Innovation-driven growth policies for Finland

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Contents

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Main results

The novel recent Ministry of Finance report on productivity emphasized the productivity slowdown after financial crises and especially in digital services.[2] In Finland, labor productivity has been catching up with the world's forefront for a long time, but the trend reversed around 2008 and the productivity difference between industries has since then spread again. In manufacturing, labor productivity is claimed to be at a good international level, but in many service sectors it is far from the level of the comparison countries.

The analysis here examines broad intangibles as the major determinants of productivity and these include organizational capital and ICT, which is more broadly defined than covering just software and database. The major difference to national accounting is also that organizational capital (management and marketing capital) is included in the analysis. At firm-level, the method is applied in four countries Finland, Denmark, Norway and Slovenia as part of Globalinto project 2019-2022 financed by EU 2020 Horizon Framework. The analysis benefits greatly on data produced in EU Horizon Project Globalinto and related 50 scientific publications. [3] We evaluate technical change driven by R&D and OC workers through a novel measurement of innovation labor–biased technical change. The analysis shows that in Finland technical change driven by R&D and OC has continued at the level it was in 2010's and there is no dive in it after financial crises in any of the considered countries.

Broad intangibles are vital for the evaluation of profitability of the firms, too. The analysis for Finland shows that markups and hence profitability of the firms were lowered during the slow-growth period 2011-2014. Markups would even be negative if intangibles are not properly considered. Intangible work creates large fixed costs and therefore should be excluded from flexible work or in any comparisons of unit labor costs across countries. After these corrections, and including organizational capital, it becomes evident that markups in slow growth period in Finland still never decreased below that in Denmark and Norway. Finnish large firms have otherwise been among the most profitable ones relative to comparison countries Denmark, Norway and Slovenia.

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[2] "Tuottavuus ja voimavarojen kohtaanto – Digitaalisten palveluiden tuottavuuden taso ja kehitys Suomessa heikko" (Productivity and allocation of resources – weak productivity and its growth in digital services) with comparability to the analysis in other OECD countries emphasized the productivity slowdown after financial crises in Finland and especially in digital services STENBORG, M., MALIRANTA, M., KIEMA, I., HUOVARI, J. & ELMGREN, P. 2021. Tuottavuus ja voimavarojen kohtaanto – Digitaalisten palveluiden heikko tuottavuuden taso ja kehitys Suomessa. *Valtiovarainministeriön julkaisuja.* Helsinki: Valtiovarainministeriö Tuottavuuslautakunta.

[3] EU Horizon 2020 GLOBALINTO project for the years 2019–2022 [grant number 822229] titled "Capturing the value of intangible assets (IAs) examines intangibles to promote the EU's growth and competitiveness. GLOBALINTO is a continuation to the FP7 INNODRIVE project 2008-2011 that developed the Innodrive methodology in measuring intangible assets at the firm level and also coordinated by Hannu Piekkola. The project has also conducted a European-level survey on intangible capital during the period 2019-2020 when the economies were hit by Covid (www.globalinto.eu).

The analysis also shows that business services have progressed relatively well in Finland compared to the reference countries Denmark and Norway and far better than in Slovenia. Knowledge intensive services have had value added growth rate of 5.7% in recent years (2016-2019) and the annual growth rate has been 3% since 2001 (respective figures for private sector growth as a whole are lower 1.7% and 2.5%). Finland is surely behind Sweden in digital services, but we find no evidence for backwardness in respect of other Nordic countries Denmark or Norway.

The research here, finally, raises doubts on using total factor productivity as a measure of technological change as changes in it largely relate to changes in markups. Hence, it is not a proper measure for evaluating technical change, which depends on broad intangibles. An unexplored topic is also the declining public sector R&D intensity since financial crises. The levelling down of R&D activity does not hence cover only universities, whereas the whole public sector.

1. Introduction

The purpose of this project is to evaluate the determinants of productivity growth in knowledge-intensive Finland in the Nordic framework. Economic growth is substantially driven by intangible capital, but relatively little is known about the intangible capital base in a broad sense, which includes digitalization (not just databases and software) and the ability to organizational capital (OC) related to management and marketing. Intangibles can also be expected to create large spillovers, which are better understood as intangible commons. The high depreciation of intangibles can also be interpreted as a rate at which valuable intangibles translate into public knowledge that hence loose its private value. Such intangible commons are important part of the total value of intangibles.

Mirror image of this challenge in measuring depreciation is the problems with price deflators. Nakamura (2021) suggest that especially rapid decline in input price deflators due to intangibles are not correctly measured. We simply do not have a special category for intermediate input deflators for inputs that benefit from rapid technological improvement due to intangibles. Especially the mismeasurement of information and community technology products creates challenges. Aizcorbe, Oliner, and Sichel (2008) introduced a new index for microprocessors used in desktop personal computers. Their preferred index fell at an average rate of 42 percent a year between 2009 and 2013, while the most comparable official price measure (the producer price index for microprocessor units) declined by an average rate of only 6 percent a year. This suggests that multifactor productivity growth in semiconductors—the general-purpose technology behind much of the digital revolution—has been far more rapid than official indices suggest.

In particular, services rely to a greater extent on other intangibles, such as organizational capital and digitalization, where information is gathered only in ad hoc surveys. However, a substantial portion of intangible assets relate to advertising and marketing, organizational capital. At the same time, intangibles have not grown uniformly, causing substantial differences among growth in European economies (Hintzmann Colominas et al., 2021). Our knowledge of innovation capacity is largely based on formal R&D surveys, which are not enough extensive to cover deeper technical change in various industries or technology-type sectors.

In the U.S., intangible capital in a broad sense contributed 0.83 percentage points to 2.96% of annual labor productivity growth between 1995 and 2006 (Van Ark et al., 2009). Jona-Lasinio and Meliciani (2018) find that between 2000 and 2013, the contribution of intangibles to total factor productivity growth ranged from 14 percent (Denmark) to 30 percent (Netherlands) and was even slightly higher in Spain, Finland and the UK (e.g., 33%). According to the authors, the overall decline in labor productivity growth is mostly the result of the total factor productivity (TFP) growth slowdown and is not caused by tangible and intangible capital. The analysis here suggests that in Finland the decrease in TFP was temporary in 2011-2015 related to the decrease in markups (profitability). The productivity growth slowdown in Europe, or at least no decreasing in the productivity gap with the US, raise concerns about the welfare and competitiveness of the EU/EA. A cross-country sectoral perspective on the origins of these productivity problems suggests that they are concentrated in certain EU/EA countries and specific sectors of the economy, notably market services – NACE codes G-K, M-N, R and S (Roth and Sen 2021).

The focus here is also on the unmeasured part of TFP and on making it measurable by evaluating technical change and markups. Markups relate to the ability to generate pure profits or to increase returns to scale. Intangibles are probably the greatest contributors to higher profits. Nakamura (2021) shows that the proportion of GDP in the US devoted to tangible investment (gross domestic private investment less intellectual property (IP) products) has fallen from a ten-year moving average of 17% in 1976-85 to 12.6% in 2011- 2020. At the same time GDP share of intellectual property (intangibles as measured in national accounting) has risen from 2.0% to 4.5% over the same periods. Such intellectual property still excludes organizational capital and marketing, which have also grown at fast rate. Despite the drop in tangible investment, corporate profits during this period have risen relatively dramatically. Using the same periods, Nakamura (2021) shows that corporate pre-tax economic profits in US were 7.9% in 1976-85 and rose to 11.3% in 2011-2020, an increase of 3.4 percentage points. Intangible investments lead to increase in profits, which are in growth accounting partly included in the residual, namely in total factor productivity. All analysis of TFP are confronted with the challenge whether its growth is explained by technological improvement or by higher profit. Only the technological growth gives a permanent effect on growth, while changes in profitability may relate to business cycle effect, variation in imperfect competition or (temporary) high returns to scale.

The EU Horizon 2020 Globalinto project for 2019-2022, coordinated by Hannu Piekkola of the University of Vaasa, has analyzed at the firm level the importance of intangibles proxying intangibles from intangible work evaluated from occupations using linked employer-employee data. Microlevel LEED data had to be individually constructed to cover all employees and firms over the specified period in Finland, Denmark, Norway and Slovenia. A significant effort was made to have comparable data across countries with remote access to Statistical Office data made available in the Globalinto project. The duration of the data varies by country, while the data period is the longest for Finland, ranging from 1995 to 2018.

The innovation work is behind technical change, which we measure here by “innovation-labor biased technical change” (IBTC) generating important knowledge spillovers (Piekkola 2020). Intangible capital occupations relate to R&D, management, marketing and ICT; see Appendix Box A.1. A firm-level analysis is made possible by measuring innovativity from related occupations. IBTC allows for increasing returns from intangibles when the relative value of R&D or OC work is positively related to the share of respective workers within firms.

Finland is one of the Northern European countries with relatively high intangible intensity, meaning productivity growth is driven to a large extent by intangibles (Hintzmann Colominas et al., 2021). The countries covered here are Finland, Denmark, Norway and Slovenia. For all countries, full data on firms and employees are available, and data for Finland and Slovenia also cover the public sector. The measures of intangibles are also broad. For example, in Finland, over 80% of firms with 10 employees or more have R&D workers. The intangible work is extended to cover OC (organizational capital, such as management and marketing) capital and information and communication capital (ICT), where the coverage regarding OC occupations is equally pervasive. However, only 40% of OC and 33% of ICT occupations are assumed to be used for intangible investment; the rest are used for running the existing business.

Bloch et al. (2021) used updated EU 7th framework Innodrive data on intangibles for Finland with a method extended to Denmark with a somewhat broader definition of OC occupations. The study shows that growth in intangible assets (IAs) was much larger in Finland than it was in Denmark in the period leading up to the crisis, as seen in Table 1 below.

Table 1 Growth comparison of IAs in Finland before and after financial crises (Bloch et al., 2021)

Variable	Finland	Denmark
Employees	125	81
Value-Added	10314.3	5789.0
Growth over period 99-03	1.8%	4.5%
Growth over period 03-08	2.3%	3.6%
Growth over period 08-13	−4.8%	−0.9%
R&D	4268.7	2961.9
Growth over period 99-03	4.1%	3.7%
Growth over period 03-08	3.3%	2.5%
Growth over period 08-13	−2.5%	0.5%
OC	1075.3	565.3
Growth over period 99-03	4.2%	3.3%
Growth over period 03-08	1.6%	2.2%
Growth over period 08-13	−3.5%	6.5%
ICT	1196.0	157.2
Growth over period 99-03	8.1%	5.0%
Growth over period 03-08	7.9%	2.4%
Growth over period 08-13	−5.4%	5.0%
Number of observations	63,377	91,005

Value added and intangible assets in thousand euros.

Following the financial crisis, the growth path of intangible assets (IAs) in Finland was highly negative. All types of IAs decreased in Finland, which is connected to the fact that GDP dropped 8% in 2009 and only began to approach the pre-financial crisis level in 2018. These finding are consistent with the low growth in GDP during 2011-2014. On the other hand, the paper finds that R&D output elasticity increases from 0.036 to 0.039 after the crisis. While investments in R&D may have helped in the recovery, Finnish firms still had to contend with a more severe economic downturn than, for example, Denmark. ICT elasticity for Finland was negative both before and after the crisis, which can potentially reflect overinvestment in ICT prior to the crisis. Still business services have grown more than the rest of the economy. Musolesi and Huiban (2010) find business services, the core of market services, to be as innovative as manufacturing in R&D investment and patenting with a strong influence on productivity growth.

Increases in elasticities for both R&D and OC may partially reflect consolidation on the part of Finnish business through large declines in intangible investments following the crisis. Lome et al. (2016) find that in Norway, R&D-intensive firms performed significantly better during the financial crisis, and we find the same pattern to be true for Danish firms.

Analysis shows here that the slow-growth period during 2010–2014 was been left behind and that technical change continued during that period and afterward. In terms of both technical change and markups, Finland fares well in comparison with the Nordic reference countries of Denmark and Norway. Slovenia is a good example of a country with internationally competitive large firms with continuing technical change which is burdened with fairly weak business services.

It is important to note that the role of intangibles in global value chains (GVCs) on industries can also be assessed with similar methodologies by observing the use of intermediate inputs in other industries created by KIS industries (Tsakanikas et al., 2020). The open-access GLOBALINTO I-O intangibles database available at www.globalinto.eu provides an important link in quantifying the impact of intangibles in the connection of GVC across countries using the world-input-output database WIOD.

An important and unique advance of the research, therefore, is that Globalinto examines intangibles with similar tools over several countries at both the industry and firm levels. This gives an appropriate description of growth and related policies over Europe and across countries. In the micro approach of Globalinto, all four partners have remote access to the Statistics Office's full data on employees and firms in the respective economies. The partners are the University of Vaasa, the University of Århus, Statistics Norway research department and the University of Ljubljana.

Section 2 shows background statistics on intangibles and their allocation in firms of different technology types. Section 3 analyses technical change measuring innovation-labor-biased technical change (IBTC) driven by R&D and OC workers. Section 4 describes markups and their development since 1995 in Finland and other countries. Section 5 shows the estimation of production function using innovations and IBTCs as input in a system estimation. Section 6 derives conclusions, and Section 7 broadens the policy analysis to other fields relevant to sustainable growth. All intangible capital activity can be considered to save physical resources and lead economies away from tangibles to intangible assets that are potentially environmentally friendlier.

2. Background statistics on intangibles and technology

Intangible assets have become increasingly important over the last twenty years. This raises interest not only in the contribution of intangibles to productivity but also in how innovation 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 (Bresnahan and Jones, 2012). In this respect, we also explore the value of intangible work in creating innovation-biased technical change.

The primary sectors that are considered to be producing intangibles (intangibles for use in other sectors), referred to as knowledge business services (KIS) are ICT industries J62-J63 (Computer programming, consultancy and related activities; Information service activities), R&D industry M72 (Scientific research and development), OC industries M69 (Legal and accounting), M70 (Head office, management consulting services), and OC jobs M73 (Advertising and market research). Value-added formation of KIS implies that labor costs are approximately two-thirds of all factor inputs with regard to all kinds of intangibles. Therefore, labor costs are also the primary source of expenditures in innovation activity. The analysis of the private sector in what follows excludes agriculture (Nace A), forestry and mining (Nace B), financial services (Nace K), water supply (Nace E), construction (Nace F), private education (in Nace P), private health (in Nace Q), and other services (Nace Q, S, T, U, X). Data still cover over 99% of value added and employment in the private sector. Many of these industries have different products and services that are unique in their intangible input content.

Appendix A reports the broad IA occupations used in the analysis [Box A.1 GLOBALINTO Intangibles Assets occupations (based on ISCO08 Occupation classification)]. Table 2 shows the annual earnings in Finland, deflated by wage earnings, in 2015 prices for full private sector data that include all firms with at least five workers on average. Skilled workers are those with higher tertiary education and other skilled worker are among those with have no intangible work (IA work).

