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# Intangibles from intangible capital work – their valuation and technological change

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# Intangibles from intangible capital work – their valuation and technological change[1,2]

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**Abstract**

Intangibles can contribute to technological change and productivity through a number of channels, among these, intangible capital deepening, improvements in the quality of knowledge assets and through innovation that allows firms to generate larger markups. This paper analyses the relationship between intangibles, technological change and productivity in four countries, Finland, Denmark, Norway and Slovenia, both for the business sector overall and for specific industry groups over the period 2000-2019. The analysis utilizes linked employer-employee datasets and an occupation-based approach to measure intangible capital work and assets, which are then used to derive measures of intangible-work-biased technological change (IBTC) with focus on R&D and organizational capital (OC). IBTC indicates technological improvement over the period, which did not slow down after the financial crises in any sectors, except for variations observed for Norway. Multi-factor productivity (MFP) that accounts for intangible capital deepening has grown moderately, while IBTC indicates continuous or increasing returns from innovations. However, most of the R&D capital work biased technological change (R&D-IBTC) is driven by large firms in manufacturing, whereas in services, SMEs are usually the technological leaders. Technological change is also broad-based as organizational capital work biased technological change (OC-IBTC) amounts to about half of the R&D-IBTC. Higher R&D-IBTC is usually associated with higher MFP and markups, while results are more heterogeneous for OC-IBTC.

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

**Keywords**: Intangible capital, R&D, organizational change, technological change, markups, productivity

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[2] Globalinto's partners involved are University of Vaasa, University of Aarhus, Statistics Norway, University of Ljubljana). We wish to thank Leonard Nakamura and Catherine Robinson for their valuable comments made at the IARIW-ESCoE Conference on "Measuring Intangible Assets and the Contribution to Growth" in November 2021 in London, and Aleš Gorišek and Daša Farčnik for their support in data preparation for Slovenia.

# 1 Introduction

Alternative views have been presented on whether the slowdown in productivity growth relates to a decrease in total factor productivity (Jona-Lasinio and Meliciani, 2018, Gordon, 2016), reduced intangible capital deepening (Goodridge and Haskel, 2022) or technological diffusion (Bartelsman et al., 2017, Andrews et al., 2015) such that real rates of return have a long run decreasing trend. As such, intangible assets have grown in importance in explaining productivity over the last 20 years, bringing a corresponding shift in overall investment levels from tangible to intangible assets. Possible channels through which intangibles can contribute to productivity may go beyond intangible capital deepening. Intangibles investments may also augment productivity contributions through improvements in the quality of intangible assets. Intangibles may also generate innovations that allow for greater product differentiation, leading to larger markups on firm costs.

This paper is one of the first measuring technological change from intangible capital work, defined as the work time involved in the generation of intangible investments, that goes beyond analysis of intangible capital deepening and uses novel ways to measure changes in the quality of intangible capital work. Our interest is in how intangible capital work and intangibles interact with technological change. We consider the relation of intangible-work-biased technological change (IBTC) as defined in Piekkola (2020) to multi-factor productivity (MFP) after accounting for both tangible and intangible capital deepening. It is also important to understand how IBTC affects markups being an important component of TFP, since perfect competition rarely applies also because intangibles cause high fixed costs. Piekkola et al. (2023) shows that R&D-work-biased technological change (R&D-IBTC) has been positive in Nordic countries also in intangible intensive and high tech industries and also organizational work has contributed to IBTC. Goodridge and Haskel (2022) instead find that the slowdowns in labor productivity and TFP growth are largest in the more intangible-, knowledge-, technology- and digital-intensive industries in the UK.

The analysis builds on work within the EUs Horizon 2020 project GLOBALINTO and former EUs 7th Framework project INNODRIVE, and evaluates intangible investment (organizational, R&D, and ICT) from the related labor costs, intermediate and physical capital costs in four countries (Finland, Denmark, Norway and Slovenia).[3] The important contribution of this paper is to measure how intangible capital work creates technological change measured by intangible-work-biased technological change, IBTC (Piekkola, 2020).

