investment among the tangible capital intensive firms with relatively poor export performance and then decreasing markups in 2011-2014.

Though markups recovered back to high levels in 2016-18, it is clear that the role of manufacturing has diminished over time in all Nordic countries and markups are generally higher there, as seen in later figures. In Finland, manufacturing has remained more important. Markups are steadier over time in Norway and have also not decreased since the financial crises. In addition, the decrease in oil prices since 2014 did not appear to affect the markups in the entire economy very much, which is contrary to the negative impulse seen in R&D-IBTC. Figure 2 shows markups in production.

Figure 2. Markups in high-tech and low-tech production

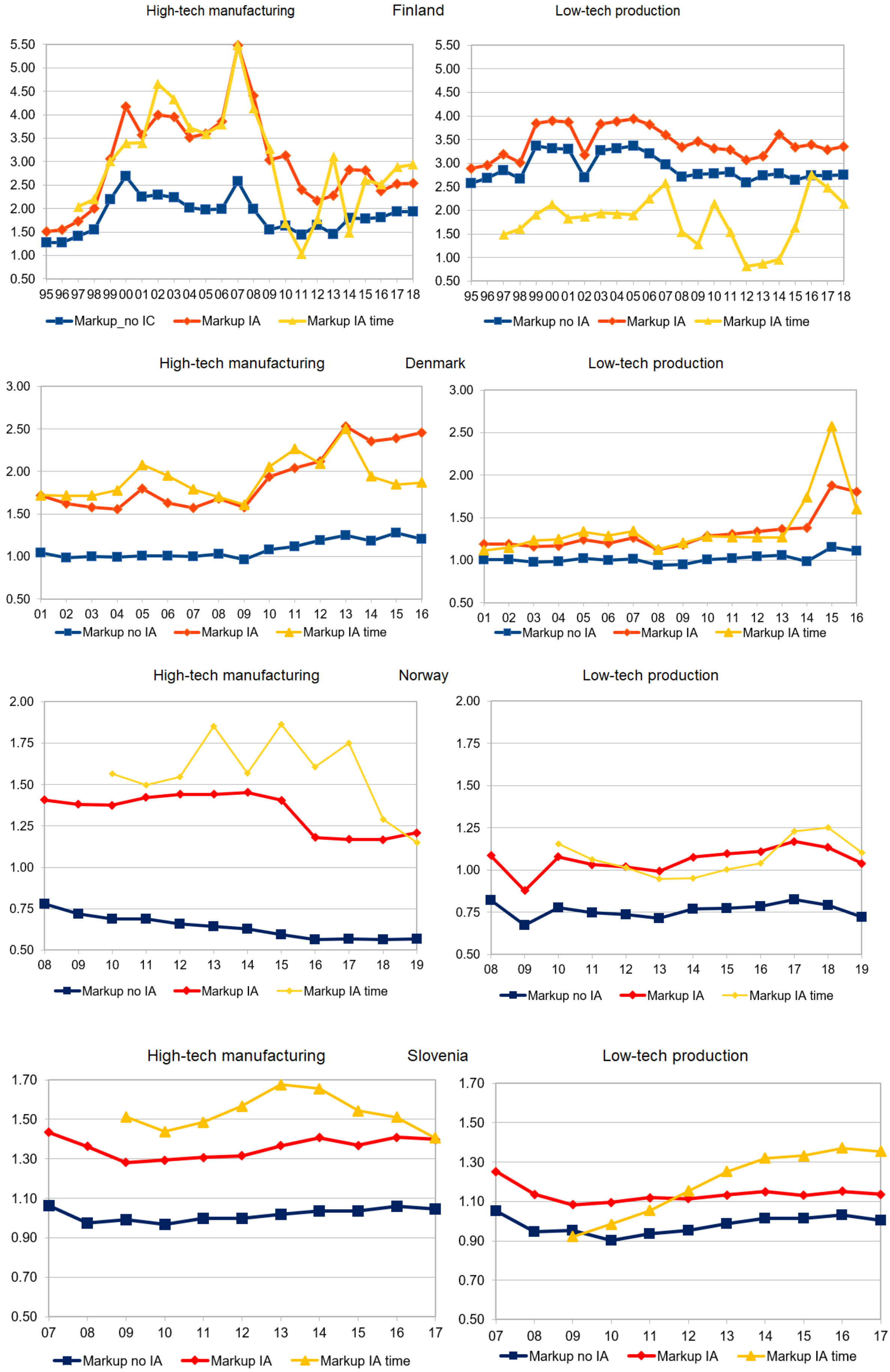


Figure 2 shows the markups in high-technology manufacturing and low-technology production (low-tech manufacturing and energy). The former includes pharmacy, compute, electronic and optimal product as the highest technology category. It also includes chemical electrical and machinery equipment, motor vehicle and other transport. Low-technology includes other manufacturing (such as oil, rubber, basic metal, metal products etc.) and energy.