Table 2. Annual earnings per employee in thousand 2015€ producer prices, Finland

Year	All	R&D work	OC work	Other skilled work	Skilled work	Unskilled work
1999	28.4	38.3	56.1	21.5	23.9	19.4
2000	28.9	39.6	56.0	22.0	25.3	20.4
2001	29.7	40.0	57.9	21.6	25.3	20.3
2002	30.1	40.1	59.0	21.1	25.6	18.9
2003	30.1	40.8	60.8	20.5	25.3	19.5
2004	31.4	42.8	63.2	21.5	26.9	20.0
2005	32.3	42.7	62.3	21.7	27.1	21.0
2006	32.9	43.5	63.4	21.1	26.4	19.7
2007	33.6	44.2	65.1	21.1	26.6	19.7
2008	33.9	45.1	64.7	21.0	26.8	19.5
2009	33.4	45.2	63.9	21.5	27.5	19.4
2010	34.0	47.4	68.4	21.4	27.7	21.5
2011	34.4	47.4	70.3	20.9	26.5	20.7
2012	34.7	48.0	71.3	21.4	27.7	19.0
2013	34.6	47.9	71.0	20.4	27.2	17.9
2014	34.7	48.3	71.5	19.9	26.7	16.5
2015	35.0	47.9	72.4	19.6	26.4	15.7
2016	35.9	48.6	74.5	19.2	25.9	15.7
2017	36.3	49.0	73.1	19.0	25.3	15.2

Note. Annual earnings include all earnings from the same firm earned during the year. For unskilled workers, in particular, figures are downward biased due to the large share of temporary work. For part-time workers, labor input is 0.7; otherwise, the headcount is not adjusted for months worked.

Organizational work is the most highly paid, with annual earnings of 73 thousand 2015€ in 2017, while earnings were 49 thousand € in R&D work. In IA work, annual earnings have increased by approximately 30% in 19 years, while the earnings of other high-skilled workers with tertiary education have remained approximately the same. IA workers, thus, earn noticeably more than other skilled workers with tertiary education. For unskilled workers, in particular, annual earnings have decreased. The increasing share of other skilled workers has, hence, led to widening wage inequality among skilled workers, causing an increase in inequality (Kerr et al., 2020).

In what follows, after private/public sector comparisons the private sector excludes 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 3 shows the distribution of IA workers in the sample data, following the OECD classification of technological level for manufacturing and services (see Appendix A Table A.1 Industries by technology type), divided into the KIS market, OC (Nace 69, 70, 73), ICT (Nace 72), R&D (Nace 72), and non-KIS services with related occupations listed as Box A.1 in Appendix A. IC work depends on the share of time spent on innovative services, which is assumed to be 70% in R&D, 40% in OC and 60% in ICT occupations.

Table 3. IA and other skilled work shares with tertiary education by technology type in the private sector, Finland 1995–2018

Technology type	OC	R&D	ICT	Other skilled
		Production		
High-tech.	0.032	0.211	0.039	0.136
High-Middle	0.017	0.135	0.010	0.128
Low-Middle	0.014	0.096	0.009	0.091
Low-tech	0.013	0.068	0.007	0.091
		Services		
KIS market	0.012	0.040	0.018	0.173
ICT	0.028	0.028	0.255	0.152
R&D	0.015	0.340	0.015	0.151
OC	0.056	0.032	0.014	0.301
Non-KIS	0.012	0.029	0.005	0.109

Note. Occupations are from the Isco08 classification and reported in Appendix A Box A.1 and sectors in Table A.1.

The OC work share (when 40% of OC workers' time goes to OC investment activities) rises to 5.6% in OC services (legal 69, head office 70, advertising, market research 73). OC work share is lower, 1.2%–3.2%, in other sectors. R&D work shares are much higher 13.5-21.1% in high-middle or high-tech manufacturing or 6.8-9.6% in low-tech or -middle low-tech manufacturing and energy. Table 3 shows that OECD technological level classification together with IA type classification of sector M is rather good at identifying sectors with different types of IA composition.

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

The factor multipliers also vary by type of IA and related KIS sector (OC, R&D or ICT intensive). They can be said to be on the upper bound of the share of tangible capital and intermediate inputs in intangible investments. This is because value-added creation in business services, where these figures are derived, typically relies more on intermediate inputs in the form of subcontracting than other sectors (Corrado et al., 2014), so intermediates can be overvalued when multipliers are applied to other sectors.

Table 4. Factor multipliers for one unit of labor costs in microdata

EU region	**OC**	**R&D (M72)**	**ICT**
<u>Globalinto</u>			
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 to measuring "overheads" in the OECD (2010)), a method applied to evaluate ICT from related labor costs in most NSIs, proxying software and database expenditures in most countries. In their satellite accounting of investment in intangible assets, the Office for National Statistics (ONS) in the UK 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 nonlabor 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 firm *i* in year *t* is given by

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

where labor costs, M_{it}^{IC}, are multiplied by a total multiplier, A^{IC} from Table 4, 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 R&D investment deflator for R&D, the innovation property investment deflator (including R&D and software and database) for ICT and the labor costs weighted average of the 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

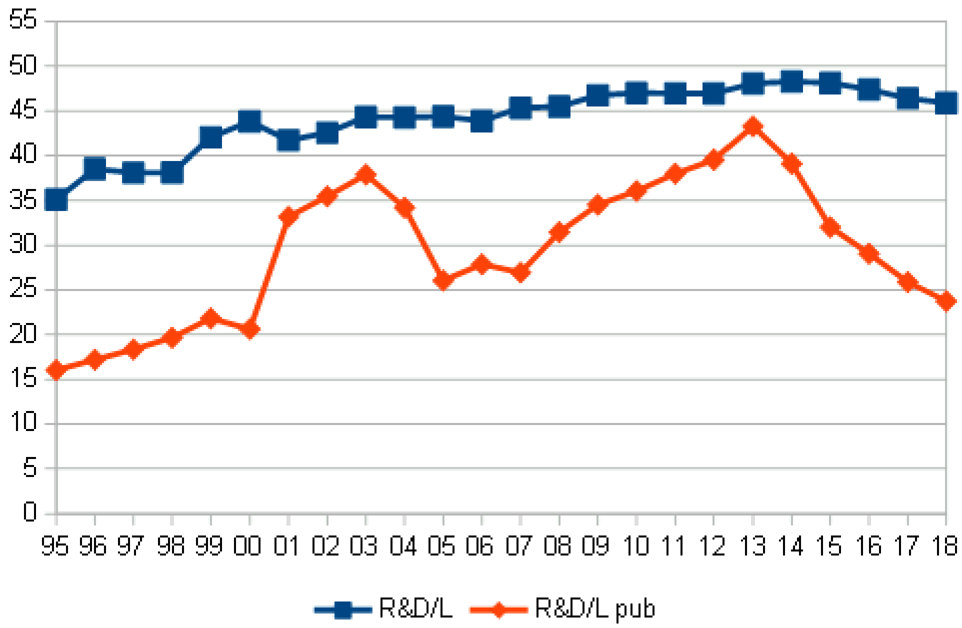
$$R_{it}^{IA} = R_{it-1}^{IA}(1-\delta_{IC}) + N_{it}^{IA},\ R_{i}^{IA}(0) = N_{i}^{IA}(0)/(\delta_{IA} + g_{IA}), \tag{2}$$

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 cost growth. We apply linear depreciation rates for IA investment that follow the literature (15% for R&D, 33% for ICT and 20% for OC). Box A.1 shows IA occupations.

We also measure public sector intangibles that form a nucleus for intangible commons that are an indispensable part of growth and innovation for the economy as a whole. Intangible commons depend on their growth in positive network externalities, interoperability (e.g., through norms and standards), flows across economies, and investment in public infrastructures that builds up capabilities. Additionally, here, intangibles are evaluated from innovative work done in the general and municipal administration, health and education sectors.

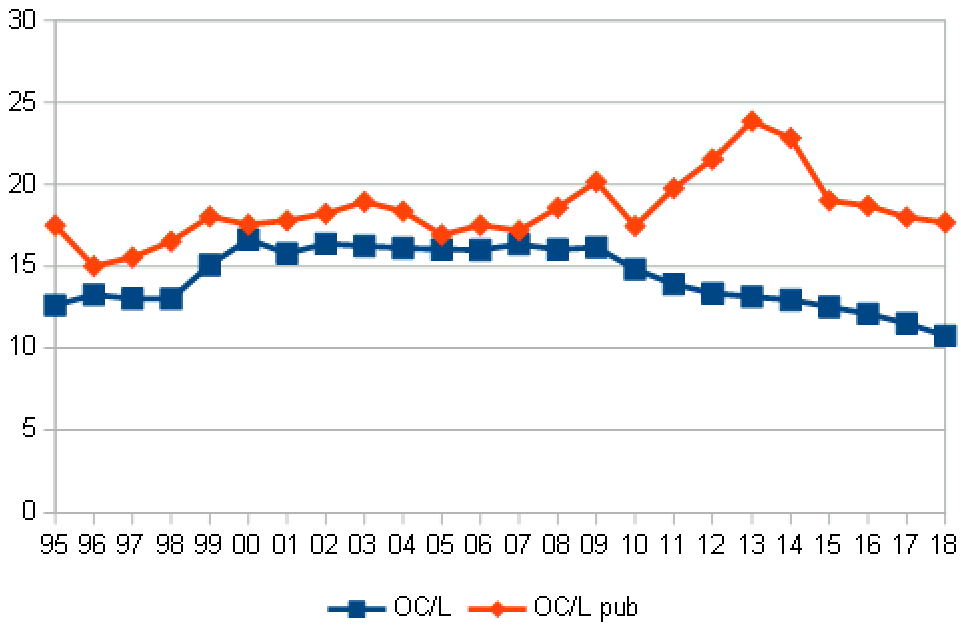
We limit our sample to firms with at least 5 employees on average divided into nine groups differing by technology level. Figures 1 and 2 compare intangible intensities between private and public sectors in Finland (this comparison includes all private sector). These are obtained by summing up intangibles and the number of employees and calculating the ratio. The public sector here includes firms that are public, which includes all nonprofit firms owned by the state or municipalities. The private sector employs approximately 690 thousand employees. Private firms in health and education industries employ approximately 300,000 employees that could also be considered to be related to services under close regulations and public authority control. Figure 1 shows R&D (capital stock) per employee in the private and public sectors.

Figure 1. R&D per employee in private and public firms



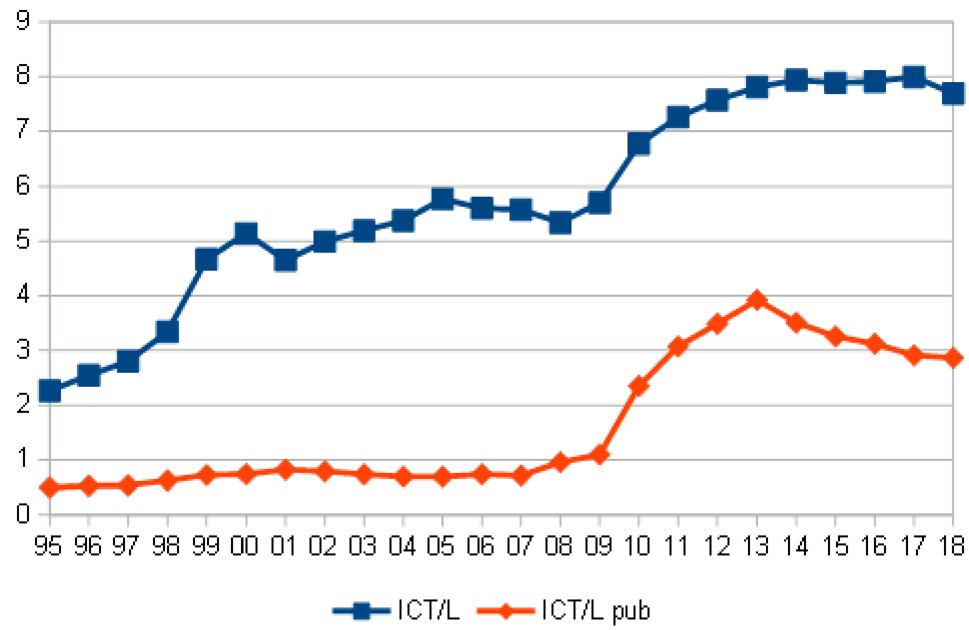
The public sector share of total employment is 50%, while the share of public sector units from all firms is tiny, just 0.4% in our data, and only covers firms with at least 5 employees. Public discussion has expressed concern about the decrease in R&D, but the decrease in broad R&D here is relatively small in the private sector. In private firms, the R&D stock per employee is on average 45 thousand € per employee (in 2015 prices). There is, instead, a clear decrease in R&D per employee in public sector firms since 2013, after the long trend of increasing R&D intensity. In public firms, R&D intensity reached close to 40 thousand € per employee, but it almost halved in just five years. The following figure shows the development of OC (capital stock) per employee.

Figure 2. OC per employee in private and public firms



OC intensity in private and public firms was fairly the same at approximately 15–17 thousand € until 2009. OC intensity increased to its highest level in 2013, after which it returned to its original level. The private sector instead shows a steady decrease in OC intensity since 2009. Given the importance of management and marketing in innovativity and branding, this decrease to all time low levels is not to be ignored. The following figure shows ICT per employee over time.

Figure 3. ICT per employee in private and public firms



Private firms increased their investments in ICT in 1998 in the wake of the technology hype at the end of the 1990s. A second jump was observed after the financial crisis, followed by the public sector. ICT intensity is more than twice as low in the public sector as it is in the private sector. Naturally, the public sector can benefit from the scalability of ICT as units are higher. However, quite opposite to expectations, ICT intensity in the public sector has been decreasing since 2013.

Table 5 goes back to the private sector only and to the narrower coverage (excluding 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 non-profit sectors (Nace Q, S, T, U, X). Table 5 shows the evolution of IA work over time after assuming again the innovative work share to be 40% for OC-, 70% for R&D- and 50% for ICT-workers.

Table 5: Intangible 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 approximately 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 6 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 6: 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). Intangibles also create technical change and create markups, where the order does not follow the intangible intensities. As we shall see, Finland will turn out to be the leading country among the four in these dimensions.

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 and R&D as well as branding such as advertising. It can roughly said that OC is about third of R&D. However, we will show that technical change created by OC can be of the same magnitude as by R&D, as is the case for Denmark.

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). Such studies often rely on industry or country-level data and the broader definition of economic competencies as in Corrado et al. (2005). Our analysis also ignores purchased intangibles and some minor component in innovation property measure in statistical offices such as mineral exploration and literary and artistic originals. 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€.