Considering potential differences across industries and to understand more deeply the productivity puzzle, our intention is to analyze of the effects of IBTC in raising multi-factor productivity (MFP) and

[3] For more details, see Piekkola et al. PIEKKOLA, H. 2011. Intangible capital - INNODRIVE perspective. *In:* PIEKKOLA, H. (ed.) *Intangible capital - driver of growth in Finland.* Vaasa: University of Vaasa., guidelines in OECD 2010. *Handbook on deriving capital measures of intellectual property products,* Paris, OECD Organisation for Economic Co-operation Development. and BLOCH, C., PIEKKOLA, H., DEREK, T. & RYBALKA, M. 2021b. Valuing intangible assets at the firm level – development of an occupation based approach. *D3.4 Globalinto* .

markups at the sector level. Growth accounting methodologies have been used to estimate MFP that accounts for intangible deepening at industry level. We apply the Wooldridge (2009) method at the firm-level. The traditional total factor productivity, TFP, accounts only for tangible capital deepening and thus is sensitive to variation in gross returns to intangible investment over time.

It is also important to understand how IBTC affects markups being an important component of TFP. Schumpeterian innovative growth requires sufficient high markups and hence internal funding to finance new innovations. Intangibles bring high fixed costs, thereby hindering the entrance of new firms to the market, giving another source of market power to incumbent firms. Competing firms must invest in uncertain innovations and risk losing large amounts of money if they fail. Intangibles are indeed considered to be firm-specific capital or intangible capital that helps differentiate a firm from others (De Ridder, 2021).

We analyze profitability through markups following the production function method by De Loecker and Warzynski (2012) and De Loecker et al. (2020). The main idea there is that the gap between the productivity and employment costs of flexible workers gives a better estimate of markups than any estimate for intangible capital work, where fixed costs are prominent and private returns may gradually materialize over a longer period. Syverson (2019) shows that markups essentially depend on the multiplication of pure profits from value added and the scale elasticity. De Loecker et al. (2020) find an increase in returns to factor inputs from 1.03 to 1.08 between 1980 and 2014. Syverson (2019) suggests that the scale elasticity has increased for the finding to be consistent with actual data.

Following De Loecker and Warzynski (2012), markups are proxied by a production function approach arising from the ratio of flexible factor inputs' output elasticity to the labor factor's expenditure share. Such a measure is well suited to the modern economy with more limited importance of manufacturing blue-collar work that is often seen to be the most flexible part of the labor force. Such an approach can also apply to the Nordic labor markets with highly unionized manufacturing labor, where exporting industries are usually considered to be leaders in economy-wide wage setting.

Jona-Lasinio and Meliciani (2018) found applying the broad measures in INTAN-invest data that the share of intangible assets in total productivity growth ranged from 14% to just over 30% between 2000 and 2013 (Netherlands, Denmark, Finland, United Kingdom). Sanandaji et al. (2022) present an 'innovation triangle' in the intangible intensive Nordic region with Oslo, Helsinki and Copenhagen in the corners and Stockholm in the center. Our choice of countries is interesting because of the differences in R&D orientation of Nordic countries and Slovenia. Copenhagen region is a leading European innovation center and Nordic regions form an important innovative center of global importance (Commission, 2021). It is then interesting to apply similar data on Slovenia, which is also a small country with an export orientation and relatively strong manufacturing.

Given the technological heterogeneity, it is also of interest to analyze separately high-tech and low-tech manufacturing and to separate knowledge intensive services (KIS) from basic services. This is especially relevant for the design of innovation policy.

Our analysis relies on official register datasets obtained from national statistical institutions (NSIs).[4] This facilitates the formation of linked employer-employee datasets where intangible capital work is assessed based on specific (innovative) occupations. Such labor costs are combined with other related factor inputs and used in further firm-level analysis where we develop a measure of improved quality as a measure of IBTC. Such a comparison is possible since occupation-based intangibles can be measured in a unified way based on ISCO occupational coding. Organizational (OC), R&D and ICT work are thereby also not overlapping, and we separate here OC work driven IBTC and R&D work driven IBTC.

We find that technological change has been ongoing in Nordic countries with both quality improvements and also through its positive effect on MFP. The largely unexplored part of it is OC-IBTC which is on average half to that of R&D-IBTC. Denmark leads in R&D-IBTC, while Norway has relative strength in OC-IBTC. In Finland, IBTC leads to high markups in general and especially in high-tech manufacturing. We also find that most of the rise in R&D-IBTC is driven by large firms in manufacturing.