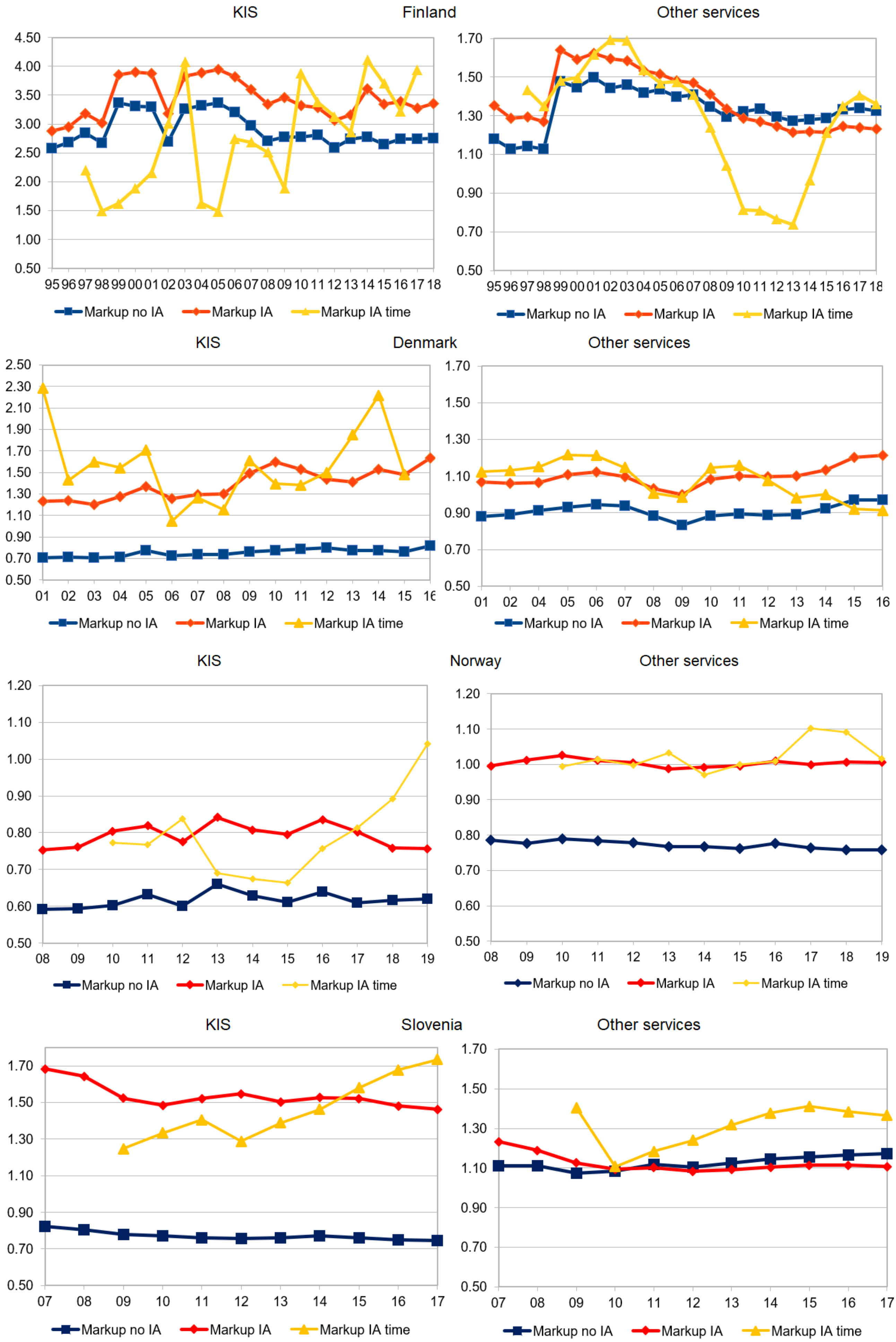
All countries have high-tech manufacturing activity with relatively good profitability. In high-tech manufacturing we can see a huge difference between high markups with intangibles compared to ignoring it. Intangibles thus play the largest role for markups in high-tech. However, high-tech industries have experienced a decrease in markups over time, which trend strengthened since financial crises. However, in Denmark the decrease took place only after 2014. In Norway, the decrease also occurred only after 2017, which is opposite to the general trend of increasing markups in Norway as of 2017. High-tech industries are highly competitive so the decrease in margins may have been worldwide. Markups were abnormally high in Finland before the financial crises, which is naturally explained by the phenomenal performance of Nokia.

Low-tech production (low-tech manufacturing and energy) has substantially lower markups than high-tech manufacturing. Finland and Denmark show an increase in markups in low-tech production in the last years. In Finland an important part of the story is the recovery of cellulose prices in paper and pulp industry and better export opportunities for the metal industry. While the recovery of Finnish exports since 2016 has relied on low-tech industry, markups have been decreasing in Norway and Slovenia.

Figure 3 below shows the markups in KIS and other services. The former includes transport, publishing, motion picture, employment activities in excess of the intangible product industry related to software, database, consult, head office and R&D activities.

In KIS, the difference between markups with and without intangibles is even greater than in high-tech manufacturing showing the importance of intangibles in these industries. In other services this is true only in Norway, while markup around 1 imply low profitability/scalability. In Finland, markups are of the highest level in KIS industries and comparable to the level of high tech since 2009. This fits with the story of transfer of knowledge from declining Nokia to KIS with consequent increase in markups. Such development leads to higher output elasticity of flexible work that explains all of the trend. However, we can also observe the increasing markups over time in all the other countries, too.

Figure 3. Markups in KIS and Other services



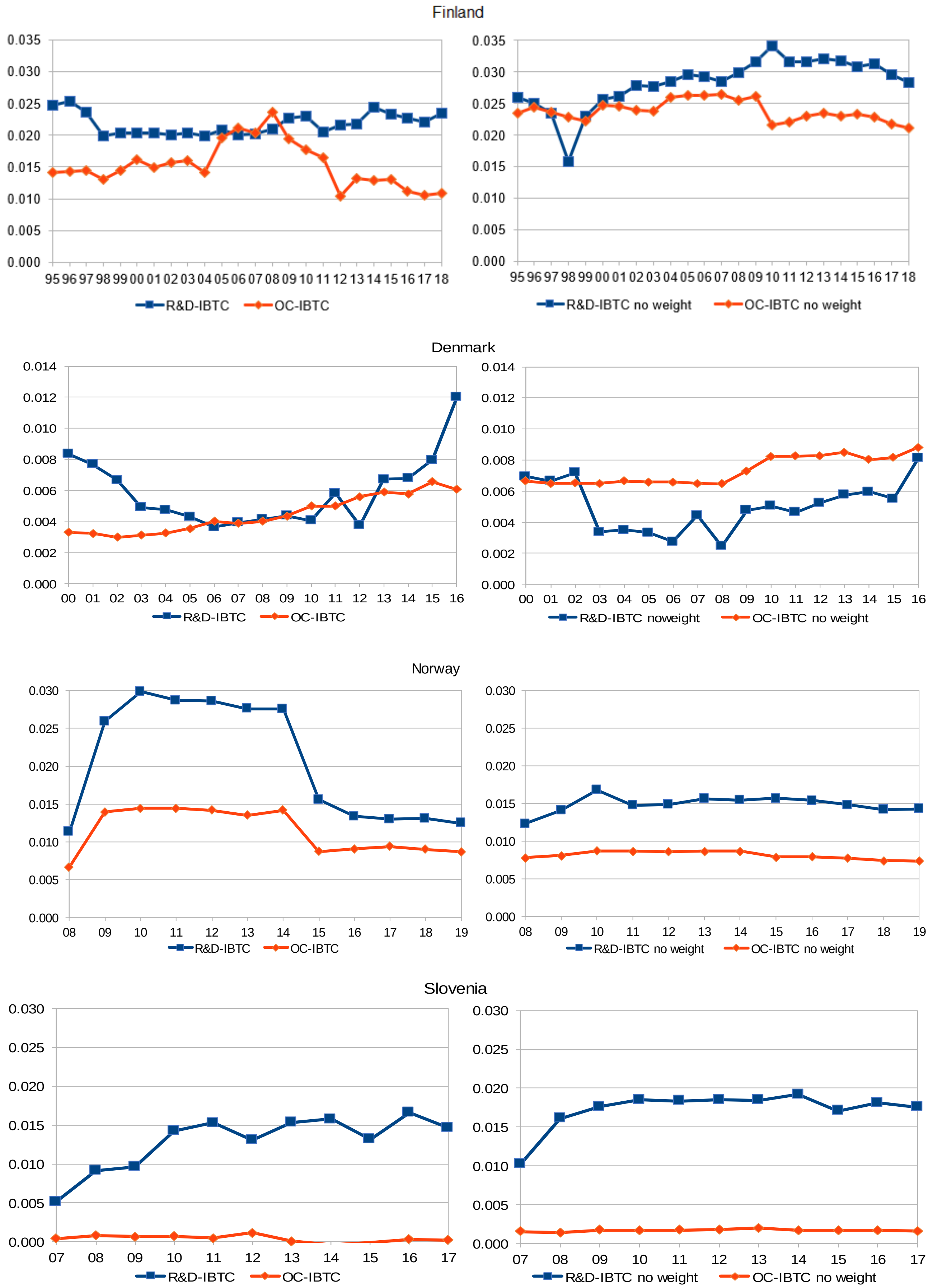
The scaling of the vertical axis is made the same on the bottom across the countries to see that markups are generally highest in Finland but with a deep dive below one in low-growth period 2010-2014. Other services have low markups but not below 1 when accounting for partly unobserved intangibles, except for Finland in 2010-14. Other services have also seen a recovery of markups in the latest years.