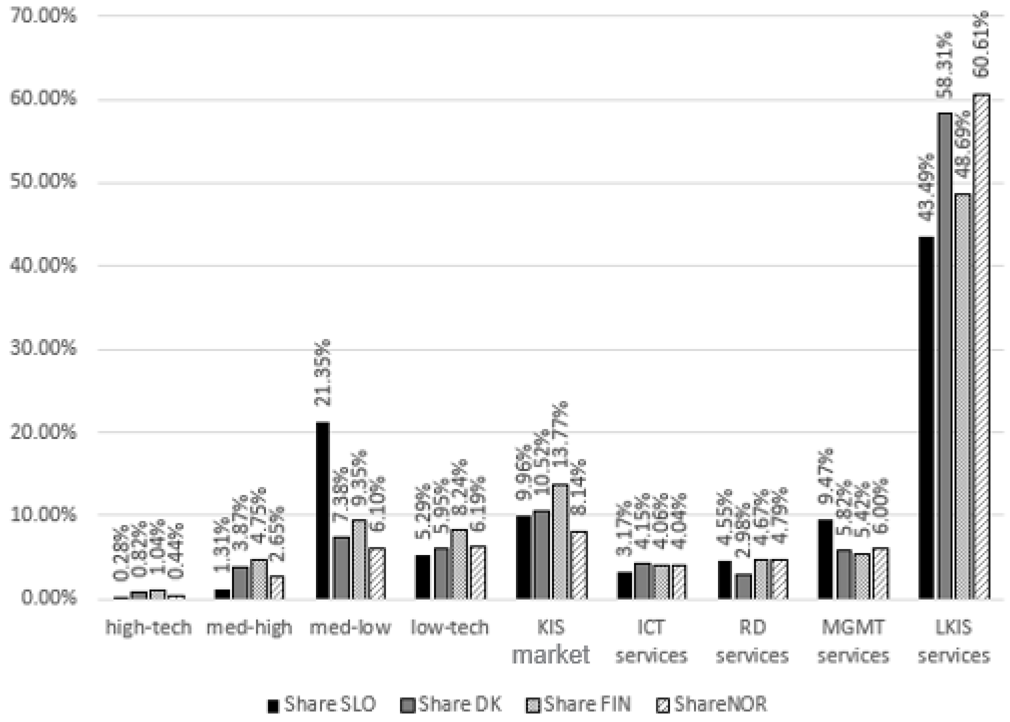
We have already observed in Table 2 the decreasing share of R&D workers in Finland. Thereby large structural changes in Finland have created shockwaves, where a large part of intangibles have been misallocated to wrong sectors. The occupation classification has been also less consistent over the years 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.

Next, we consider industries by technology type, following OECD classifications, the KIS typology and other services. KIS is further divided into market, ICT, R&D and OC KIS industries (industries by technology type are reported in greater detail in Appendix Table A.1). The three Nordic economies (Denmark, Finland and Norway) have high shares of KIS market firms and high-tech and medium-high tech manufacturing firms, compared with Slovenia with their share of medium-low tech manufacturing firms. In Finland, KIS market firm shares (other than related to R&D, ICT or OC) are 13.8% of all firms, followed by Denmark with 10.1% and Norway with 8.3% (in the latest year in the 2016–2019 period). However, the share of KIS firms (OC, R&D, ICT) in this study is fairly equal across countries. In Finland and Denmark, high-tech manufacturing firms represent approximately 0.8–1% of all companies. There is almost a 5% share of medium high-tech firms in Finland compared with 3.8% in Denmark, 2.6% in Norway and only 1.3% in Slovenia.

Figure 4: Nordic and Slovenian firms by technology type, % of all (Piekkola et al., 2021b)



The micro approach in Globalinto, and in previous projects by Hannu Piekkola, measures intangibles at the firm level that cover organizational (management and marketing) capital and information and communication capital (ICT). This is made possible by measuring innovativity from intangible work-related occupations. In Finland, over 80% of firms with at least 10 employees are thereby engaged in innovation activity of some sort. In the micro approach of Globalinto, all four partners have remote access to the Statistics Office's full data on employees and firms in the respective economies. The partners are the University of Vaasa, the University of Århus, Statistics Norway research department and the University of Ljubljana.

3. Technical change

New technologies are complementary to intangible work. A general important policy question at the European level is how productivity growth can be improved through various innovation policies. Globalinto has developed a unique way to measure technological change through innovation-labor-biased technological change (IBTC), which is analogous to skill-biased change (Piekkola, 2020).

Brynjolfsson et al. (2021) find 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 a longer time so that the hidden intangible stocks generate measurable output. Productivity slowdown associated with new revolutionary ideas in Brynjolfsson et al. (2021) is considered a "pause," given the time delay between radical technologies being developed with abundant use of intangibles. We, however, find no direct evidence of such postponement, as firms are in different stages of technological adoption.

David (1990), Allen (2009) and Bresnahan (2010) consider ICT to be a general-purpose technology, but it would also require the accumulation of knowledge before implementation. Technical change is considered to be driven especially by the structural capital of the firm, such as innovative work related to R&D and OC. OC work is important because it is oriented toward the quality, innovation and care of the environment (F-Jardón and Martos, 2009). Bresnahan et al. (2002) indeed combine organizational change with ICT use to create product innovation at the firm level. Organizational innovations have a direct effect on productivity, create lead times, and improve flexibility (e.g., Womack et al., 1990; Hammer and Champy, 1993; Goldman et al., 1995), and marketing innovations are bound to these innovations (Greenan and Guellec, 1998, Mohnen and Hall, 2013).

Such an approach, including both R&D and OC work, fits with technological change considered as potential for "the reuse of existing innovations in new areas", as this depends on the degree of quality of innovation work. Piekkola (2020) invented innovation-biased technical change (IBTC) with such broad measures of intangibles as controls. Technical change through IBTC depends not only on the recruitment of intangible workers (Ilmakunnas and Piekkola, 2014) but also on their quality. Piekkola (2020) shows that innovation-biased technical change and related intangible commons remain important productivity growth factors that, overall, do not fluctuate in the rapid way that value added per labor does. Quality of labor creates a constant source of new innovations and growth, even if the adoption of any single new technology may take time. Intangible work, however, varies over time.

Piekkola (2020) argued that public policy should, in addition to technology policy, account for R&D-IBTC and OC-IBTC and related knowledge spillovers in industries, while OC-IBTC is most important among SMEs. We use the preferred method. Empirical modeling is refined and extended to include Denmark, Norway and Slovenia (Piekkola et al., 2021a). Quality is first proxied by the relative compensation for innovation work, but the real returns are driven by production function estimates at NACE 3-digit levels. Such an approach is important, as intangible capital accumulation should, in the longer term, lead to diminished returns unless the innovation-labor quality is continuously improved.

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 also needed to estimate markups proxied for the output of flexible labor, which excludes intangible work that 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. Previous definitions of homogeneous labor, such as blue-collar work, do not easily extend to services. Relative returns and output elasticities to employees are needed to evaluate IBTC. The labor excludes the part of IA occupation work going to IA investment. We exclude it in the evaluation of both IBTC and markup (in the next section), since omitting intangible work from flexible work also has some econometric merits. 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. 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 $A(L_{OC}, L_{RD})$ measures the relative quality intangible work (set at one for markup estimation), R_{it}^{IA} refers to the sum of capital stocks of intangible assets of type IA=OC, R&D and ICT, K_{it} is tangible capital using, again, the perpetual inventory method from investment in machinery and equipment (with 5% depreciation for machinery and equipment and 13% for buildings), and e_{it} is an error term. The measurement of IBTC and markups uses total intangibles since R&D, OC and ICT are highly correlated. Controlling for IBTC and markups would fairly closely imply constant returns to scale (Piekkola et al., 2021a). The production function is also assessed separately by the leading 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 (1) 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 the two-digit level and year) and all intangible and tangible assets are considered together as total capital. This share is an appropriate proxy for measuring the quality of intangible workers relative to other workers when the shares are small; hence, nonlinear estimation need not be done from

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

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

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 (subindex for firm *i* is not shown here), and $L = L_Y + L_{RD} + L_{OC}$ is the total labor force including the labor input in intangibles. The logarithmic approximation of quality A is $ln\left((a_{Rt} / \bar{a}_{Lt} - 1)L_{Rt} / L_t + (a_{Ot} / \bar{a}_{Lt} - 1)L_{Ot} / L_t + 1 \right) \approx (a_{Rt} / a_{Lt} - 1)L_{Rt} / L_t + (a_{Ot} / a_{Lt} - 1)L_{Ot} / L_t$ 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. The production function estimation is then used to revise the initial figure. The idea is that a coefficient of total labor b_L lower than the coefficient for the quality estimate (that should be the same) implies that the relative productivity of intangible work must be revised up from $b_{IBTC,IA}(w_{IAit} / \bar{w}_{Lit} - 1)L_{IA} / L = b_L(\hat{a}_{IAit} / \hat{\bar{a}}_{Lit} - 1)$, where $b_{IBTC,IA}$ is the coefficient on relative wages $w_{IAit} / \bar{w}_{Lit} - 1$ and b_L on flexible work.

IBTC estimation applies simple OLS over approximately 170 Nace 3-digit industries. These estimations include year dummies but not industry dummies. OLS estimation is considered sufficient since, within specific industries, year dummies control productivity shocks, and R&D and OC activity vary fairly little over economic cycles (here, it is found that IBTC did not decrease in the financial crisis period very much). An important part of the applied approach is to check for outliers since the wage ratio can vary from zero to infinity. In addition, in small firms, R&D workers are not necessarily better paid, in which case these observations with relatively lower R&D wages are ignored. In addition, for some firms, we observe that intangible capital workers are paid less than average workers are, 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.

The following table shows the results and summary for Finland in the estimation period 1995–2018.

Table 7. IBTC-estimation summary for Finland 1995–2018

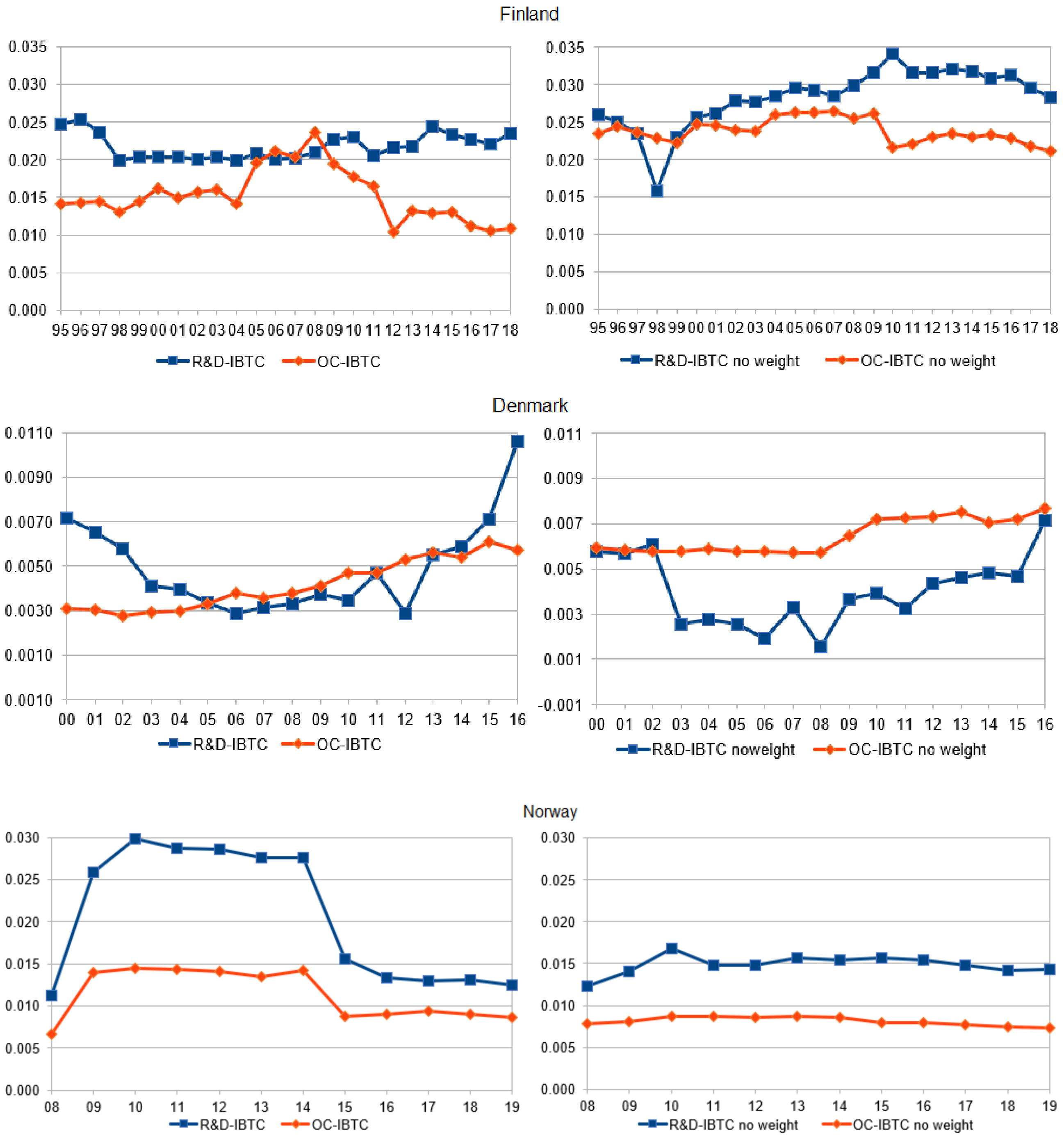
Variable	Mean	Median	Std	N
Value added/L	81.2	58.7	531.0	530155
Employee	38.4	11.0	227.0	530155
OC/L	31.5	17.9	67.3	192193
R&D/L	54.2	30.8	146.0	305665
ICT/L	17	5	66	82718
Total Capital/L	247	127	1226	530155
Output elasticity of employment (excl. IA work)	0.76	0.80	0.14	530155
Output elasticity of relative quality of R&D work	0.18	0.15	0.11	530155
Output elasticity of relative quality of OC work	1.46	1.50	1.72	225718
Output elasticity of capital	1.80	1.85	0.97	131618
Initial relative quality (wages) of R&D work	1.23	1.22	0.28	225731
Initial relative quality (wages) of OC work	1.84	1.77	0.47	131618
Relative quality of R&D work	1.120	1.040	0.245	210675
Relative quality of OC work	1.180	1.110	0.263	131616
R&D-IBTC	0.028	0.004	0.063	210675
OC-IBTC	0.024	0.008	0.037	131616
R&D spillover	0.018	0.005	0.035	301633
OC spillover	0.012	0.005	0.014	190052

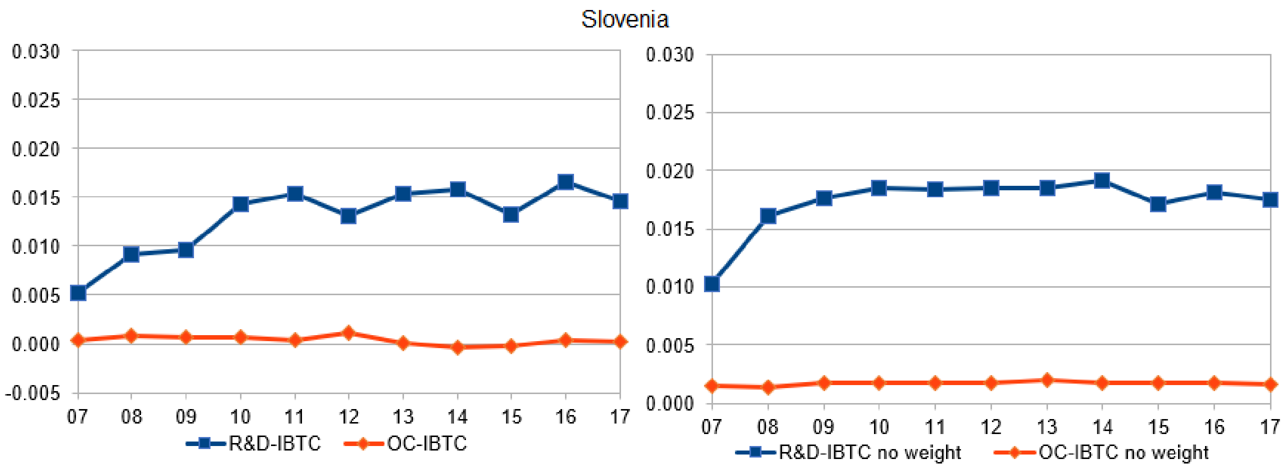
Table 7 shows that the mean average wage of R&D workers is 23% more than the average wage level in the firm, while OC workers are paid on average 84% more than average workers are. These are the initial estimates of the relative productivity differences between innovative and average workers. A coefficient of total output elasticity of labor higher than the coefficient for the quality estimate (which should be the same b_L) at each of the about 160 Nace 3-digit industries implies that the relative productivity of intangible work must be revised down. However, given that coefficients vary by 170 industries on average the true average relatively quality IA work turns out to be lower than what is the initial relative quality implied by the wage ratios.