The paper is divided into five sections. Following this introduction, section 2 describes GLOBALINTO's methodology for measuring intangibles, and demonstrates the evolution of intangibles in Finland, Denmark, Norway, and Slovenia. Section 3 presents the estimated results for returns to intangible capital work, while section 4 is related to IBTC and firms' performance. Section 5 concludes and discusses policy implications of our results.

# 2 Measurement of intangibles and IBTC

The measurement of intangibles in the GLOBALINTO project is conducted over several steps and follows several statistically important principles, with the goal of fitting the analysis into the broader context of established statistical classifications. Methodologically, the measurement of intangible investment is based on employee data, where occupations in particular serve as the main criteria for identifying intangible capital (IC) work. First, individuals' wages, aggregated from employee (individual) data on the level of core occupational groups (ICT, RD, organizational, and other work),

[4] The data analysis is based on linked employer-employee data. For Denmark, Finland and Norway, the data were prepared based on register data made available by Statistics Denmark, Statistics Finland, and Statistics Norway, respectively. For Slovenia, the data was prepared using the protected micro datasets with assistance of the Statistical Office of the Republic of Slovenia and the support of the User relations section of the Data publication and communication division (Statistical Office of the Republic of Slovenia, 2020).

which allow the generation of intangible investments, are linked to employer data. In the second step, the linked dataset is used in the detailed firm-level analysis with regard to IBTC, markups, and productivity.

A crucial issue in GLOBALINTO's micro-based approach is how work with intangibles utilizes tangibles and intermediate inputs together in producing an intangible investment. We extend here the EU 7th framework project Innodrive methodology (Piekkola, 2020, Bloch et al., 2021b). While Innodrive's approach considers own in-house developed as well as purchased intangibles to be complements, we claim that own-account production is more firm-specific than purchased intangibles and, hence, is more important for improving the firm's competitive advantage.

Box A.1 in Appendix A lists relevant occupations that engage in IC work, i.e. organizational (management and marketing), R&D and ICT occupations (Bloch et al., 2021b, Piekkola et al., 2023). Only a proportion of working time is devoted to intangible investment. Based on earlier work and work in the GLOBALINTO project (Piekkola et al., 2023) we assume that the share of labor cost dedicated to the production of intangible goods is 0.6 in ICT occupations, 0.9 in R&D occupations, and 0.45 in OC-related management and marketing occupations.

Purchased intangibles should, on the other hand, not always be seen as part of intangible capital because they are also available to rivals. However, internal intangible investment also includes a purchased intermediate intangible input (as part of intermediate input) and tangible investment which are considered quite mechanically by observing factor input relations in IC-producing services, for details, see Bloch et al. (2021b).

In estimating intangible-work-biased technological change (IBTC) the relative returns to intangible capital (IC) work and output elasticities to employee of intangible capital, $R_{it}^{IC}$, for industry *i* in year *t* were estimated using a production-function-based approach.[5] Output elasticities of flexible labor are needed to estimate markups proxied by the output of flexible labor. Relative returns and output elasticities to employee are required to evaluate IBTC. The production function that accounts for intangible assets is given by

$$Y_{it} = b_0 \left( A(L_{OC}, L_{RD}) L_{noICit} \right)^{b_L} \prod_{IA} \left( R_{it}^{IC} \right)^{b_{IC}} K_{it}^{b_K} \exp(e_{it}) \ , \qquad (1)$$

where labor $L_{noICit}$ excludes the part of IC work going to IC investment. The separation of IC work also has some econometric merits as, for example, Schankerman (1981), Hall and Mairesse (1995) show that R&D work should be excluded from employment figures to avoid double counting, which can lead to downwardly biased estimates of the output elasticity of R&D. For this reason, value added

[5] PIEKKOLA, H. 2020. Intangibles and innovation-labor-biased technical change. *Journal of Intellectual Capital,* 21, 649-669. introduces intangible-work-biased technical change (IBTC), which is analogous to skill upgrading, better known as skill-biased technical change.

also excludes income accruing to broad OC and R&D. $A(L_{OC}, L_{RD})$ measures the relative quality of IC work compared to non-IC work; $R_{it}^{IC}$ refers to the capital stock of intangible assets of types *IC*=OC, R&D, and ICT; $K_{it}$ is tangible capital which considered as total fixed capital in the markup and IBTC estimation, while $e_{it}$ is an error term.