5 Innovation-labor biased technical change

An important part of measuring IBTC from (4) and (5) is to check for outliers since the wage ratio can vary from zero to infinity, meaning that extreme values can have a substantial influence on estimated values. In addition, small firms may not be fully able to utilize the competences of R&D workers, who as a result may not be better paid than other staff. In such case, these observations with relative lower R&D wages are ignored. For some firms, we also observe that intangible capital workers are less paid than average workers, in which case we use the average wage ratio existing in Nace 4-digit industries as a proxy wage for the corresponding type of intangible capital workers. In addition to this correction, wage rates are set to be within the 5th and 95th percentiles of the overall distribution. Figure 4 shows R&D-IBTC and R&D spillovers for Finland, Norway, Denmark and Slovenia.

Table A.2 in Appendix shows summary statistics. The relative average wage of R&D worker to average wages is 23% in Finland, 91% in Norway, close to 0% in Denmark and 100% in Slovenia. OC workers are paid on average somewhat less except the figure being 84% in Finland and 8% in Denmark. These are the initial estimates of the relative productivity differences between innovative and average workers. From (5) a higher coefficient of total labor b_L than the coefficient for the quality estimate (that should be the same) implies that relatively productivity of intangible work must be revised down. It appears that true relatively productivity $\hat{a}_{IAit} / \hat{\hat{a}}_{Lit}$ narrows down to be closer to 1 from the initial figures, since average output elasticity of labor is generally high than that on relative productivity of intangible work. R&D-IBTC is then the results of multiplying the corrected figures (relatively quality of R&D) by the share of R&D workers from all in the firm. For example, from Table A.2 in Finland relative quality increases productivity at median level by 4.2. Within one/tenth of standard deviation around this median value R&D-IBTC is 5.4% and the share of R&D occupations from all 22% (R&D engaged in R&D investment is 70% of this or 15.4%).

Figure 4. R&D-IBTC and OC-IBTC



It is seen that R&D-IBTC has progressed over years at around 1.5-2 per year in the countries considered, except that the technical change has been double lower in Denmark. In Denmark, R&D-IBTC has been the lowest but increased in years 2015-2016 closer to that in other countries considered. Salaries for R&D-work are on average 20% higher than average, while the respective ratio is 100% for Finland. As a result, there are also relatively many firms where R&D-wages are below the average. Here in firms with less than five R&D workers we also use Nace 4-digit industry R&D wage / average wage ratio that is less sensitive to the outlier observations.

OC-IBTC shows greater variation that is highest and about the same level than R&D-IBTC in Denmark, but around half of R&D-IBTC in other countries. Finland thus relies on R&D-IBTC in technical change, while in Denmark OC-IBTC has about the same effect. IBTC without sales weights attachs greater weight to the development of IBTC in SMEs. It is seen that in Danish SMES OC-IBTC takes the leading and in Finland more prominent role.Overall in the economies, R&D-IBTC has not been decreasing over time so technical change has progressed as before, also after financial crises. There are thus no downward shifts in R&D-IBTC after financial crises, rather an increase in Norway and Slovenia. After the financial crises, the only significant drop is the decrease in oil prices in 2015 that is also associated with a decrease in R&D-IBTC in Norway. Technical change has increased over time in SMEs so that new technology has been implemented at a wider scale in Finland and Denmark but not in Norway and Slovenia. Given the relatively poorer performance of large firms in Finland, findings are still in line with Piekkola (2018) that innovation potential has not necessarily increased in recent years especially in firms with highest R&D that are export orientated. SMEs have improved their technical capacities more than the large firms.

According to Piekkola (2018) OC and ICT growth has concentrated in the greater Helsinki areas and in firms with already highest OC and ICT levels. These firms are more oriented to the domestic market in their sales. The growth opportunities since financial crises have been modest with a decrease in OC-IBTC. OC-IBTC decreased especially in high-tech manufacturing and other services, where it used to dominate technological change before 2009. Denmark has instead seen a surge in OC-IBTC.

It can be seen that for SMEs in Finland, R&D-IBTC without weights has improved over the period until 2011 after which the progress has stopped. R&D-IBTC for SMEs is also larger than the average in economy for Finland, while the opposite is true for Norway.

In Norway, data begins around the financial crises when R&D-IBTC first improves after which R&D-IBTC has been around 0.015 as well as for SMEs over the period (R&D-IBTC without weights). Since then, firms may have been more oriented to global value chains. Many firms in the industry are from upstream industries and their knowledge improves the quality of products produced.

In Slovenia, the OC-IBTC is around zero for the entire period 2007-2017, while R&D-IBTC is positive and has been gradually increasing throughout the period. R&D-IBTC increases from around 0.12 in 2007 to 0.23 in 2017.

In Finland, OC-IBTC shows a clear decrease after financial crises, while in Norway, 2015 is the turning point for lower OC-IBTC. In both Norway and Finland, OC-IBTC is lower for SMEs despite having on average higher OC intensity. Thus, large firms appear to be relatively more able to run successful organizational changes with relatively lower resources used.

Figure A.1 in the Appendix shows IBTC in KIS industries that are the biggest producers of purchased intangibles to other industries. GVC analysis also reveals that such intangibles are especially important for the innovativeness of firms. R&D-IBTC in Finland (around 0.15 decreasing) and Denmark (around 0.1 increasing) fare well in technological change driven by R&D. R&D-IBTC is somewhat lower in Norway (around 0.8).