R&D-IBTC is the result of multiplying the relatively quality of R&D minus one by the share of R&D workers. For example, in Finland the median R&D work share is 0.1. Within one standard deviation around the median the relative value of R&D work is 1.038 and the total of these two median values yield (1.038-1)*0.1=0.0038. The median R&D-ibtc in the same range is higher 0.0063 as the share of R&D and the relative value of R&D work have positive correlation of 0.33. R&D-ibtc therefore also accounts for the complementarity between the share of R&D and their relative value of the R&D work and showing evidence of increasing returns to scale in firms with high value of R&D workers.

Figure 5 shows R&D-IBTC and OC-IBTC for Finland, Denmark, Norway and Slovenia. The left side shows IBTCs weighted by turnover, which better shows the nation-wide effects on productivity and its variance.

Figure 5. R&D-IBTC and OC-IBTC





R&D-IBTC has progressed at approximately 1.5-2 per year in the countries considered, except that the technical change has been twice as low in Denmark. In Denmark, R&D-IBTC has been the lowest but increased in 2015–2016 to an amount closer to that in the other countries considered. Overall, in economies, R&D-IBTC has not been decreasing over time, so technical change has progressed as before and after the financial crises. There are thus no downward shifts in R&D-IBTC after the financial crises but rather increases in Norway and Slovenia. After the financial crises, the only significant drop is the decrease in oil prices in 2015, which is also associated with a decrease in R&D-IBTC in Norway.

OC-IBTC shows greater variation; it is in Denmark about the same level as R&D-IBTC, but twice as low as 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 attaches greater weight to the development of IBTC in SMEs. It is seen from the figures on the right that in Danish SMES, OC-IBTC plays the leading role, and Finland plays a more prominent role.

The right side of Figure 5. shows IBTC without sales weights and thus attaches greater weight to the development of IBTC in SMEs. 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. Otherwise, the figures are about the same as the nation-wide effects, expect that large firms were relatively more hurt by oil price decline in Norway on for the low-growth period 2011-2014 in Finland. Given the relatively poorer performance of large firms in Finland, the findings are still in line with Piekkola (2018) that innovation potential has not necessarily increased in recent years, especially in firms with the highest levels of R&D that are export oriented.

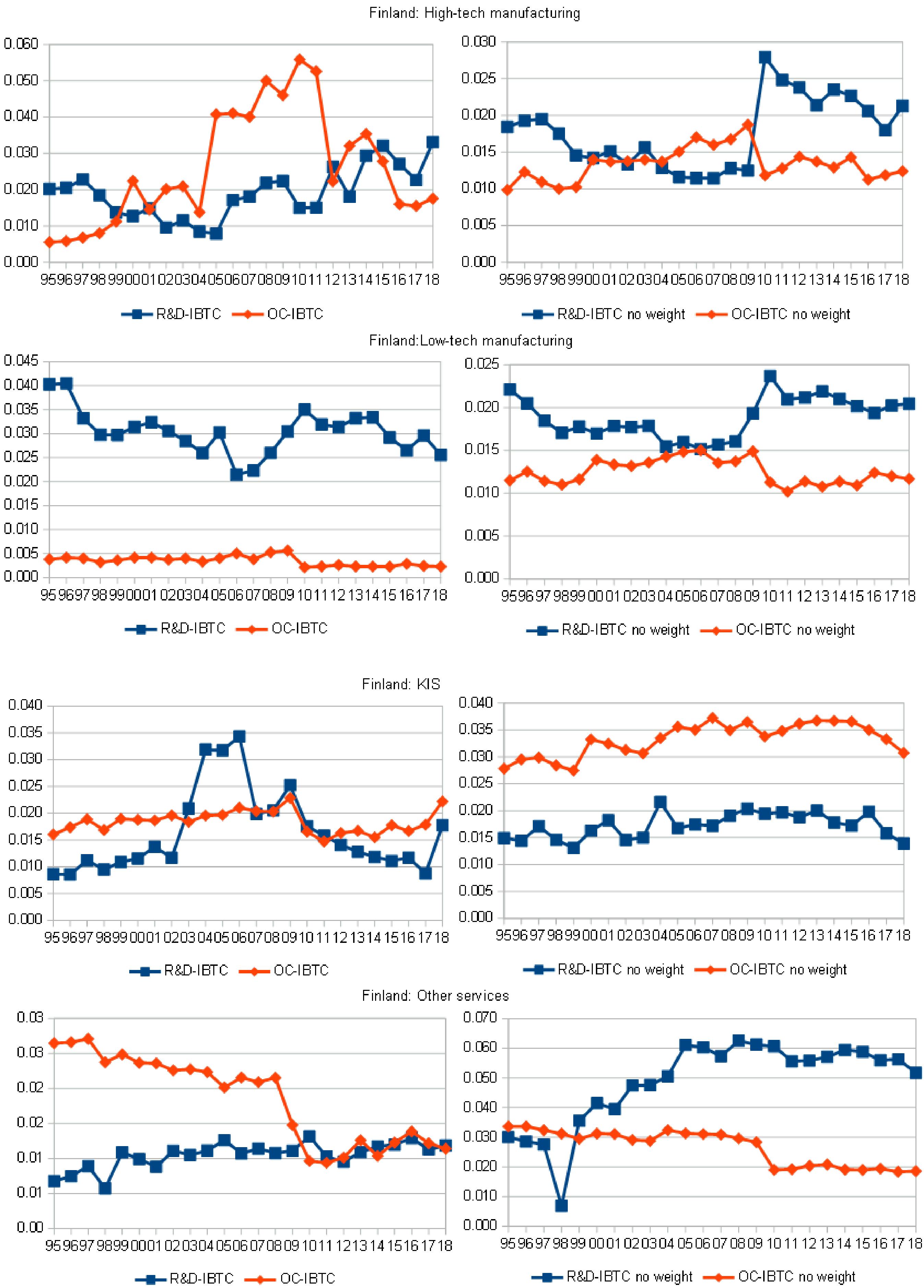
According to Piekkola (2018), OC and ICT growth has concentrated in the greater Helsinki area and in firms with already the highest OC and ICT levels. These firms are more oriented to the domestic market in their sales. The growth opportunities since the financial crises have been modest with a decrease in OC-IBTC. OC-IBTC decreased, especially in high-tech manufacturing and other services, where it previously dominated technological change before 2009. Denmark has instead seen a surge in OC-IBTC. For SMEs in Finland, R&D-IBTC without weights improved over the period until 2011, after which progress stopped. R&D-IBTC for SMEs is also larger than the average in the economy for Finland, while the opposite is true for Norway.

In Norway, data begin around the financial crises when R&D-IBTC first improves, after which R&D-IBTC is approximately 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 approximately zero for the entire period 2007–2017, while R&D-IBTC is positive and has been gradually increasing throughout the period. R&D-IBTC increased from approximately 0.12 in 2007 to 0.23 in 2017.

In Finland, OC-IBTC shows a clear decrease after the 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 using relatively lower resources.

Figure 6 below shows IBTC for Finland divided into four technology types: high-tech manufacturing, low-tech production (includes manufacturing and energy), KIS industries and other services

Figure 6. IBTC by technological type



In high-tech manufacturing, RD-IBTC has been increasing over time. The increase was notable, especially for SMEs that were better represented in the graphs without revenues as weights. We see in the later analysis that in high-tech manufacturing, markups have, instead, been decreasing over time. Relatively well-performing low-tech manufacturing has maintained approximately the same level of technical change as before, with some decreasing trend, as shown in the left figure.

KIS industries are what makes Nordic economies different from that of Slovenia, where R&D-IBTC is very low. KIS industries are the largest producers of purchased intangibles from other industries. R&D-IBTC Finland (approximately 0.15 decreasing) fare not so well in technological change driven by R&D in later years. R&D-IBTC is somewhat lower in Norway (approximately 0.8), while R&D-IBTC is increasing in Danish KIS. In Finnish KIS R&D-IBTC, 0.02 is also lower than in low-tech production (0.03).

OC-IBTC has played a significant role in high-tech and in KIS. It is seen that intangible intensive industries such as high-tech or KIS need all forms of structural capital, including OC-IBTC, to attain technological change. This is less important in low-tech manufacturing.

In other services, OC-IBTC 0.025 dominated technological change until the financial crises, but some of this may reflect a shift from OC to ICT-related work. Digitalization is particularly challenging in other services. At the same time, in SMEs, R&D-IBTC has been approximately the highest at 0.06, and organizational technical change has been at the same level as in high manufacturing. High R&D-IBTC in other service SMEs is remarkable, but the next section shows that markups have stayed at a low level. This suggests severe competition.

Appendix A Table A.2 provides an IBTC comparison of the four countries by technology type for the total economy. KIS industries are the largest producers of purchased intangibles from other industries. The GVC analysis by Tsakanikas et al. (2020) also reveals that such intangibles are especially important for the new innovativeness of firms. R&D-IBTC in Finland (approximately 0.15 decreasing) and Denmark (approximately 0.1 increasing) fare well in technological change driven by R&D. R&D-IBTC is somewhat lower in Norway (approximately 0.8). The biggest difference between Nordic countries and Slovenia is that in the latter, R&D-IBTC is close to zero or negative in KIS. IBTC in high-tech production is notably higher in Finland than in other countries, and the difference in favor of Finland is most striking in low-tech production (which includes energy). In other services, the technological change has also been approximately twice as low as that in Finland, which is approximately 0.01. It can be said that technological change has generally been higher in all technology type firms in Finland than elsewhere. It is noteworthy that markups have also been high in Finland, as can be seen in the analysis below.

For the SMEs, we saw that R&D-IBTC is faster in other services than in KIS. The same is true for Norway, although technological change is still only one-fourth of that in Finland (figures not shown). Bloch et al. (2021)

4. Markups

Intangibles cause high fixed costs and depreciate at varying rates across time and industries. The share of innovative work from all working time is also uncertain, given that this certainly depends on how broadly management and marketing occupations, in particular, are chosen to be innovative. Performance-based estimates show that expenditures and performance match fairly well, although not necessarily in high-tech industries where formal R&D may be better approximated for R&D investment, although it is highly endogenous and therefore instrumented in many studies. The performance-based estimates imply constant returns to scale and hence zero markups. For overall consistency, it is important to check what the implied markups are, how they vary over time and what their effects are on the output elasticities of intangibles. Given that this approach is interesting as such, the markups should also reflect the degree to which intangibles are firm-specific capital that creates profit opportunities for the firms.

Furthermore, the intangible work that intangible investments entail may allow firms to differentiate products and processes from competitors. Markups may reflect the degree to which 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.

The performance-based estimates above show that expenditures and performance match fairly well, although not necessarily in 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 the 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 is that the gap between productivity and employment costs of flexible workers provides a better estimate of markups than does 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 it from work that generates intangible assets, which is prominent among management, marketing, R&D and ICT work. Intangible 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) use total variable costs (labor, intermediate inputs, electricity, and others) because labor costs are not available.

De Loecker et al. (2020) find that the sales-weighted average markup in the United States climbed from approximately 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) find an increase in returns to factor inputs from 1.03 to 1.08 during 1980–2014. Another assumption in the 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 markup dimensions. The first is sales-weighted markup, and the second is the average of all markups irrespective of firm size. We argue that one apparent difference between the two is that the former gives much greater 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.

The estimation for each firm i and year t from (3) and $A=1$ in log form is provided by

$$\ln Y_{it} = \ln b_{0i} + b_{Flex} L_{Flex.it} + b_{IA} \ln\left(\sum\nolimits_{IA} R_{it}^{IA}\right) + b_K K_{it} + b_Z^{'} \ln Z_{it} + \ln e_{it} \ , \tag{6}$$

where L_{itFlex} refers to flexible workers that are other than those engaged in intangible work and estimation is done over about 63 Nace 2-digit industries. Following De Loecker and Warzynski (2012), the markup is given by

$$\gamma_{it} = \frac{b_{Flex}}{P_{it}^L w L_{Flexit} / P_{it}^L Y_{it}} \ , \tag{7}$$

where b_{Flex} denotes the output elasticity of flexible workers (non-innovative labor input) and $P_{it}^L w L_{Flexit} / P_{it}^L Y_{it}$ is the nominal share of expenditures on non-innovative labor input (i.e. labor costs net of those for innovative work in current production per value added) over nominal value added. The elasticity is in preferred case allowed to vary by time, where the elasticity of labor is calculated using moving three periods. The expenditures share of labor varies by firm. We also report the De Loecker et al. (2020) case, where all workers are considered flexible workers and ignoring broad intangible investment in value added.

Markup estimations use instrumental variable GMM regression from (6), where instruments are lagged values of the explaining variable and productivity shocks are controlled by tangible investment lagged up to the period. The estimations are made separately on approximately 90 Nace 2-digit industries in Finland over the 1997–2018 period. The preferred time-varying elasticity of labor is hence calculated by moving three periods. Expenditures' share of labor varies by firm, and the output elasticity of flexible labor varies in the 90 industries and over time.