Ilmakunnas and Piekkola (2014) evaluate the relative productivity of intangibles by measuring the employment shares of IC workers. It can be shown that this share is an appropriate proxy for measuring the quality of IC workers relative to other workers, when the shares are small and hence a non-linear estimation need not be done:

$$A(L_{OC}, L_{RD})L_{noIC} = \left( \left( \frac{a_{RD}L_{RD}}{\bar{a}_{Lnoic}L_{noIC}} + \frac{a_{OC}L_{OC}}{\bar{a}_{L}L_{noIC}} \right) + 1 \right) L_{noIC}, \text{ where} \qquad (2)$$

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

where $a_{RD}$, $a_{OC}$ are the quality of IC work, *IC=R&D, OC*, relative to the average quality $\bar{a}_{Lt}$ of non-IC work in the firm (a sub-index for firm *i* is not shown here). The logarithmic approximation of *A* is

$$ln\left( (\frac{a_{RDt}}{\bar{a}_{LnoICt}} - 1)\frac{L_{RDt}}{L_{noICt}} + (\frac{a_{OCt}}{\bar{a}_{LnoICt}} - 1)\frac{L_{OCt}}{L_{noICt}} + 1 \right) \approx \qquad (3)$$

$$\left( \frac{a_{RDt}}{a_{LnoICt}} - 1 \right) \frac{L_{RDt}}{L_{noICt}} + \left( \frac{a_{OCt}}{a_{noICLt}} - 1 \right) \frac{L_{OCt}}{L_{noICt}}$$

given that the first two terms are not too far from zero. The quality component *A* captures changes in the quality of intangible capital and also the possible synergies of having larger number IC workers such as of, for example, R&D workers in the same R&D lab.

The production function estimation is then used to revise the initial figure in each industry. The relative productivity can subsequently be assessed from

$$b_{IBTC,IC}(w_{ICit} / \bar{w}_{LnoICit} - 1)L_{IC} / L_{noIC} = b_L(\hat{a}_{ICit} / \hat{\bar{a}}_{LnoICit} - 1),$$

where $b_{IBTC,IC}$ is the coefficient on relative wages multiplied by labor share $(w_{ICit} / \bar{w}_{LnoICit} - 1)L_{IC} / L_{noIC}$ and $b_L$ on labor. A lower coefficient of total labor $b_L$ than the coefficient for the quality estimate (which should be the same) implies that the relative productivity of IC work must be revised up from $\hat{a}_{ICit} / \hat{\bar{a}}_{LnoICit} = b_{IBTC,IC} / b_L(w_{ICit} / \bar{w}_{LnoICit} - 1)L_{IC} / L_{noIC} + 1.$

The estimation for NACE-industries at the three-digit level over firm *i* and year *t* from (3) in log form is provided by

$$\ln Y_{it} = \ln b_{0j} + b_L L_{noICit} + b_{IBTC,IC} A_t + b_K \ln K_t + b_Z' \ln Z_{it} + \ln e_{it}, \text{ where}$$

$$A_t = \left( \frac{a_{RDt}}{\overline{a}_{LnoICt}} - 1 \right) \frac{L_{RDt}}{L_{noICt}} + \left( \frac{a_{OCt}}{\overline{a}_{LnoICt}} - 1 \right) \frac{L_{OCt}}{L_{noICt}} \quad , \qquad (4)$$

where $A$ is from (3), $K_{it}$ is the sum of tangibles and intangibles $\sum_{IC} R_{it}^{IC}$ and control $Z_{it}$ includes dummy variables for years.

Controlling for outliers is important since the wage ratio can vary from zero to infinity, meaning that extreme values can have a substantial influence on estimated values. Wage rates are set to be within the 1th and 99th percentiles of the overall distribution. In addition, small firms may not be fully able to utilize the competencies of R&D or OC workers, who in turn might not be better paid than other staff. In this case, these observations with low wages for R&D or OC workers are ignored in the small firms with at most 5 intangible capital workers and with firm's size below 40 employees. After these deletions, we still observe firms where IC workers are paid less than average non-IC workers, in which case we use the average IC wage ratio at NACE 4-digit industries as a proxy wage for the corresponding type of IC workers.