The biggest difference between the developed Nordic countries and Slovenia is that the OC-IBTC in KIS services is very low and decreasing, being close to zero, while the R&D-IBTC is unstable with the peak in 2013, but then declining sharply. Slovenian KIS depend thus more on OC-IBTC, which is also expected given the nature of the dynamics in the KIS industries in Slovenia and the fast increasing role of finance, insurance, real-estate, etc., where the role of R&D is lower.

6 Production function with IBTC and markups

Table 5 below shows the random effects production function estimates that include IBTCs and markups. R Squared within are highest in Finland and Denmark and overall R Squared is 80% or higher. Unobserved variation is still about 60% of overall variation (Rho). Overall total output elasticity of intangible capital is highest around 20% in Finland and Slovenia, somewhat lower at 13% in Norway and 7% in Denmark. These relatively high output elasticities also include markups due to intangibles.

It seen that human capital (education years) has a positive effect in all technological levels and usually has more positive effect on value added in production. Exception is Finland that has shown here to be more R&D driven country and with well performing low-tech production. Norway has highest returns on education. One more year education increases value added by 15.2% followed by 11.6% in Slovenia, 9.6% in Denmark and 5.4% in Finland. On average, in Finland average education years have increased by a half year in every decade leading to a 2.5% increase in value added.

Finland has the highest output elasticity of the sum of intangibles 24%, followed by Slovenia 16%, Norway 10% and Denmark 6%. KIS has about the higher output elasticity of intangibles. In general, countries with high returns on human capital rely less on intangibles. For R&D activity, Finland and Norway stand out as the best performers including in high-tech manufacturing. Otherwise, in Denmark R&D performance is in general the lowest. R&D is usually highest in R&D services (insignificant positive in Norway). Given that production in these sectors and R&D are to large extent used as input in other industries, external intangibles also play a significant role in profitability. Intangible performance is supported by the output elasticity of OC, which is generally not much lower than for R&D. In Slovenia, the OC output elasticity is even higher in all sectors except R&D services. Table 2 also showed that the share of OC workers is double to that in the Nordic countries.

In the Nordic countries and Slovenia, the output elasticity of labor is significant, signifying potentially high markups as we will see. Denmark has highest output elasticities of markups. Given the lowest output elasticity of intangibles, other factors than intangibles observed here seem to explain the profitability in Denmark. The human and intangible capital analysis so far ignores how new technology is absorbed. R&D-IBTC is an important determinant of value added in all countries, with least significance in Slovenia. R&D-IBTC is very important in Norway, also compared with Finland where technological change has been more rapid. Denmark distinguishes itself with a low coefficient of R&D, while R&D-IBTC is comparable to other countries, where not in other services than KIS.

OC-IBTC is truly the other cornerstone of technical change, where coefficients are of the same magnitude as for R&D-IBTC, although the level of OC-IBTC where generally lower in Denmark and Slovenia, see Figure 4. These results also indicate that intangibles create large spillovers as these are measured at 3-digit industries. Moreover, they also indicate the importance of absorptive capacity as technical change here depends on the development of the share of respective intangible worker shares of overall employment.

All of these observations indicate that Nordic countries are intangibles-driven economies causing significant markups that can also explain the relatively good profitable level of the companies. In these small economies large firms dominate the economy causing large difference in GDP growth not only due to changes in exports whereas also due to changes in markups. The latter is naturally also to large extent explained by changes in terms of trade. It is also seen that for Finland and Norway there are increasing returns, since scalability (returns to scale) is over 1. This is even after partly accounting for returns to scale through markups. Slovenia has lower intangible intensity but the output effects in Table 5 are comparable to those in Nordic countries. As indicated earlier, OC-IBTC is more important than RD-IBTC, which as such could also be more typical outside Nordic countries in Central Europe {Piekkola, 2018 #225}.