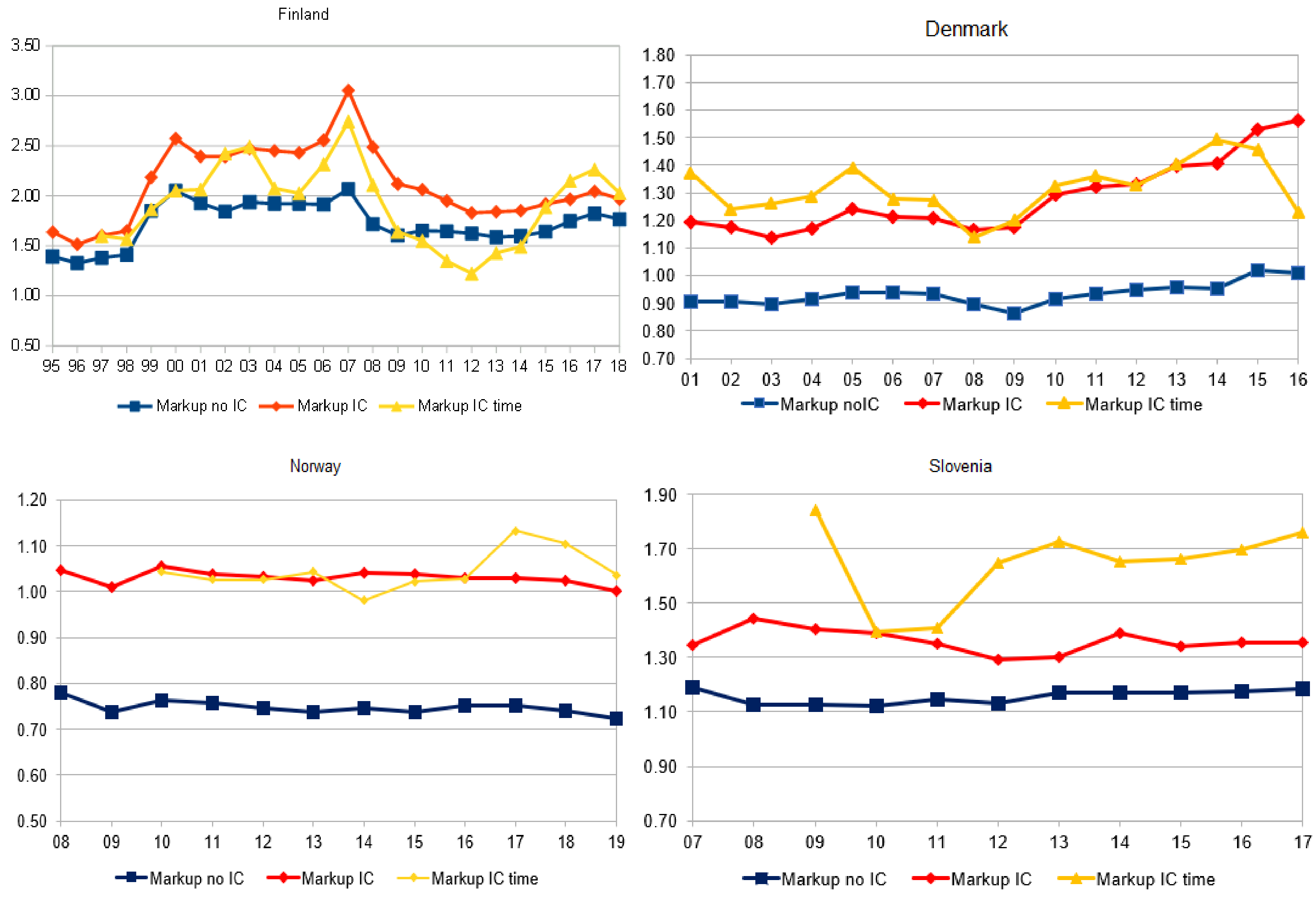
The figures below show the development of markups over time, where the time period differs somewhat across countries. Markup IC is a markup for intangible labor, while markup noIC is a markup for not excluding any IC labor costs from total costs and not including unmeasured IC investment in value added. Markup IC time has an annually varying output elasticity of flexible work, while nontime varying estimates apply for data over the whole observation period. We rely primarily on markups with flexible output elasticity of labor over time. Finland had the longest observation period beginning in 1995, while the observations for Denmark and Slovenia were from 1999–2000 and from 2008 in Norway. In the empirical estimation, we find that both market shares and intangibles increase markups. Therefore, it is clear that market forces, scaling opportunities and profits from firm-specific intangibles explain markups. While this finding is clear when comparing firms with each other, the situation appears more mixed over time.

In Finland, the results available from 1995 show that the output elasticity of labor first decreased from 64% to approximately 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 approximately 2.7 in 2007 after rapidly decreasing to approximately 1.4 in the low-growth period 2010–2011 and returning to over 2 in 2016. The volatility of markups in the Finnish economy is higher than that in other Nordic countries. De Loecker et al. (2012) instead use total labor costs and nontime varying output elasticities, which is consistent with our approach of using no account for IS, and includes deducting it from value added when calculating the labor costs-value added ratio in (10). It is seen in De Loecker et al. (2020) that by using this method, the markups would be at the same level as those observed in the U.S., which would be 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 IC investment includes value added but is excluded from flexible labor costs.

The curves of markups with and without IC are still similar in shape. Brynjolfsson et al. (2021) find 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 a 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 appear statistically at the macro level because the increase in the level of IC intensity over time in countries other than Finland has been gradual (see Table 3).

In Norway, markups remained at approximately 0.75 throughout 2008–2019 if intangibles were 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 (since it is part of total wage costs). In all countries, markups accounting for IC are above 1. Unmeasured intangibles and all intangible work should be appropriately considered to see that firms are profitable. In what follows, we concentrate on reporting markups with intangibles.

Figure 7. Markups and its components Finland, Denmark, Norway and Slovenia



“Markup noIC” is the approach by De Loecker et al. (2012) which uses total labor costs and non-time varying output elasticities. 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 preferred “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 “Markup IA time”, i.e on the markups with flexible output elasticity of labor overtime. The drift in markups (with sales weights) is particularly high with time-varying output elasticity. Markups with time-varying output elasticity of flexible work (yellow line) are above the curve with fixed values in Slovenia, whereas the opposite is the case in Finland.

In Finland, large firms suffered in the low-growth period of 2011–2014, but markups were still reasonable at 1.2. It is evident that the time-varying output elasticity of labor over time gives a better view of the profitability of firms over time. Markups accounting for intangibles first increased from 1.6 in 1997 to approximately 2.7 in 2007 after rapidly decreasing to approximately 1.4 in the low-growth period 2010-2014and to return back to over 2 in by 2016.

In Norway, the relative position differs, being below fixed values in 2014 and above in 2017–2019. In Denmark, the time-varying markup is close to those with fixed values but below that value in 2016–2017, when the time-varying output elasticity fell from the previous values of approximately 66% to 58%. Overall, it can be seen that there is no definite trend regarding whether time-varying output elasticities are higher or lower than the fixed values over time. Another finding is that Norwegian firms have low markups of just over 1, which are values that are significantly lower than those in Finland, Denmark and Slovenia.

Slovenia is the other country with relatively high markups and high volatility among large firms with time-varying markups. In Slovenia and Finland, markups with time-varying output elasticity better show fluctuations in the economy and profitability. In Slovenia, markups for intangibles decreased to 1.45 to 1.3 in 2010–2011 but returned to approximately 1.7 since 2012. The level of markups is comparable to those in Finland. Denmark also has a reasonably high and stable markup of approximately 1.3 but experienced a drop in markups from 1.4 in 2014 to 1.2 in 2016.

All of this indicates that Nordic countries, with the exception of Norway, are intangible-driven economies causing significant markups, which also explains the relatively good profitability level of the companies. In these small economies, large firms dominate, causing a large difference in GDP growth which is not only due to changes in exports but is also due to changes in markups. The latter is, naturally, to a large extent explained by changes in the terms of trade.

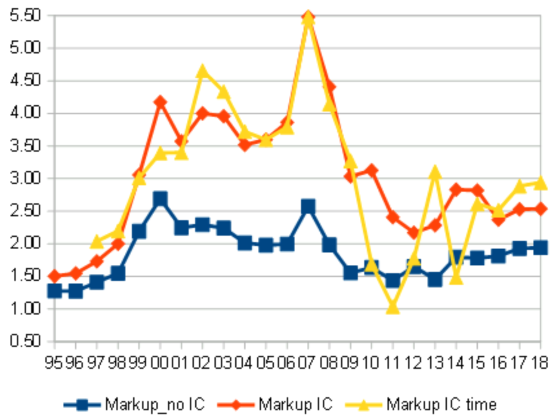
Overall, the financial crisis in 2009 was associated with strong decreases in markups in Finland until 2014 and in Slovenia in 2010–11. However, markups were not below the level in Denmark and Norway even at that time. High markups before the financial crises in Finland likely relate to the Nokia phenomenon and the relatively strong performance of the Finnish paper and pulp industry in the 2000s. However, markups recovered back to high levels in 2016–2018. It is clear that the role of manufacturing has diminished over time in all Nordic countries and that 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 not decreased since the financial crises. In addition, the decrease in oil prices since 2015 did not appear to affect the markups in the entire economy very much, which is contrary to the negative impulses seen in R&D-IBTC.

Figure 4 shows the markups in the production side. The graph shows the markups in high-technology manufacturing and low-technology production. The former includes pharmacy, computing, electronic and optimal products as the highest technology category. It also includes chemical, electrical and machinery equipment, motor vehicles and other transport. Low technology includes other manufacturing (such as oil, rubber, basic metal, metal products, etc.) and energy.

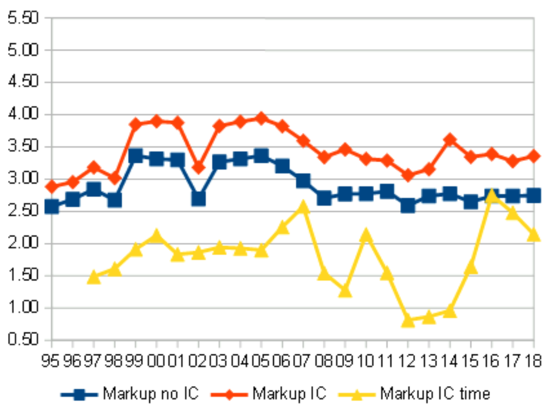
Figure 8. Markups in high-tech and low-tech production