# 3 Empirical approach: sample and descriptive statistics

We limit our sample to firms with at least five employees on average, divided into four groups by technology level using the OECD classification and typology of KIS (knowledge-intensive services) by Eurostat[6]. Table 1 presents the IC and total work shares (given the IC work share of working time at 45% for OC, 90% for R&D, and 60% for ICT employees). As we can see, the shares of organizational capital work were increasing over time for Denmark, Norway and Slovenia, while they fluctuated up and down in Finland. In 2018 (2017 for Slovenia), these shares in Norway were 3.2, Denmark 2.4, Slovenia 2.93, and Finland 1.5.[7] In the most recent years observed, R&D work shares were approximately the same in the Nordic countries. In 2018, these shares were about 7.5 in the Nordic countries and (in 2017) 4.9 in Slovenia. There was a flat trend in R&D shares in Finland, a small increasing trend in Slovenia, while the shares have risen by 2 percentage points or more in both Denmark and Norway during the observed period. Overall, by 2018 the shares of IC work as a share of all work were 13.8 in Norway, 12.8 in Denmark, 11 in Finland, and 9.7 in Slovenia.

[6] Note: we exclude agriculture (NACE A), forestry, mining (NACE B), water supply, etc. (NACE E), construction (NACE F), financial intermediation and insurance (NACE K), public administration (NACE O), education (NACE P), health (NACE Q), and non-profit sectors (NACE Q, S, T, U, X).

[7] These shares for organizational work of the all work reported in Table 2 are smaller than in the earlier work by Innodrive due to the narrower choice of management and marketing occupations.

**Table 1: IC 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 | 1.56 | 5.03 | 1.39 | 7.98 |
| 2002 | 1.77 | 8.27 | 1.72 | 11.75 | 1.53 | 5.37 | 1.41 | 8.31 |
| 2004 | 1.57 | 7.64 | 1.72 | 10.93 | 1.56 | 5.03 | 1.51 | 8.09 |
| 2006 | 1.75 | 7.14 | 1.69 | 10.59 | 1.67 | 5.23 | 1.51 | 8.41 |
| 2008 | 1.80 | 7.22 | 1.65 | 10.67 | 1.81 | 5.61 | 1.60 | 9.03 |
| 2010 | 1.33 | 7.22 | 2.41 | 10.97 | 2.27 | 7.14 | 2.50 | 11.90 |
| 2012 | 1.30 | 7.19 | 2.47 | 10.95 | 2.13 | 7.00 | 2.55 | 11.68 |
| 2014 | 1.27 | 7.14 | 2.40 | 10.82 | 2.12 | 6.97 | 2.61 | 11.70 |
| 2016 | 1.25 | 7.13 | 2.31 | 10.69 | 2.37 | 7.64 | 2.79 | 12.80 |
| 2018 | 1.54 | 7.40 | 2.01 | 10.95 | 2.35 | 7.57 | 2.85 | 12.77 |
| | | **Norway** | | | | **Slovenia*** | | |
| 2008 | 2.82 | 5.78 | 2.62 | 11.21 | 2.35 | 4.42 | 1.62 | 8.39 |
| 2010 | 2.98 | 6.58 | 2.59 | 12.15 | 2.76 | 4.46 | 1.67 | 8.89 |
| 2012 | 3.20 | 7.57 | 2.87 | 13.64 | 2.85 | 4.49 | 1.74 | 9.08 |
| 2014 | 3.18 | 8.07 | 2.90 | 14.15 | 2.95 | 4.58 | 1.82 | 9.35 |
| 2016 | 3.33 | 7.70 | 2.99 | 14.01 | 2.86 | 4.77 | 1.83 | 9.46 |
| 2018* | 3.20 | 7.47 | 3.10 | 13.78 | 2.93 | 4.93 | 1.83 | 9.69 |

*2017 for Slovenia

Table 2 presents variation in the stock of intangible capital (all estimates are in EUR thousands and in 2015 prices using GDP deflator) per employee following the occupation-based methodology for four countries. Both R&D and OC per employee have increased in Norway and Slovenia, while OC stock per employee has fallen over time in Finland and R&D capital has declined in Denmark. The R&D capital stock per employee figures in Norway are highest and are about EUR 76.2 thousand in 2018. Finland and Denmark had about the same R&D per employee of around EUR 45–50 thousand (in 2018), while accumulated R&D per employee was much lower in Slovenia at around EUR 24.2 thousand (in 2017). Later we will see that R&D-IBTC is strongest in Denmark so that IBTC does not go hand in hand with R&D intensity.