Table 5. Random effects estimation of production function

		Technology type production				Services			Technology type production				Services	
	All	High-High Middle	Low-Middle	Low	KIS	R&D	Other services	All	High-High Middle	Low-Middle	Low	KIS	R&D	Other services
			Finland							**Norway**				
Education	0.054***	0.033**	0.040**	0.048**	0.109***	0.052***	0.058***	0.152***	0.173***	0.157**	0.148*	0.117***	0.101***	0.117***
	(0.005)	(0.012)	(0.012)	(0.015)	(0.011)	(0.013)	(0.010)	(0.011)	(0.034)	(0.049)	(0.059)	(0.019)	(0.029)	(0.018)
Employee	0.772***	0.820***	0.830***	0.772***	0.717***	0.686***	0.766***	0.896***	0.842***	1.121***	0.802***	0.770***	1.115***	0.737***
	(0.006)	(0.018)	(0.015)	(0.017)	(0.014)	(0.020)	(0.011)	(0.015)	(0.057)	(0.044)	(0.048)	(0.026)	(0.058)	(0.021)
OC	0.110***	0.093***	0.109***	0.049**	0.203***	0.052*	0.115***	0.016	0.056	-0.029	0.179***	0.04	-0.151**	0.071**
	(0.006)	(0.016)	(0.014)	(0.016)	(0.016)	(0.021)	(0.012)	(0.014)	(0.047)	(0.040)	(0.041)	(0.028)	(0.047)	(0.023)
R&D	0.123***	0.103***	0.092***	0.161***	0.119***	0.252***	0.096***	0.088***	0.143***	0.049	0.015	0.110***	0.138**	0.080***
	(0.005)	(0.016)	(0.013)	(0.015)	(0.013)	(0.017)	(0.009)	(0.010)	(0.042)	(0.030)	(0.031)	(0.018)	(0.052)	(0.016)
ICT	0.010***	0.009**	0.004	0.008*	0.025***	0.012**	0.006*	0.010***	0.005	-0.004	0.004	0.048***	0.007	0.018***
	(0.001)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.009)	(0.008)	(0.009)	(0.008)	(0.011)	(0.004)
Tangibles	0.036***	0.015	0.033***	0.034***	0.032***	0.043***	0.033***	0.041***	0.056**	0.009	0.068***	0.042***	0.007	0.063***
	(0.002)	(0.008)	(0.007)	(0.007)	(0.005)	(0.009)	(0.005)	(0.006)	(0.019)	(0.017)	(0.020)	(0.011)	(0.023)	(0.010)
R&D-IBTC	1.131***	1.336***	1.903***	0.635	1.350***	0.415	0.941***	3.139***	0.388	4.403***	0.234	0.423	5.551**	3.353***
	(0.095)	(0.258)	(0.155)	(0.398)	(0.198)	(0.289)	(0.246)	(0.465)	(1.093)	(1.261)	(2.632)	(1.155)	(1.911)	(0.730)
OC-IBTC	0.787***	2.028***	-0.138	2.189***	0.083	-2.034**	0.426	3.906***	-1.021	2.019	-2.319	4.766**	1.986	4.410**
	(0.142)	(0.476)	(0.444)	(0.406)	(0.293)	(0.673)	(0.231)	(0.985)	(2.841)	(3.481)	(2.867)	(1.791)	(6.607)	(1.414)
Markup	0.014***	-0.062***	-0.004	-0.045***	0.023***	0.063*	0.052***	-0.01	-0.111	-0.016	-0.065	0.048	0.01	0.028
	(0.003)	(0.005)	(0.010)	(0.013)	(0.006)	(0.026)	(0.012)	(0.025)	(0.074)	(0.068)	(0.066)	(0.060)	(0.114)	(0.036)
Observations	44853	8424	7664	6767	7004	2866	12128	8083	1170	1189	981	1239	562	2942
R^2 within	0.43	0.349	0.483	0.39	0.447	0.501	0.442	0.275	0.159	0.388	0.274	0.352	0.433	0.273
Rho	0.65	0.548	0.621	0.617	0.734	0.55	0.719	0.526	0.416	0.461	0.453	0.564	0.565	0.748
Scalability	1.05	1.04	1.07	1.02	1.10	1.05	1.02	1.05	1.10	1.16	1.07	1.01	1.12	0.97
IA total	0.24	0.21	0.21	0.22	0.35	0.32	0.22	0.11	0.20	0.03	0.20	0.20	0.00	0.17
			Denmark							**Slovenia**				
Education	0.096***	0.111***	0.082***	0.181***	0.034	0.029*	0.113***	0.116***	0.138***	0.168***	0.120***	0.113***	-0.131	0.102***
	(-0.004)	(-0.012)	(-0.018)	(-0.019)	(-0.017)	(-0.013)	(-0.015)	(0.010)	(0.019)	(0.017)	(0.021)	(0.024)	(0.087)	(0.024)
Employee	0.887***	0.883***	0.934***	0.964***	0.907***	0.798***	0.878***	0.712***	0.798***	0.711***	0.784***	0.727***	-0.044	0.616***
	(-0.005)	(-0.012)	(-0.014)	(-0.014)	(-0.021)	(-0.023)	(-0.024)	(0.014)	(0.028)	(0.025)	(0.028)	(0.032)	(0.208)	(0.034)
OC	0.022***	0.020***	0.009	0.016**	0.008	0.022**	0.01	0.109***	0.115***	0.100***	0.104***	0.082*	0.244	0.121***
	(-0.002)	(-0.004)	(-0.005)	(-0.006)	(-0.010)	(-0.007)	(-0.010)	(0.012)	(0.021)	(0.020)	(0.024)	(0.035)	(0.164)	(0.028)
R&D	0.027***	0.042***	0.008	0.025***	0.025**	0.147***	0.019**	0.064***	0.078***	0.043**	0.060**	0.085***	0.375***	0.061***
	(-0.002)	(-0.006)	(-0.005)	(-0.004)	(-0.008)	(-0.015)	(-0.007)	(0.008)	(0.021)	(0.015)	(0.021)	(0.024)	(0.109)	(0.017)
ICT	0.021***	0.014***	0.013**	0.004	0.023**	0.025**	0.041***	0.006**	-0.003	0.004	0.009*	0.027***	-0.014	0.008
	(-0.002)	(-0.004)	(-0.005)	(-0.005)	(-0.007)	(-0.009)	(-0.007)	(0.002)	(0.003)	(0.003)	(0.004)	(0.007)	(0.021)	(0.004)
Tangibles	0.007***	0.009***	0.021***	0.029***	0.016***	-0.003	0.003	0.076***	0.085***	0.102***	0.081***	0.048***	0.012	0.092***
	(-0.001)	(-0.003)	(-0.003)	(-0.004)	(-0.004)	(-0.004)	(-0.005)	(0.004)	(0.010)	(0.006)	(0.010)	(0.013)	(0.030)	(0.012)
R&D-IBTC	1.853***	0.721*	5.309***	2.883***	1.673*	-1.895***	-3.089*	0.060***	0.03	0.087***	0.099*	0.082***	0.892	0.169***
	(-0.136)	(-0.284)	(-0.455)	(-0.530)	(-0.680)	(-0.447)	(-1.249)	(0.013)	(0.017)	(0.022)	(0.038)	(0.025)	(0.488)	(0.026)
OC-IBTC	1.793***	2.494**	4.471***	4.859**	6.582***	0.728	3.963***	2.254***	1.413**	2.065***	1.650*	1.713*	-2.064	2.452***
	(-0.342)	(-0.920)	(-1.062)	(-1.641)	(-1.260)	(-1.069)	(-1.200)	(0.286)	(0.460)	(0.519)	(0.647)	(0.779)	(2.277)	(0.672)
Markup	0.050***	0.123***	0.102***	0.039**	-0.029*	0.049*	0.591***	3.618**	-0.245	-0.892	3.085	6.476**	-10.333	8.909**
	(-0.007)	(-0.015)	(-0.014)	(-0.013)	(-0.015)	(-0.024)	(-0.091)	(1.144)	(2.256)	(1.963)	(2.095)	(2.248)	(18.594)	(2.894)
Constant	3.471***	3.229***	3.581***	2.330***	4.336***	3.917***	2.643***	6.872***	5.861***	6.304***	6.284***	7.107***	5.613**	6.965***
	(-0.068)	(-0.129)	(-0.177)	(-0.201)	(-0.228)	(-0.201)	(-0.225)	(0.172)	(0.315)	(0.272)	(0.344)	(0.422)	(2.118)	(0.365)
Observations	32999	8172	5347	4028	1821	2266	1000	7969	1659	2269	1529	533	56	1923
R^2 within	0.367	0.331	0.367	0.363	0.352	0.374	0.347	0.288	0.451	0.37	0.417	0.676	0.534	0.294
Rho	0.557	0.57	0.628	0.571	0.636	0.568	0.538	0.668	0.705	0.726	0.675	0.887	0.744	0.639
Scalability	0.96	0.97	0.99	1.04	0.98	0.99	0.95	0.97	1.08	0.96	1.04	0.97	0.58	0.90
IA total	0.07	0.08	0.03	0.05	0.06	0.19	0.07	0.18	0.19	0.15	0.17	0.19	0.61	0.19

Note. Firms with at least 20 employees. R Squared all is about 0.8-0.89. *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

We have seen high significance of intangible accumulation when IBTC and markups are considered. Table A.3 instead shows that the expenditure/performance-based estimates of intangible output elasticities are significantly lower when excluding IBTC and markups. The performance-based estimations are formed by assuming constant returns and making output elasticity of intangibles equal to the respective value added intangible investment shares through adjusting the total multiplier in (1). Here, this adjustment makes little difference between performance-based estimates and original expenditure-based ones so that our initial setting of multipliers in Table 1 appear to be correct. In other words, intangible investment per value added is equal to the output elasticity of respective intangible capital to begin with, for method see Piekkola and Rahko (2017).