Finland

High-tech manufacturing

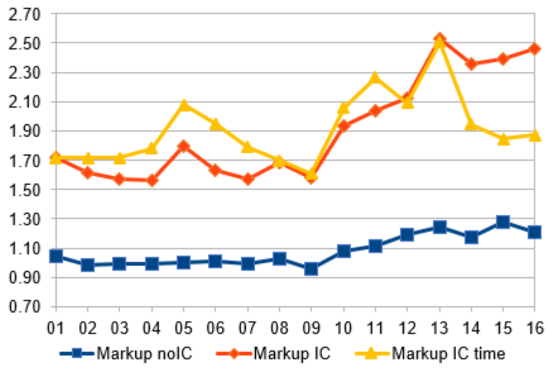


Low-tech production

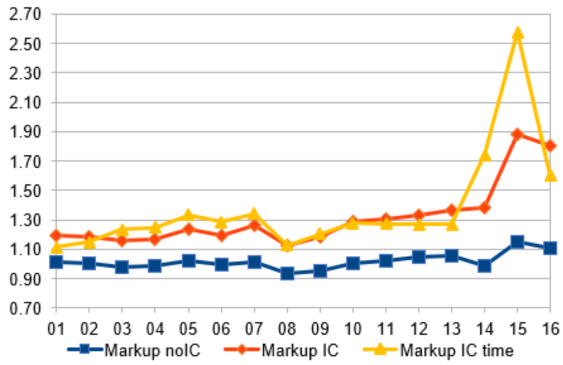


Denmark

High-tech

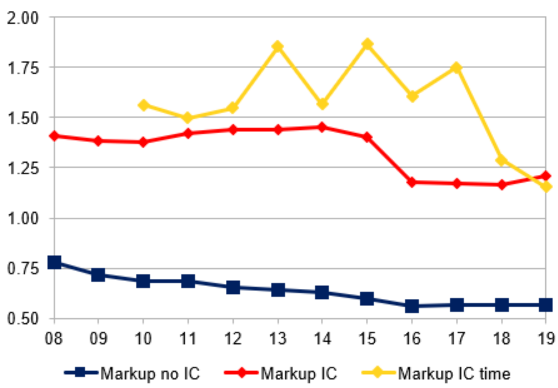


Low-tech production

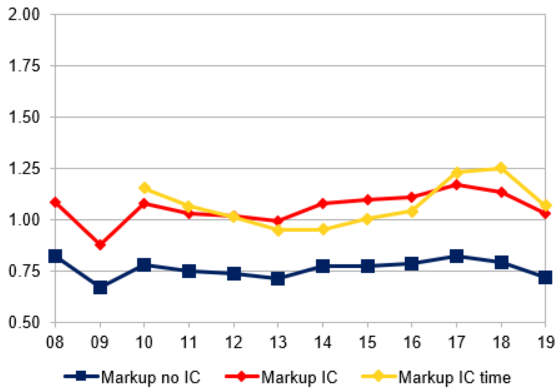


Norway

High-tech manufacturing

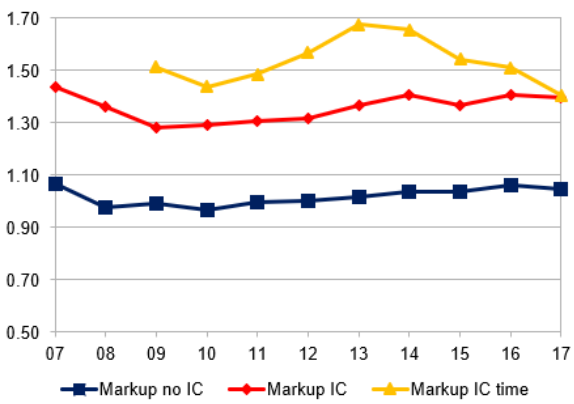


Low-tech production

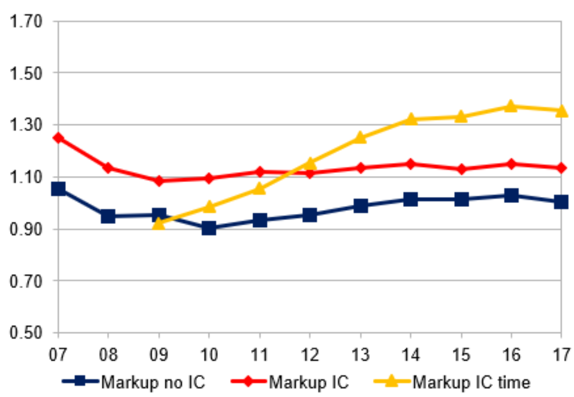


Slovenia

High-tech manufacturing



Low-tech production

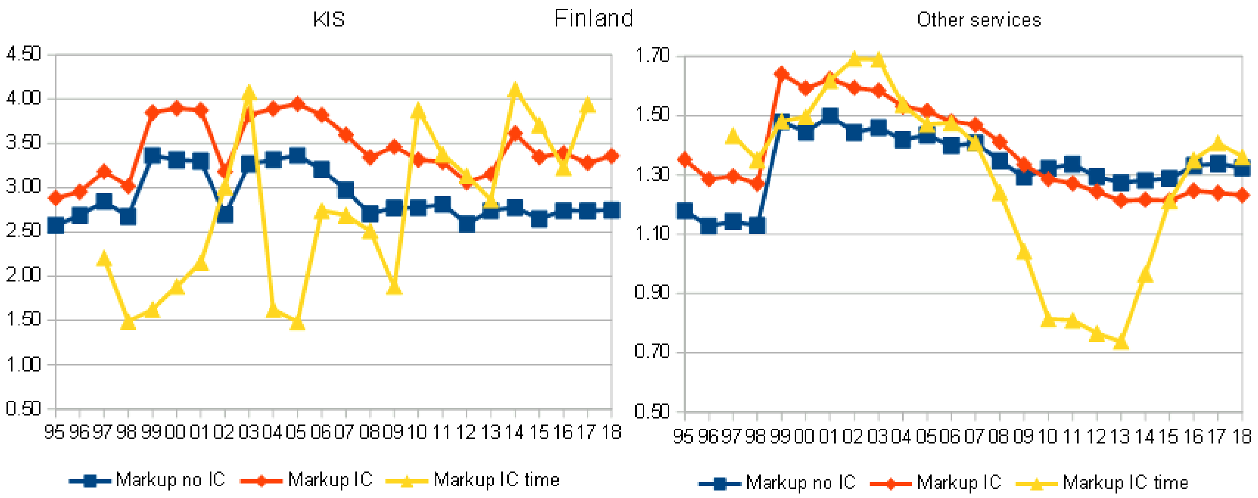


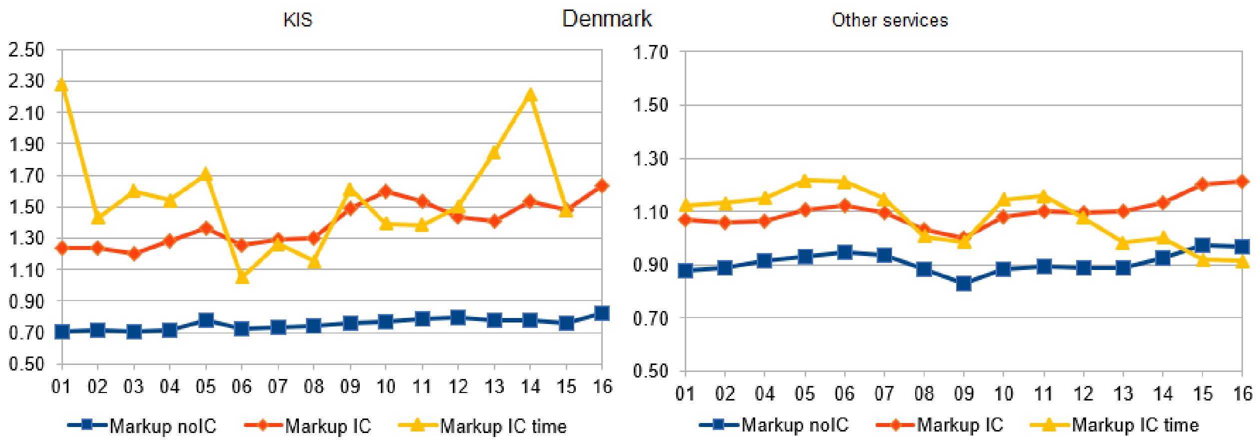
All countries have high-tech manufacturing activity with relatively good profitability. In high-tech manufacturing, we can see a huge difference between using high markups with intangibles compared with ignoring them. Intangibles thus play the largest role for markups in high tech. However, high-tech industries have experienced a decrease in markups over time, and this trend has strengthened since the financial crises. However, in Denmark, the decrease took place only after 2014. In Norway, the decrease also occurred only after 2017, which is the opposite of 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.

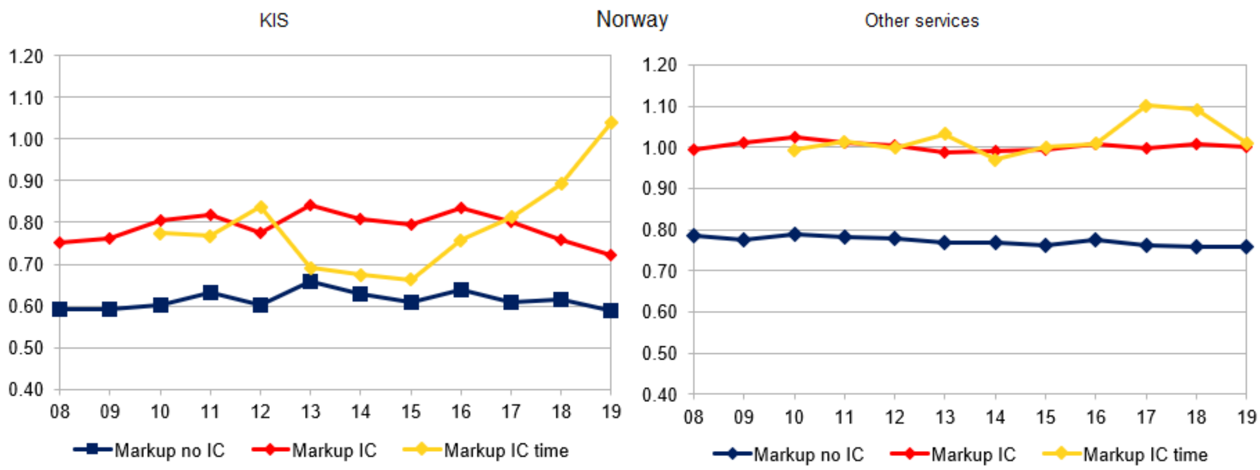
Low-tech production (low-tech manufacturing and energy) has substantially lower markups than does high-tech manufacturing. Finland and Denmark have shown an increase in markups in low-tech production in recent years. In Finland, an important part of the story is the recovery of cellulose prices in the 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.

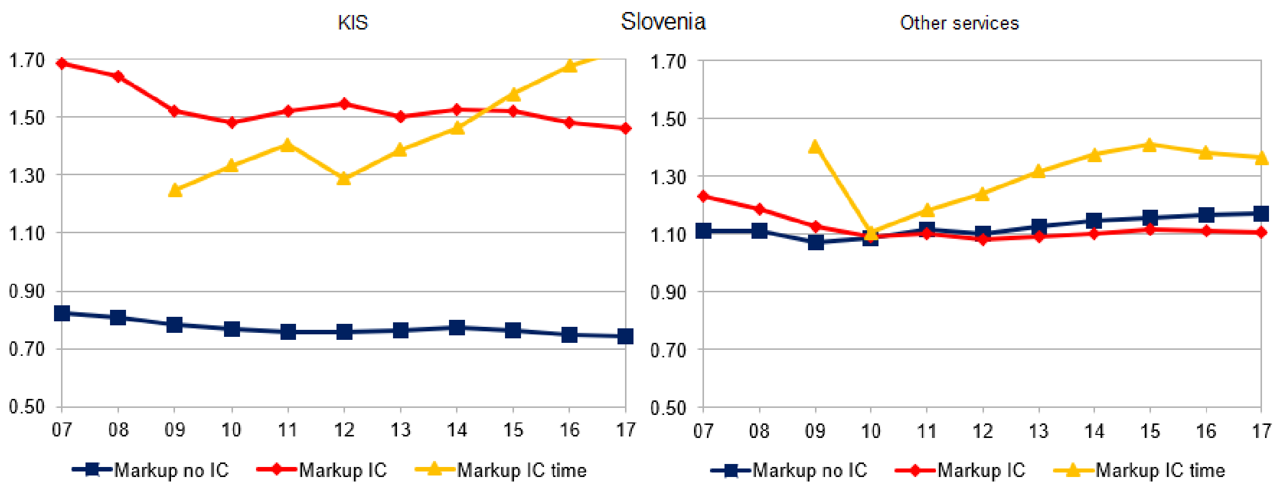
Figures below show the markups in KIS and other services. The former includes transport, publishing, motion pictures, employment activities in excess of the intangible product industry related to software, databases, consulting, head offices and R&D activities.

Figure 9. Markups in KIS and other services


Finland
KIS
Other services
Markup no IC
Markup IC
Markup IC time


Denmark
KIS
Other services
Markup noIC
Markup IC
Markup IC time


Norway
KIS
Other services
Markup no IC
Markup IC
Markup IC time


Slovenia
KIS
Other services
Markup no IC
Markup IC
Markup IC time

In KIS, the difference between markups with and without intangibles is even greater than that in high-tech markups, and graphs show the growing importance of intangibles. 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 the transfer of knowledge from declining Nokia to KIS with a consequent increase in markups. Such development leads to higher output elasticity of flexible work that explains the entire trend. However, we can also observe increasing markups over time in all the other countries.

In other services, scaling of the vertical axis is made the same across the countries to see that markups are generally highest in Finland, but they show a deep dive below one in the low-growth period of 2010–2014.

5. IBTC, innovativity and growth

The main aim of previous productivity studies has been to explain aspects of firm performance, such as total factor productivity (Polder et al., 2010), sales (Evangelista and Vezzani, 2010), value added (Battisti and Stoneman, 2010) or profitability (Cozza et al., 2012, Cho and Pucik, 2005, Prajogo, 2006). None of these papers accounts for the share of labor productivity explained by unobserved intangibles or aims to analyze the role of imperfect markets causing high markups and profitability. Earlier papers have also analyzed the total factor productivity effect from the residual of the production function, as in Añón Higón, Gómez, and Vargas (2017). Innovations associated with new technology are generally found to increase productivity (Corrado et al., 2016).

System estimation is a step further by using intangibles as inputs to new innovation, which, together with IBTC, explains the value added. The literature also finds organizational innovations to be successful responses to the efficient use of product and process innovations (Caroli and Van Reenen, 2001, Damanpour et al., 1989, Piva and Vivarelli, 2002). Our approach uses OC as input to such business innovations. Piekkola (2021) reduces analyzing product rather than process innovations because they are more likely to be radical and because process innovations have more ambiguous performance than product innovation (Hall et al., 2010). Another type of innovation is business innovations, which are a combination of organizational and marketing innovations [4]. With similar

[4] Oslo Manual defines organizational innovation as the implementation of a new organizational method in the firm's business practices, workplace organization or external relations. Marketing innovation is defined as the implementation of a new marketing method that involves significant changes in product design or packaging, product placement, product promotion or pricing (OECD 2005. Oslo manual: Guidelines for collecting and interpreting innovation data. Paris.).

Finnish data, Piekkola and Rahko (2020) find that product innovations alone, rather than together with process innovations, have the greatest effect on productivity growth.

An analogy applies between skill-biased technical change as described in Acemoglu (1998) and IBTC. A large increase in the supply of innovation workers (such as 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 innovativity and induces a change in the direction of technical progress and a shift of the relative demand curve. Therefore, innovation-labor-biased technical change will 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. The second effect is the quality-price effect, which can also first have a negative effect now affecting IBTC rather than through intangibles. The overall positive effect of IBTC comes from the long-run benefits that outweigh the first negative effects. The output elasticity of intangibles is higher due to these complementarities and because the first negative direct effect on costs is born by IBTC, which better measures marginal changes in intangible work, where intangibles have been accumulating over longer periods. Output elasticity of labor can also be lower because it formerly accounted for the markups that are now separately controlled.

The occurrence of dichotomous innovations is analyzed in Piekkola (2021) with a system of tripartite models of the occurrence of product innovations, business innovations and their relation to productivity. The method is analogous to SURE estimation accounting for the correlation of random effects and combines a probit model with analysis that explains continuous variables (Roodman, 2011). IBTC is considered part of the innovation system generating technical change. The identification conditions for innovation output require the inclusion of variables that are not used in the productivity estimation. Cooperation has been suggested as one identifying factor that explains innovation output and not productivity. Cooperation also interacts with ICT per employee when explaining business innovations. Additionally, product and business innovations depend on their primary finance, which largely uses self finance for products and debt finance for business innovations. An additional identifying variable for business innovation is its dependency on OC-IBTC. External demand shocks, such as exports, also cause exogenous variation in the inputs used in product innovations. Hall et al. (2009) instead use dummies for the presence of European, international or domestic competitors related to trade. Experiments with linear instrument estimations support all these identifying variables.

One related study by Polder et al. (2010) used a tripartite design to model R&D, OC and information and communication technology (ICT) investment in a system of three innovation output equations (product, process and organizational innovation). They find organizational investments to be important drivers of innovation (see also Bloom et al. (2013) and Syverson (2011)). Therefore, product innovations and business (organizational and marketing) innovations are studied. The value chain runs from research and development to prototyping, production, parts assembly (with their own value chains) and implementation, commercialization and marketing.

The analyses show how product and business innovations depend on innovation inputs (R&D, OC, ICT, OC-IBTC) and how innovations and R&D-IBTC improve productivity. Innovations are dichotomous variables, and business innovations are a combination of the occurrence of marketing and/or organizational innovations [5]. IBTC can affect both the innovations obtained from the Community Innovation Survey (CIS) every second year since 2000 and directly the productivity measured from LEED data in a panel for 2000–2018. The occurrence of innovations has been tracked for the past two years, so we can build a panel of the years and link this with financial accounts data. Another novelty in addition to IBTC is to evaluate missing formal R&D data regarding SMEs in ICS by predicting it by R&D evaluated from related intangible work from LEED. In the firm-level system estimation in Table 8, labor productivity growth is explained in Column 1 by product and business innovations, and in Columns 2–3, these innovation outputs are explained by intangible intensities, OC-IBTC (regarding business innovations) and average education year in the firm, among others.

Table 8. Innovation-labor productivity tripartite model estimates.

[5] In the Oslo Manual ibid., organizational innovation is defined as the implementation of a new organizational method in the firm's business practices, workplace organization or external relations. Marketing innovation is defined as the implementation of a new marketing method that involves significant changes in product design or packaging, product placement, product promotion or pricing.