Finland has a higher OC intensity than Denmark or Slovenia despite having a smaller share of OC workers, but in Norway OC per employee is the highest at around EUR 27 thousand in 2018. The sum of the OC and ICT intensity is approximately 18 thousand (2015€) in Finland and Denmark, 40 thousand (2015€) in Norway, and 9 thousand (2015€) in Slovenia. Two-thirds of this is OC. Later we see that Denmark with relatively meagre amount of OC have OC-IBTC that fosters high MFP. Organizational or firm-specific human capital and ICT are among the biggest subcategories of intangible investment in many other studies (Bloom and Van Reenen, 2010, Piekkola, 2016), while in our occupational measure of intangible capital, R&D always exceeds the sum of OC and ICT.

**Table 2: Intangibles per employee across country in thousand EUR (2015 prices)**

| Year | OC/L | RD/L | ICT/L | All | OC/L | RD/L | ICT/L | All |
|---|---|---|---|---|---|---|---|---|
| | | Finland | | | | Denmark | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2000 | 16.6 | 43.8 | 5.1 | 65.6 | 10.0 | 66.6 | 12.7 | 89.2 |
| 2002 | 16.4 | 42.6 | 5.0 | 63.9 | 9.6 | 67.1 | 12.1 | 88.8 |
| 2004 | 16.1 | 44.3 | 5.4 | 65.8 | 9.8 | 62.6 | 11.4 | 83.8 |
| 2006 | 16.0 | 43.9 | 5.6 | 65.5 | 8.8 | 56.6 | 10.0 | 75.4 |
| 2008 | 16.0 | 45.5 | 5.3 | 66.8 | 8.0 | 48.4 | 8.4 | 64.8 |
| 2010 | 14.8 | 47.0 | 6.8 | 68.6 | 9.6 | 54.8 | 9.5 | 73.9 |
| 2012 | 13.4 | 47.0 | 7.6 | 67.9 | 9.6 | 53.6 | 9.3 | 72.5 |
| 2014 | 13.0 | 48.3 | 7.9 | 69.2 | 9.5 | 50.8 | 9.0 | 69.3 |
| 2016 | 12.1 | 47.4 | 7.9 | 67.4 | 9.5 | 50.3 | 9.0 | 68.8 |
| 2018 | 10.8 | 45.9 | 7.7 | 64.3 | 9.6 | 50.9 | 9.2 | 69.6 |
| | | 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 | 6.6 | 24.3 | 2.9 | 33.8 |

Norway stands out as the most ICT-intensive country with around 12.8 thousand per employee (2015€) in 2018, followed by Denmark 9.1, Finland, 7.7, and Slovenia 2.9 (in 2017). However, we do not implement ICT driven technological change in our model given its general purpose nature.

Slovenia differs from the Nordic countries in several ways. Even though R&D intensity is increasing over time and ICT capital is also growing, ICT capital per employee is still very low in Slovenia. In fact, with 8.8% of total IC capital it is the lowest among the four countries in the study. As for the value added per employee, it is about one third in Slovenia to that in Denmark, and about 20% lower in Norway and Finland than in Denmark (see Table B.2 for other descriptive statistics in the Appendix B).