Markups also control for the wealth of the firms, and are partly an outcome of imperfect markets. Now markups due to intangibles are more purely measured.

7 Conclusion

Intangibles improve performance, ensure constant returns instead of decreasing returns and generate technological change. Our analysis covers intangibles widely showing that it pays to invest in intangibles. It has also been shown that intangibles are a central part of markups so that markups would likely be negative without intangible input in technically advanced economies. Some countries like Finland are facing more severe competition in their exports with steady, or in some periods decreasing markups. Thereby relatively higher labor costs should be covered by increasing innovativeness.

Nordic countries are able to maintain their good competitive position by investing in KIS and generating profitabilility that goes beoynd that explained by broad intangibles here. Norway has a challenge to adapt to relative low oil prices since 2015 and increasing production costs.

An important issue is also whether countries have invested enough on R&D. In Finland R&D worker shares have been declining slowly. At the same time, public sector may have outsourced significant amount of their own R&D activity to the private sector, making the total decline in R&D work more significant. However, the bottleneck rather seems to be the lowest returns to human capital. Another interesting finding is that technical change has continued after financial crise and progress in R&D-IBTC has been strongest in Norway and Slovenia. At the same time R&D-IBTC is at the highest level in Finland.

It can be said that technological change has widened to cover all sectors and IBTC complements intangible accumulation. Future studies should go deeper to the structural change of the economies. In recent years the share of high-tech industries in the Nordic countries have been decreasing.

It is worthwhile to discuss government R&D subsidies and their important role in maintaining competitiveness of knowledge-based societies such as Nordic countries. Analysis suggests that R&D subsidies are desirable given their significant role in production, technical change and large knowledge spillovers. R&D-IBTC has been strongly positive and some of this effect can be attributed to sector spillovers. Technical change has thus moved ahead. Piekkola (2007) found that the marginal return on R&D investment is positive but declining, but R&D investment promotes innovativeness at a wider scale. Non-linear effects show that subsidies also have their limits in any particular industry.

Our results rely on occupational data and thereby on the skill level of employees. Personnel reporting could ensure that firms are actually investing to R&D. Then the support will go better to those companies that also expand R&D on their own initiative. Previously, national R&D subsidies were given only for new innovations without proper further funding in the future. However, it is still difficult to identify companies that successfully carry out R&D when the balance sheet data has very little to say about future prospects of R&D investments and on the whole structural capital that also includes organizational capital. Our methodology based on intangible assets occupations would be easy to carry out also as a survey form for firms applying for R&D tax deductions and should be part of personnel reporting.

New innovations also require organizational skills (management and marketing) and good access to markets (large companies utilize their customer network and all companies, especially small ones, have good ICT skills to create customers). OC-IBTC was in general almost as important as R&D-IBTC or the dominant driver in Slovenia. New innovations and the launch of new goods and services require in the second stage of innovation value chain organizational and marketing skills. Thereby tax deductibility of R&D expenses, most of which is labor costs, could be followed by new forms of tax deductibility for OC and ICT expenses, too.

Future research should further analyse the complementarity between intangibles and IBTC. Knowledge spillovers should also be analysed to understand intangible commons, which as such could also improve the rivalry of competitors (Blundell et al. (1995), Blundell et al. (1999)).

8 References

ACEMOGLU, D. 1998. Why do new technologies complement skills? Directed technical change and wage inequality. *The Quarterly Journal of Economics,* 113, 1055-1089.

BLOCH, C., PIEKKOLA, H., DEREK, T. & RYBALKA, M. 2021. Valuing intangible assets at the firm level – development of an occupation based approach. *D3.4 Globalinto*

BLOOM, N. & VAN REENEN, J. 2010. Why do management practices differ across firms and countries? *Journal of economic perspectives,* 24, 203-24.

BLUNDELL, R., GRIFFITH, R. & VAN REENEN, J. 1995. Dynamic count data models of technological innovation. *The Economic Journal,* 105, 333-344.

BLUNDELL, R., GRIFFITH, R. & VAN REENEN, J. 1999. Market share, market value and innovation in a panel of British manufacturing firms. *The Review of Economic Studies,* 66, 529-554.

BRYNJOLFSSON, E., ROCK, D. & SYVERSON, C. 2021. The productivity J-curve: How intangibles complement general purpose technologies. *American Economic Journal: Macroeconomics,* 13**,** 333-72.
CHAMBERLIN, G., CLAYTON, T. & FAROOQUI, S. 2007. New measures of UK private sector software investment. *Economic & Labour Market Review,* 1**,** 17-28.
CORRADO, C., HASKEL, J., JONA-LASINIO, C. & IOMMI, M. 2014. Intangibles and industry productivity growth: Evidence from the EU. *Manuscript available at www. intan-invest.net*.
DE LOECKER, J., EECKHOUT, J. & UNGER, G. 2020. The rise of market power and the macroeconomic implications. *The Quarterly Journal of Economics,* 135**,** 561-644.
DE LOECKER, J. & WARZYNSKI, F. 2012. Markups and firm-level export status. *American economic review,* 102**,** 2437-71.
F-JARDÓN, C. M. & MARTOS, M. S. 2009. Intellectual capital and performance in wood industries of Argentina. *Journal of Intellectual Capital*.
HALL, B. H. & MAIRESSE, J. 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics,* 65**,** 263-293.
ILMAKUNNAS, P. & PIEKKOLA, H. 2014. Intangible investment in people and productivity. *Journal of Productivity Analysis,* 41**,** 443-456.
LEV, B., RADHAKRISHNAN, S., EVANS, P. C. & INTANGIBLES, M. E. 2016. Organizational Capital. *Measuring and Managing Organisational Capital*.
OECD 2005. Oslo manual: Guidelines for collecting and interpreting innovation data. Paris.
OECD 2010. *Handbook on deriving capital measures of intellectual property products,* Paris, OECD Organisation for Economic Co-operation Development.
PIEKKOLA, H. 2007. Public funding of R&D and growth: firm-level evidence from Finland. *Economics of Innovation and New Technology,* 16**,** 195-210.
PIEKKOLA, H. 2011. Intangible capital - INNODRIVE perspective. *In:* PIEKKOLA, H. (ed.) *Intangible capital - driver of growth in Finlan.* Vaasa: University of Vaasa.
PIEKKOLA, H. 2016. Intangible Investment and Market Valuation. *Review of Income and Wealth,* 62**,** 28-51.
PIEKKOLA, H. 2018. Internationalization via export growth and specialization in Finnish regions. *Cogent Economics & Finance,* 6.
PIEKKOLA, H. 2020. Intangibles and innovation-labor-biased technical change. *Journal of Intellectual Capital,* 21**,** 649-669.
PIEKKOLA, H. & RAHKO, J. 2017. Innovation and performance using broad measures of intangibles. *In:* VAASA, U. O. (ed.). Mimeo.
ROOS, G. & ROOS, J. 1997. Measuring your company's intellectual performance. *Long range planning,* 30**,** 413-426.
SCHANKERMAN, M. 1981. The effects of double-counting and expensing on the measured returns to R&D. *The Review of Economics Statistics,* 63**,** 454-458.
SQUICCIARINI, M. & LE MOUEL, M. 2012. Defining and measuring investment in organisational capital: using US microdata to develop a task-based approach.
SYVERSON, C. 2019. Macroeconomics and market power: Context, implications, and open questions. *Journal of Economic Perspectives,* 33**,** 23-43.
TSAKANIKAS, A., ROTH, F., CALIÒ, S., CALOGHIROU, Y. & DIMAS, P. 2020. The contribution of intangible inputs and participation in global value chains to productivity performance: Evidence from the EU-28, 2000-2014. Hamburg Discussion Papers in International Economics.