	Y/L	Product innovation	Business innovation
Product innovation	0.1303**		
	(0.0473)		
Business innovation	0.1003*		
	(0.0464)		
R&D-IBTC	0.5650***		
	(0.1394)		
OC-IBTC			2.9112*
			(1.3027)
Average education	0.0857***	0.1468***	0.0672***
	(0.0061)	(0.0165)	(0.0165)
ln(R&D/L) predicted t-1		0.2265***	0.1698***
		(0.0256)	(0.0267)
ln(OC/L) t-1		0.0635***	0.0042
		(0.0134)	(0.0180)
ln(ICT/L) t-1		0.01	0.0019
		(0.0165)	(0.0167)
ln(K/L) t-1	0.0343***		
	(0.0046)		
ln(L) t-1	0.0137**	0.1615***	0.1807***
	(0.0049)	(0.0118)	(0.0119)
Debt ratio	-0.0224***		0.0059
	(0.0021)		(0.0052)
Equity ratio		0.2260***	
		(0.0468)	
Cooperation		1.1447***	0.7416***
		(0.0359)	(0.0353)
Cooperation, ICT/L		0.0224	0.0720**
		(0.0227)	(0.0221)
Export sales share		0.0144**	
		(0.0044)	
Constant	2.5545***	-3.0362***	-1.2404**
	(0.1453)	(0.3510)	(0.4123)
Log-likelihood		-24300	
Rho12		0.462	
Rho13		-0.187	
Rho23		-0.176	

Notes. 13699 observations. All estimations include year and industry dummies. Standard errors in parenthesis. *** significant at 1% level, ** significant at 5% level, * significant at 10% level.

The Wald test of exogeneity rejects the null hypothesis of exogeneity (rho12 = 0, rho13 = 0, rho = 0); thus, the error terms in the probits of product and business innovations and random effects estimates of productivity are correlated. Fifty-one percent of firm-year observations have product innovations, and their occurrence is explained both by R&D and OC intensity. In product innovations, the 23% coefficient for R&D intensity follows those found in the previous literature (see Hall et al. (2010)) [6].

[6] However, the following articles found no relation between R&D and innovative sales for UK business services: LOVE, J. H., ROPER, S. & BRYSON, J. R. 2011. Openness, knowledge, innovation and growth in UK business services. *Research policy*, 40**,** 1438-1452. and ROPER, S., DU, J. & LOVE, J. H. 2008. Modelling the innovation value chain. *Research Policy*, 37**,** 961-977. for productivity of manufacturing firms in Ireland and Northern Ireland and WADHO, W. & CHAUDHRY, A. 2020. Innovation Strategies and Productivity Growth in Developing Countries: Evidence from Pakistan. GLO Discussion Paper. for productivity growth in the Pakistani textile and apparel

Business innovations and product innovations increase labor productivity with a 13% coefficient for product innovations and a 10% coefficient for business innovations. Product and business innovations are interrelated, given that they are all enhanced by similar types of intangibles.

Fifty-five percent of firm-year observations have, on average, business (organizational and marketing) innovations, and their occurrence is also explained by R&D intensity with a coefficient of 17%. OC intensity has lower coefficients of approximately 6–7% for the occurrence of product innovation but, surprisingly, is insignificant for business innovations. Entrepreneurial effort may be replaced by professional management that is more interested in following profit margins than in fostering innovation (Adams and Brock, 1986, Graves and Langowitz, 1993). There is a risk of replication of information in the absence of centralized management (Greenan and Guellec, 1994). However, OC-IBTC is a good proxy for technology that increases business innovations.

Turning back to the main productivity equation, R&D-IBTC is an important factor for labor productivity improvement, with a coefficient of 56.5% in the system analysis in Section 5. It is thereby seen that qualitative improvements in R&D innovative activity is important for productivity improvement. R&D-IBTC seems to also create spillovers and cannot be linked entirely with the avoidance of "stepping on toes". While R&D-IBTC was an important driver of labor productivity, OC-IBTC has a significant positive effect on business innovations and thereby only indirectly increases productivity. The insignificance of OC-IBTC in directly explaining productivity relates to the heterogeneity and nonlinearity of the effects, as Piekkola (2020) shows that it is most relevant for SMEs. In general, the avoidance of "stepping on toes" is valid, so qualified innovation workers are needed to maintain a high pace of new innovations.

Human capital (average education years in the firm) has a positive effect on both product and business innovations and on productivity. St-Pierre and Audet (2011) find that SMEs rely on knowledge or the human capital of employees and customer relations and thus on informal organization so that the results should also apply to a large set of firms.

Cooperation increases the occurrence of innovations, and its interaction with ICT intensity is a significant factor for business innovations. Firms with a large ICT intensity exploit their better network connectedness (cooperation is twice as likely for large firms than for small firms). ICT is considered vital for information dissemination, which can improve relational capital and trust and can support the collaboration of dispersed groups (Cabrilo et al., 2020, Adamides and Karacapilidis, 2006). Therefore, ICT services and related development complement the general operations of the firm. As discussed, SMEs also have to invest relatively more in ICT per employee (ICT per employee is twice as high as that for large firms with market share over the median in NACE-3-digit industries).

manufacturing sector. Love et al. (2011) and Roper et al. (2008) instead found a positive and significant impact of product innovation on sales growth.

Bjørkholt et al. (2019) find that SMEs with high network connectedness through board members are also R&D intensive.

Managers may also prefer to look at sales and profits rather than engaging in new risk-taking in the introduction of new products. A higher equity ratio increases the occurrence of product innovation, while business innovations rely more on debt finance, although the coefficient is ambiguous. However, the amount of debt finance is negatively related to productivity.

In a small open economy, such as Finland, all export activity should be driven by intangibles, leading to a high rate of domestic product innovation. Exports per sales have a positive effect on product innovations even after controlling for intangibles; hence, exports necessitate new product innovations. Finally, firms with a larger size (number of employees) tend to have higher productivity, which is also backed up by the higher occurrence of innovations. We can summarize our results as.

- Structural capital (R&D and OC) increases innovativity and productivity growth is valid for R&D, while OC increases innovativity. ICT also improves innovativity and complements the cooperative activities of firms.
- R&D-IBTC is an important part of technological change whose activity is in excess of that explained by general innovation activity, thus indicating no slowdown in technological change in Finland since 2009.
- OC-IBTC has a primarily positive effect through creating new business innovations, and in recent years, it has progressed at a slower rate than before, although it is still positive.

We cannot differentiate between the direct effect of R&D-IBTC on the quality of innovations and spillovers. The same is true for OC-IBTC although less “stepping on toes” and improved quality of organizational workers is very important for business innovations. Some of the investments in management and marketing can just increase bureaucracy.

7. Conclusion

The puzzle of productivity slowdowns explained by the slower pace of technical change is not supported by any major shift in R&D-IBTC after 2009 in Finland. It can be said that technological change has generally been higher in all technology type firms in Finland than it is in the other Nordic countries considered and in Slovenia. It is noteworthy that markups have also been high in Finland. R&D-IBTC is an important factor for labor productivity improvement, with a coefficient of 56.5%. It is thereby seen that qualitative improvement in R&D innovative activity is important for productivity improvement, which is the second most important outcome of the analysis in addition to a lack of slowdown in R&D-IBTC.

In Finnish high-tech manufacturing, RD-IBTC has been increasing over time from 0.02 in 1995 to 0.03 by 2018, and the share of high-tech firms of all firms—approximately 14%—is higher than it is in the other countries considered. The increase has been notable, especially for high-tech SMEs. In high-tech manufacturing, markups were relatively low in the slow growth period of 2010–2014, explained to a large extent by the downsizing of Nokia operations in Finland. Such a policy is likely to have been rational for a large multinational firm such as Nokia, since such firms were in short of highly skilled engineers during the 2000s to compete with Apple in handphones, which has access to a much larger innovative workforce of California's Silicon Valley [7]. However, even during this period, markups were equal to or exceeded those in Denmark, Norway and Slovenia. Relatively well-performing low-tech manufacturing has maintained approximately the same level of technical change as before, with some decreasing trend, as shown in the figure on the left.

KIS firms comprise approximately 14% of all firms with at least 5 workers (approximately 10% in Denmark; Norway and Sweden are above this). Knowledge intensive services have also progressed well with value added growth rate of 5.7% in recent years (2016-2019) and at rate of 3% since 2001 (respective figures for private sector growth are lower 1.7% and 2.5%). Finland is surely behind Sweden in digital services, but we find no evidence for backwardness in respect of other Nordic countries Denmark or Norway. KIS industries are what makes Nordic economies different from those of Slovenia, where R&D-IBTC is very low and has been shown to include types of firms that have been doing relatively better in the U.S. than in Europe. In Finnish KIS, R&D-IBTC is 0.02, which is still lower than in low-tech production (0.03). OC-IBTC has played a significant role in high-tech SMEs, especially in Finnish SMEs in KIS, where its value of 0.03 is double that of R&D-IBTC. It is seen that intangible intensive industries such as high-tech or KIS need all forms of structural

[7] Such a view is also supported by the interview of the CEO of Nokia Olli-Pekka Kallasvuo during 2006–2010 in Helsingin Sanomat newspaper, September 26, 2021.

capital, including OC-IBTC, to attain technological change; in this regard, Finland is performing relatively well.

In high-tech and other services, OC-IBTC 0.025 was the dominant form of technological change until the financial crises (for high-tech in the seven-year period 2005–2011 and for other services until 2009). However, in SMEs, R&D-IBTC has been approximately the highest at 0.06, and organizational technical change has also been at the same level as that in high manufacturing. However, thus far, this high investment in technology change has not materialized in higher markups, although we know that the service trade imbalance has been improving in recent years, where KIS also plays an important role.

Our system estimation implies that OC intensity is a worse proxy of business innovation input than OC-IBTC is. In principle, there should be some scalability of OC investments so that large firms need to invest in less organizational change, while OC-IBTC is always welcome. One possible explanation may also be that OC-IBTC has gained momentum, especially in services other than KIS, while at the same time, OC intensity is lower. Thus, cost-based measures of OC may not indicate its performance, as smaller firms may have to overinvest with high, fixed costs. It is often claimed that the bottleneck for Finnish firms is good management. Our study shows prolonged investment in OC-IBTC that may bear fruit in the future. The introduction discussed that new innovativity could first increase fixed costs before materializing in better profitability. It is clear that more attention should be paid to good management and marketing in Finland and to the different roles they play in SMEs.

8. General Policy Evaluation

Broad set of intangibles.

The former study has used a larger selection of intangibles such as R&D and organizational capital (OC), which could be extended to information and communication technology (ICT). We must also consider intangibles in a broad sense, including OC and management and marketing work-driven IBTC. The public sector employs 600,000 employees, or over 900,000 employees in a large sense, when including private sector education and health under strict public sector authority control. In the public sector, R&D intensity is 65% of that in the private sector, which is approximately 30 thousand 2015€ per employee, while public sector OC intensity is 30% higher than that in the private sector, which is approximately 18 thousand 2015€ per employee. Structural capital such as R&D and OC are shown to lead technical change, which has been pervasive, covering both SMEs and large firms in the private sector. However, we know little about intangible activity in at least 40% of the economy, namely, the public sector. Our intangible figures show that R&D intensity is now lower than that of the long-term average or those of the top figures of 40 thousand 2015€ per employee in 2011–2014.

Technical change in Finland has been considerable and has continued in the 2010s

Our interest is technological change and Globalinto has developed IBTC as a good approximation. R&D-IBTC and OC-IBTC indicate that firms have sufficient skills to absorb new technology. These measures show the significant role that the quality of intangible workers plays in productivity improvement. R&D-IBTC helps R&D efforts to avoid "stepping on toes" and shows important technological change at the industry level. The quality aspects of technological change are also continuous and not sensitive to lags in the implementation of general-purpose technologies. Innovation surveys, hence, seem to ignore an important part of the novelty of new innovations, and dichotomous measures were indeed never meant to measure the qualitative development of innovativity.

In Finland, technical change was higher than that in the reference countries of Denmark, Norway and Slovenia, and the industries suffered from decreasing markups after the recession. Large firms differ in their industries and technical change, which explains the differences in development across industries and the variation of the overall performance of the Finnish economy.

Our analysis shows that R&D-IBTC is also a very good qualitative measure of assessing technical change and its effect on value added and productivity. It also measures SMEs and microfirms well. The IA intensity effect also measures markups and pure profits generated. Piekkola et al. (2021a) show random effect estimates of the production function, including markups and IBTCs. In this context, the output elasticity of R&D, ICT and OC totals high 24%, although is a level often obtained in the national- or industry-level analysis. Even in this experiment, Finland has over double the output elasticity of IA than Denmark or Norway. Markup instead has a relatively small direct effect on value added compared to Denmark, where other IAs explain a large share of profitability. This finding is also interesting since Denmark has a higher share of R&D workers than Finland, but the R&D intensity is approximately the same. The reason is that R&D workers for firms with over 5 employees are paid on average only 20% more than the average labor costs in the firm, where in Finland, R&D workers are paid 80% more.

It is shown that product and business (organizational and/or marketing) innovations all have positive effects on labor productivity. However, new technological change can be the most important factor for growth in Finland, which has not been adequately modeled before and has not slowed down following the "productivity slow-down" when value added per employee stagnated.

There is no direct link between productivity and OC-IBTC, which has decreased since the financial crises. We also do not find a clear innovation value chain from product to organizational innovation, as observed in some of the previous literature, although as such, product and business innovations together, as in approximately one-third of firm-year observations, are likely to create better product innovations. The particular role of general knowledge such as ICT is also important, and a wider adoption of ICT is crucial, especially for SMEs in cooperative activities. Covid-19 has changed the role of digitalization. We can summarize the main results in comparison with the Nordic context and Slovenia as follows.

Technological change has been generally higher at all technology levels in Finland than in Denmark, Norway and Slovenia

a. Qualitative improvement in R&D innovative activity is important.
b. R&D-IBTC (innovation-labor-driven technological change) is an important factor for labor productivity improvement, in addition to intangible assets (IA).
c. KIS has large R&D-IBTC, especially SMEs in Piekkola (2020).
d. OC-IBTC proxies organizational change well, less so organizational capital (OC).

Changing but high markups in Finnish firms

Finnish industries faced the challenge of decreasing markups in the 2010–2014 slow growth period, a feature not found in the reference countries. In Finland, markups are driven more than in other countries by intangibles, emphasizing their important role in growth and improvement in markups.

Intangible trade for the manufacturing sectors in the EU rose in 2000–2014 independent of the financial and sovereign debt crisis. Despite cross-border trade, domestic intangible inputs are essential to innovation production, while imported intangibles and patents contribute to sectoral specialization in innovative countries such as Finland. Such value-added change also underscores the need to support intangible capital formation.

Hence, the (temporary) decrease in the unmeasured determinants of labor productivity, better known as TPF, is explained by the decrease in markup. Other factors explaining the development are opening domestic markets to foreign competition, especially due to EU membership in 1994, and some decrease in tangible investment. Dieppe (2021) indeed shows that the widespread decrease in labor productivity since the financial crises is explained equally by a lower investment rate in addition to TFP, measured as unknown factors in growth accounting.

Increasing role of knowledge-intensive sectors.