9 Appendix A. Industries by technology type and reference production function estimates

Table A.1 Industries by technology type

Technology type	Main industries	Other	Finland Value added share %
High technology manufacturing	Electronics 21 and pharmacy 26		23.8
High-middle technology manufacturing	Chemical 20, electrical equipment 27, machinery and equipment 28	Motor vehicles 29, other transport 30	10.7
Low-middle technology manufacturing	Refined petroleum 19, rubber and plastic products 22, basic metals 24	Repair and installation of machinery and equipment 33-34, energy 35	9
Low technology manufacturing	Food 10, textile 13, paper 17	Beverages 11, tobacco 12, textiles 13, wearing apparel 14, leather 15, wood and wood product 16, , printings 18, furniture 31, other manufacturing 32	4.6
KIS market (knowledge-intensive market services, excl. finance and high-tech services)	Transport 50-51 (not land) publishing 58, telecommunication 61, arts, entertainment and recreation R	Motion picture 59 programming, broadcasting 60, other professional activities 74, 75, 78 80	12.4
ICT services	Computer programming, consultancy 62 information service activities 63		5.8
R&D services	Architectural, engineering 71, R&D 72		5.7
OC services	Legal 69, head office 70, advertising, market research 73		2.1
Other services	Wholesale trade 45-47, land transport 49 , warehouse 52, accommodation, food and beverage 56, real estate 68	Rental and leasing 77, travel agency 79	25.9

Table A.2 Summary and IBTC

	Mean	Median	Std	N	Mean	Median	Std	N
			Finland				**Norway**	
Value added/L	81.2	58.7	531.0	530.2	108.0	80.5	386.0	228.0
Employee	38.4	11.0	227.0	530.2	44.6	12.9	241.0	228.0
OC/L	31.5	17.9	67.3	192.2	43.9	26.5	336.0	158.6
R&D/L	54.2	30.8	146.0	305.7	172.0	72.9	485.0	85.8
ICT/L	17.3	5.5	66.3	82.7	62.5	17.7	195.0	49.7
Total Capital/L	247.0	127.0	1226.0	530.2	515.0	128.0	4037.0	228.0
Output elasticity of employment (excl. IA work)	0.762	0.795	0.143	530.2	0.879	0.891	0.127	228.0
Output elasticity of capital	0.176	0.153	0.108	530.2	0.158	0.125	0.106	228.0
Output elasticity of relative quality of R&D work	1.460	1.500	1.720	225.7	1.720	1.410	2.280	90.4
Output elasticity of relative quality of OC work	1.800	1.850	0.969	131.6	0.715	0.613	0.841	154.7
Initial relative quality (wages) of R&D work	1.230	1.220	0.284	225.7	1.240	1.180	0.194	108.8
Initial relative quality (wages) of OC work	1.840	1.770	0.473	131.6	1.450	1.400	0.218	186.2
Relative quality of R&D work	1.120	1.040	0.245	210.7	1.050	1.030	0.125	80.1
Relative quality of OC work	1.180	1.110	0.263	131.6	1.050	1.020	0.087	152.1
R&D-IBTC	0.028	0.004	0.063	210.7	0.015	0.004	0.025	80.1
OC-IBTC	0.024	0.008	0.037	131.6	0.008	0.002	0.014	152.1
			Denmark				**Slovenia**	
Value added/L	120.0	82.2	4451.0	0.0	35.6	26.2	86.2	99.2
Employee	66.9	19.2	362.0	171.0	39.1	11.0	195.8	99.2
OC/L	22.7	15.1	61.1	91.6	7.4	1.5	17.2	99.2
R&D/L	147.0	85.0	430.0	75.2	13.6	0.0	44.2	99.2
ICT/L	47.8	10.3	158.0	29.7	2.5	0.0	11.7	99.2
Total Capital/L	121.0	62.7	344.0	171.0	55.1	22.5	382.3	99.2
Output elasticity of employment (excl. IA work)	0.750	0.800	0.210	171.0	0.673	0.708	0.203	99.2
Output elasticity of capital	1.290	1.220	0.220	69.0	0.262	0.248	0.165	99.2
Output elasticity of relative quality of R&D work	1.730	1.600	0.484	83.5	0.251	0.364	1.780	99.2
Output elasticity of relative quality of OC work	0.180	0.160	0.110	170.6	0.262	0.248	0.165	37.9
Initial relative quality (wages) of R&D work	1.200	1.070	1.700	170.6	2.000	2.160	0.595	25.7
Initial relative quality (wages) of OC work	0.780	0.690	0.650	83.4	1.530	1.370	0.580	29.4
Relative quality of R&D work	1.050	1.020	0.160	68.8	1.070	1.050	0.770	25.7
Relative quality of OC work	1.060	1.030	0.100	83.1	1.030	1.010	0.606	29.4
R&D-IBTC	0.005	0.002	0.040	68.8	0.017	0.003	0.010	99.2
OC-IBTC	0.007	0.002	0.010	83.1	0.0017	0.0003	0.0000	99.2

Note. Observations (N) are in thousands and value added, IAs and total capital intensities in thousand 2015 euro.