In Finland, technical change has been rapid in low-technology production and KIS, while high-tech industries have had diminished roles. Such a trend can also be observed in other Nordic countries except Denmark, where pharmaceutical industries have fared well in recent years. In Finland, the KIS industry is the largest of the considered countries and performs well. There has to be less of a decrease in the created productivity gap between U.S. and European firms, as in the rest of Europe. R&D-IBTC has been approximately twice as high in low-tech and KIS sectors as in other sectors. A major challenge for Finland is how to attract more high-tech industry to Finland in the future due to a shortage of intangible workers. In KIS industries, technical change has been rapid, but its size is smaller than in Nordic countries such as Sweden and Denmark, where KIS industries have expanded more (Bloch et al., 2021). As discussed, KIS industries are also the source for OC, ICT and innovativity. At the same time, Finland suffers from shortages of skilled labor. From the perspective of Finland, an important policy question is to further identify these bottlenecks.

Intangible commons.

The findings here have not analyzed intangible spillovers and their influence on the economy in addition to that explained by technical change. The private and public sectors can be important producers of intangible commons and are more OC intensive than the private sector is; their role in the efficiency of the economy has been little studied. Economics emphasizes the role of institutions in country-level performance, while our knowledge of public sector intangibles remains a mystery that should be further investigated. Our preliminary table in Section 2 shows that R&D intensity has been on the decline in the public sector since the financial crises. Public R&D policy should hence start from seeing the worsening state of public R&D activity, while on average the size of the public sector is massive and the number of employees is approaching that of the private sector as studied here (excluding finance and construction), at least if we also classify all education and health as ”public” (these sectors without public ownership cover 300,000 employees as compared to 600,000 employees in public firms owned by the state or municipalities).

The broader concept of intangibles also widens the policy perspective outside the territory of R&D (Globalinto Policy Brief D7.8 European Policy Brief – Intangibles and Public Policy available www.globalinto.eu). One also needs to identify the dual nature of intangibles. On the one hand, firms see control of intangible assets as essential to gaining a competitive advantage and may underinvest if this control is uncertain. On the other hand, from a systemic point of view, individual ownership of intangible assets can limit the 'intangible commons': the sharing and exchange of intangibles that are indispensable for growth and innovation for the economy as a whole. The policy toward improving the creation of knowledge spillovers in the economy and widening the opportunities for "learning by doing" through more flexible labor markets is at the core of this part of policy analysis. Intangible commons also depend on positive network externalities, interoperability (e.g., through norms and standards), flows across economies, and investment in public infrastructures that build up capabilities. Such considerations are also important for SMEs that are also more dependent on IBTC spillovers in the Finnish industry to which they belong.

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10. Appendix A. IA occupations, IBTC by technology type

Box A.1 GLOBALINTO Intangibles Assets occupations (based on ISCO08 Occupation classification)

1 Managers **112 °C** Managing Directors and Chief Executives **12 °C** Administrative and Commercial Managers **121 °C** Business Services and Administration Managers 122 Sales, Marketing and Development Managers **1221 °C** Sales and Marketing Managers **1222 °C** Advertising and Public Relations Managers **1223 R&D** Research and Development Managers 13 Production and Specialized Services Managers **131 °C** Production Managers in Agriculture, Forestry and Fisheries **132 °C** Manufacturing, Mining, Construction and Distribution Managers **133 ICT** Information and Communications Technology Services Managers **134 °C** 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	**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 °C** Finance Professionals **242 °C** Administration Professionals 243 Sales, Marketing and Public Relations Professionals **25 ICT** Information and Communications Technology Professionals 26 Legal, Social and Cultural Professionals 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

The following table shows that industries by technology type follow the OECD classification and own for KIS industries.

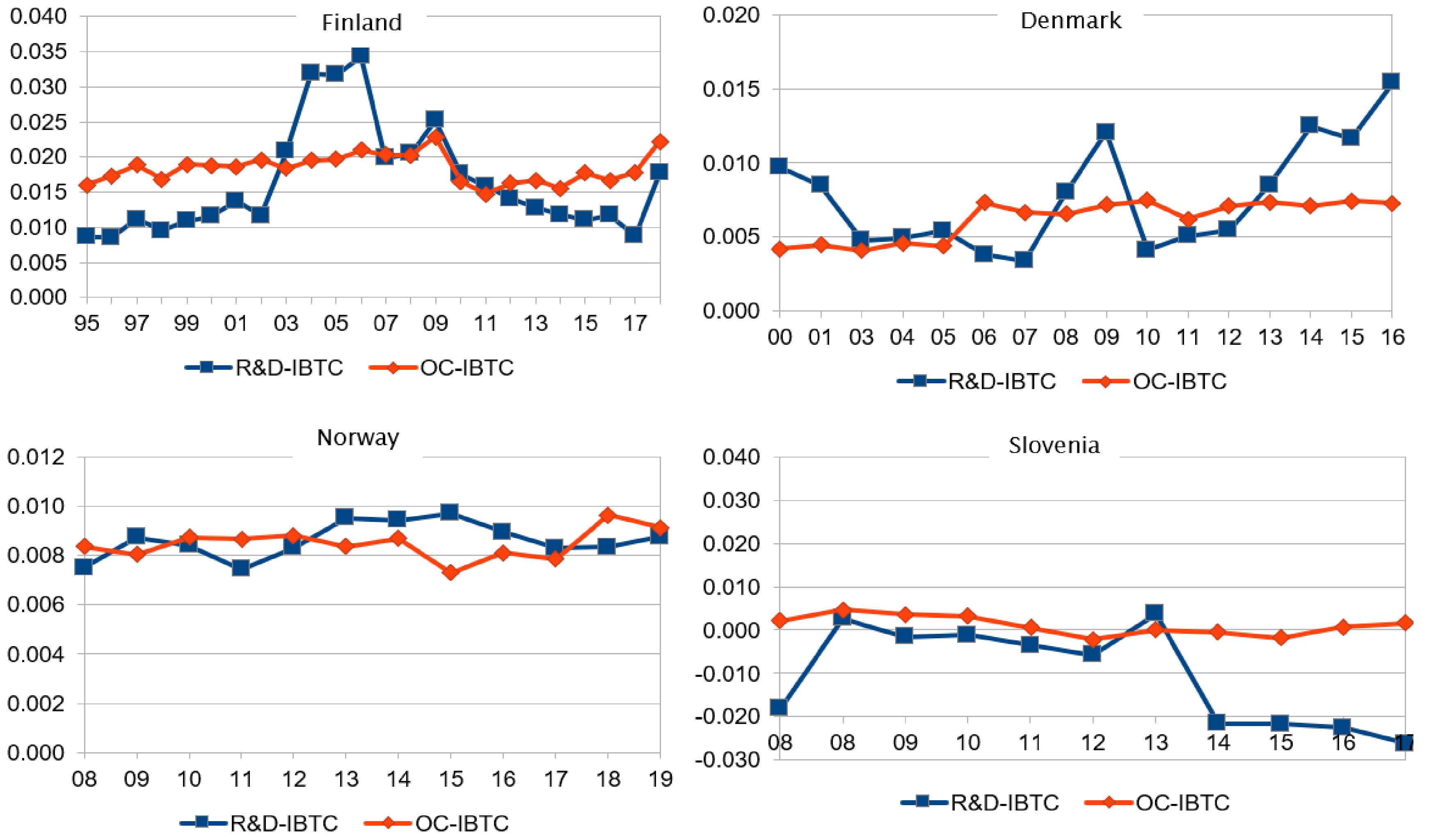
Table A.1 Industries by technology type

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

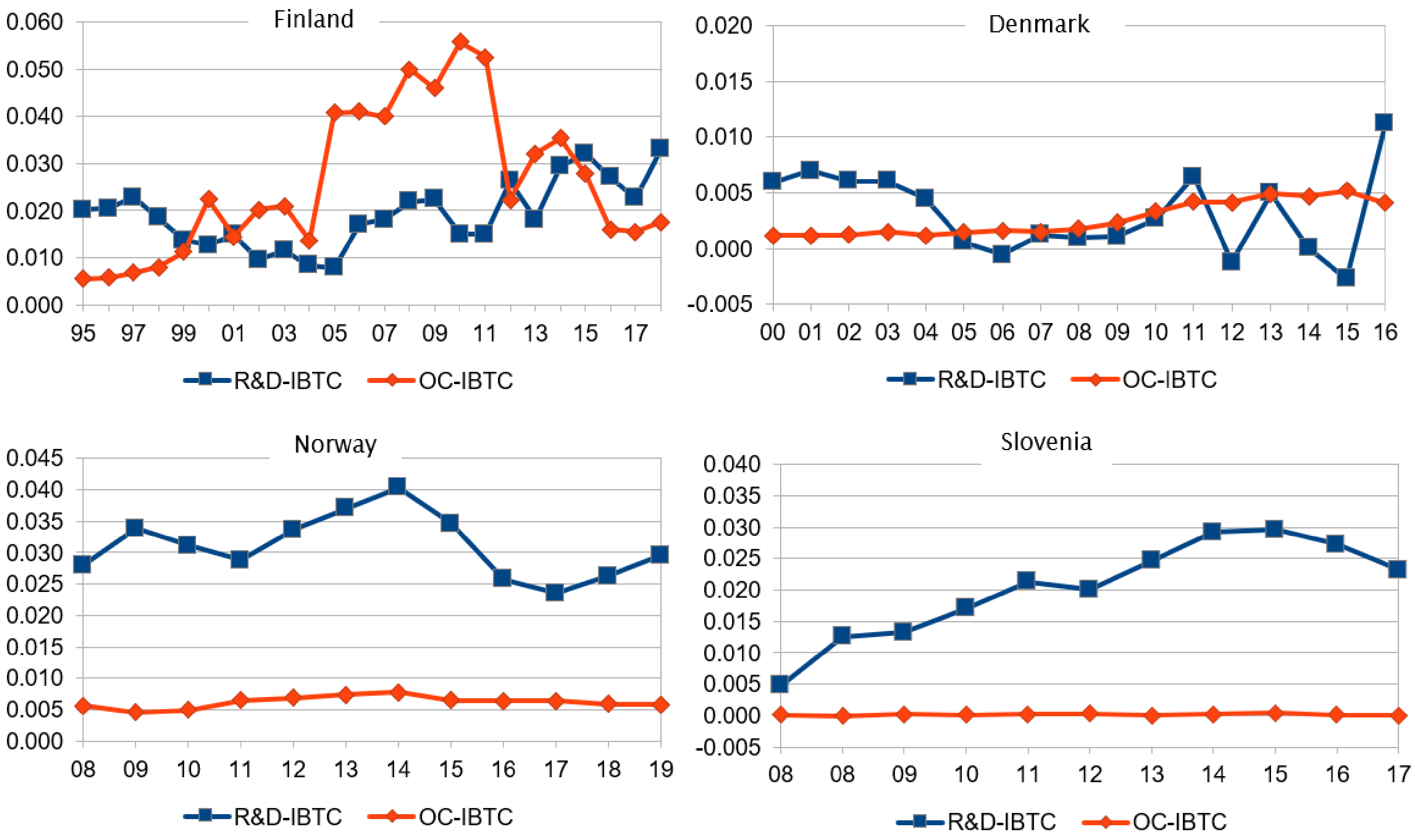
Other services	Wholesale trade 45-47, land transport 49, warehouse 52, accommodation, food and beverage 56, real estate 68	Rental and leasing 77, travel agency 79	25.9

Table A.2 IBTC by country and technology type

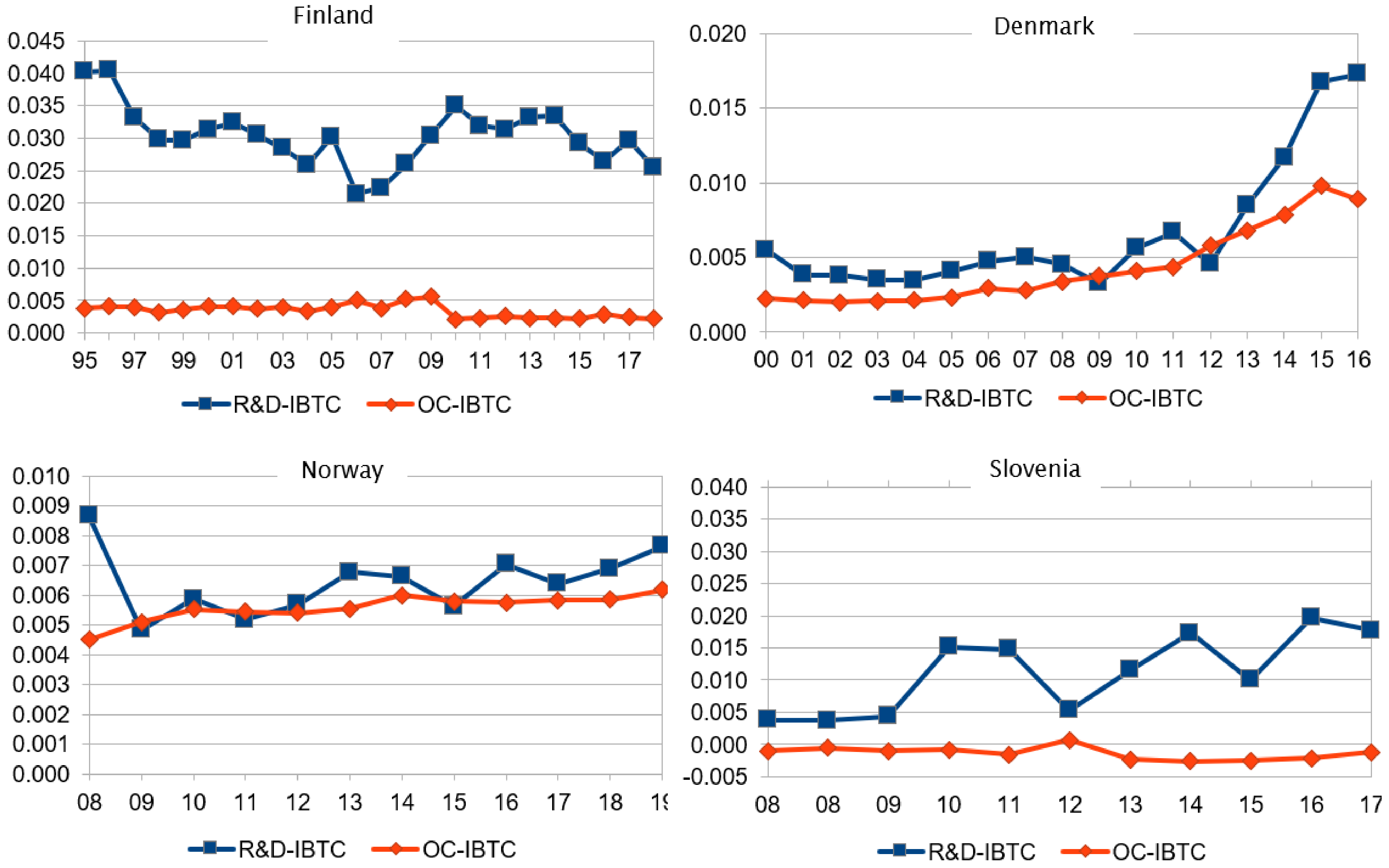
IBTC: knowledge intensive services (KIS)



IBTC: High-tech manufacturing



IBTC: Low-tech manufacturing (incl. energy)



IBTC: Other services