Figure A.1 IBTC in knowledge intensive services (KIS)

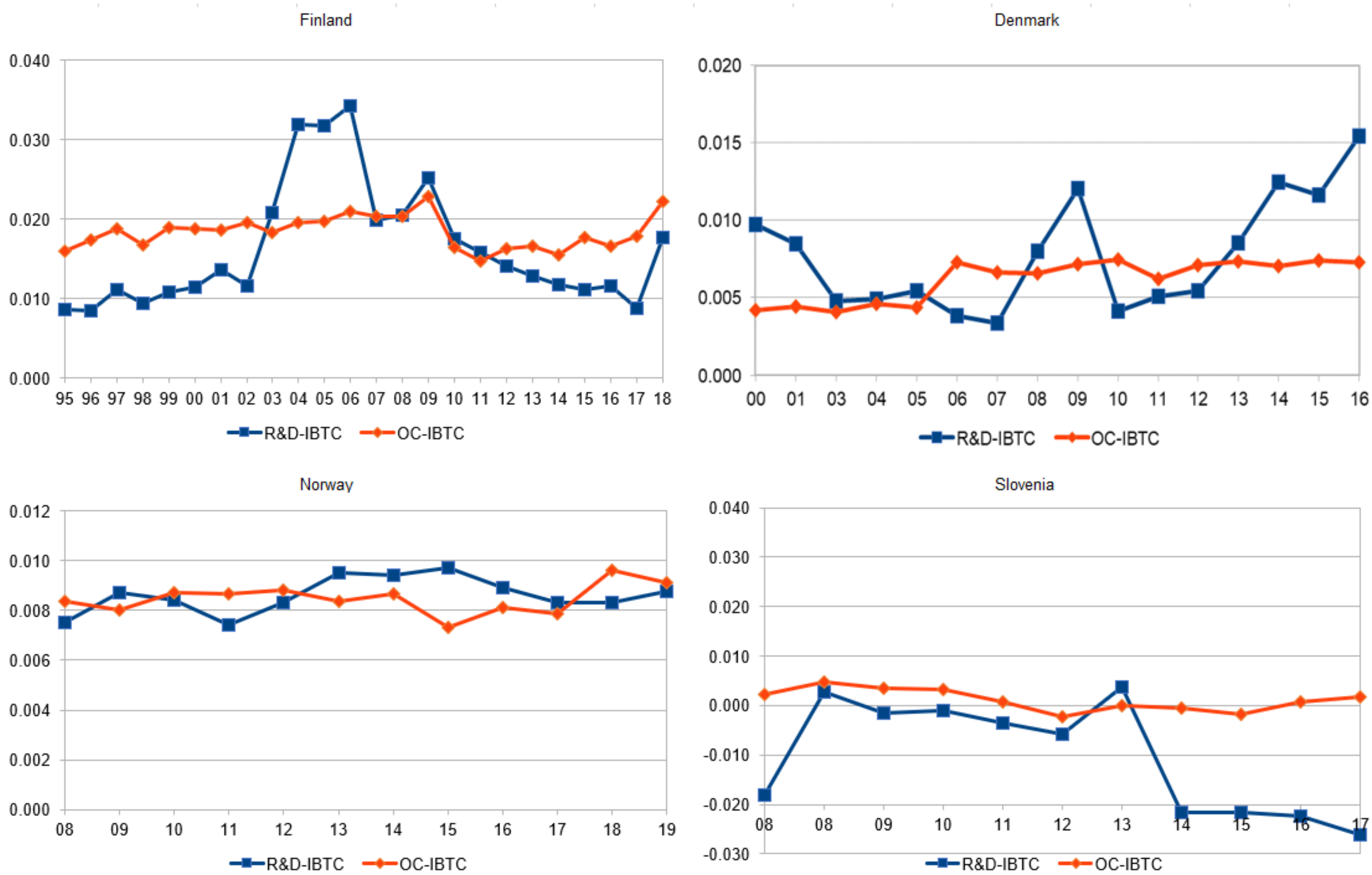


Table A.3 Expenditure and performance-based estimates of production function in comparison

	OC/L	OC/L Perform	R&D/L	R&D/L Perform	ICT/L	ICT/L Perform	OC/L	OC/L Perform	R&D/L	R&D/L Perform	ICT/L	ICT/L Perform
			Finland						**Norway**			
All	16.2	16.5	48.6	50.0	7.1	7.1	24.3	24.3	67.6	67.6	13.1	13.1
High Technology	47.4	48.0	187.7	192.4	15.3	15.8	44.7	45.6	273.2	271.9	11.9	11.7
High-Middle Technology	16.6	16.3	89.8	92.1	2.9	2.9	45.1	45.4	199.1	203.1	4.5	4.5
Low-Middle Technology	14.8	15.2	66.2	68.7	2.8	2.8	34.0	34.0	120.3	120.7	4.1	4.1
Low Technology	13.4	13.7	46.0	47.6	2.4	2.4	30.5	30.6	31.5	31.8	3.9	3.9
KIS market	10.6	10.9	25.6	26.8	5.3	5.4	23.8	23.6	56.5	57.6	20.1	20.3
ICT services	31.0	31.4	27.1	27.8	89.1	88.4	31.9	32.7	84.2	89.3	156.2	157.4
R&D services	20.5	20.6	227.5	229.0	7.6	7.3	30.5	30.6	414.7	429.8	9.0	9.1
OC-services	53.1	54.1	25.9	25.4	5.7	5.7	91.4	90.0	22.3	22.5	9.2	8.0
KIS	12.5	12.7	13.6	13.9	2.0	2.0	21.8	21.9	30.0	30.4	4.5	4.6
			Denmark						**Slovenia**			
All	11.7	11.8	76.6	76.8	15.2	15.3	8.8	11.4	35.5	46.4	9.0	11.6
High Technology	14.8	14.8	415.4	402.5	11.4	11.2	8.6	11.2	80.5	104.8	4	5.2
High-Middle Technology	12.3	12.3	105.2	106.1	5.1	5.0	5.2	6.7	26.7	35	0.9	1.1
Low-Middle Technology	11.3	11.3	61.6	62.5	3.6	3.7	5.8	7.5	28.3	36.8	0.9	1.1
Low Technology	10.4	10.4	28.9	28.9	3.3	3.3	4.8	6.2	10.8	14.1	0.8	0.9
KIS market	13.6	13.7	90.2	90.6	34.5	33.9	4.9	6.2	12	15.5	5.4	7
ICT services	10.8	11.2	85.0	85.8	181.8	182.9	11.3	14.6	21.9	28.5	58.4	75.7
R&D services	9.4	9.4	268.2	269.5	5.4	5.4	10.1	13	98.8	129.2	5.2	6.6
OC-services	49.6	49.8	26.6	28.2	15.1	15.3	24.1	31.5	33.8	44.8	4.5	5.7
KIS	8.4	8.4	19.9	21.1	5.5	5.7	4.5	5.8	6.7	8.5	1.1	1.4

Note. Perform=performance-based estimate