The IBTC estimation uses simple OLS of (5) separately in about 160 NACE 3-digit industries. Table A.2 in the appendix shows the main results and summary statistics. The average R&D and non-IC wage ratio of the firms is 34% in Finland, 32% in Norway, 54% in Denmark, and 100% in Slovenia. The average OC and non-IC wage ratio is highest 100% in Finland and Denmark and around 50% in Norway and Slovenia. These are the initial estimates of the relative productivity differences between innovative and average workers at each of the about 160 NACE 3-digit industries. From (4), a coefficient of total labor $\hat{b}_L$ higher than the coefficient for the quality estimate $b_{IBTC,IC}$ (which should be the same) implies that the relative productivity of IC work must be revised downwards. IC-IBTC $\equiv \hat{a}_{ICit} / \hat{\bar{a}}_{LnoICit} - 1 = b_{IBTC,IC} / b_L \cdot (w_{ICit} / \bar{w}_{LnoICit} - 1) \cdot L_{ICt} / L_{noICt}$ then shows technological change in each industry. The relative quality of intangible capital work is hence approximated by the relative value of intangible capital work to non-intangible work (estimated using production function) and the technological impact depends on the ratio of intangible capital work and non-intangible work.It appears that true relative quality proves to be smaller than the initial figures since on average the

output elasticity of labor is generally higher than the coefficient on the relative quality of IC work multiplied by the IC labor share.

For example, in Finland the median R&D work share is 0.1 and the median relative quality of R&D work is 1.12 (see summary Table B.2 in the appendix). The total of these two median values yield (1.12-1)*0.1=0.012. The median R&D-IBTC is higher (0.024) as the share of R&D labor and the relative value of R&D work have a positive correlation of 0.33 (evaluated for firms that are in one standard deviation distance from the median R&D work share). R&D-IBTC therefore also accounts for the complementarity between the share of R&D and their relative value of the R&D work. This result also brings evidence of increasing returns to scale.

Figure 1 shows R&D-IBTC for Denmark, Norway, Finland, and Slovenia unweighted and with the revenue weighted values presented in (Piekkola et al., 2023), where the latter panel shows better the nation-wide effects.[8]

Figure 1a) shows that in Denmark, R&D-IBTC increased almost 40% during the reported period to higher average amount 0.07 by 2019. R&D-IBTC evolves fairly similarly in Finland and Norway, but with no significant growth since 2010. Slovenia belongs to the group of EU countries with average R&D intensity and thereby also having about 0.01-0.02 lower IBTC. Our results confirm much of the difference of innovation firm types across Nordic countries, where R&D-IBTC effects are significant higher given the higher intangible intensity.

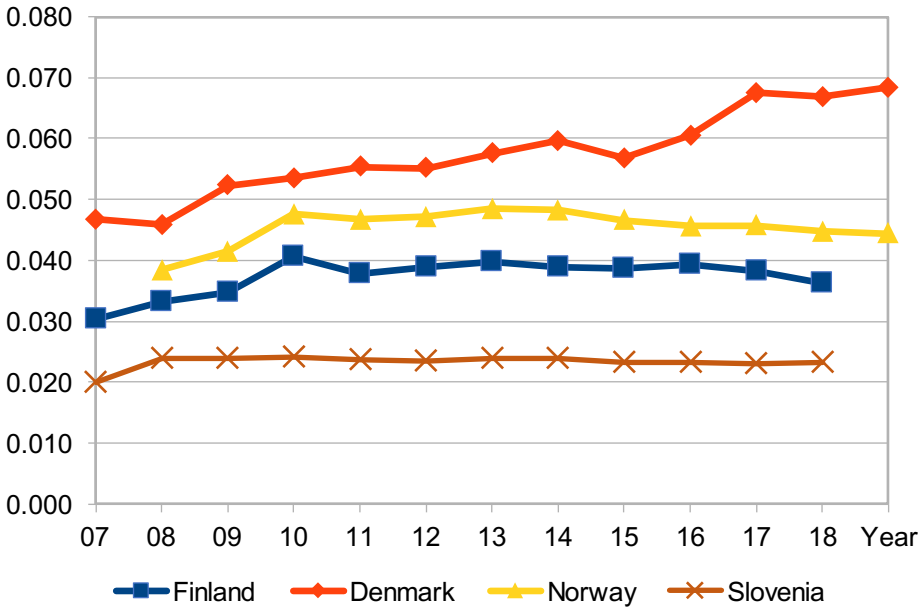
Figure 1b) with revenue weights indicate much lower level of R&D-IBTC over years at around 2 per year in the Nordic countries. Average difference between values in Figures 1a) and 1b) indicate that R&D-IBTC decreases with revenue weights by 0.014 in Finland, 0.028 in Denmark, 0.022 in Norway and 1.1 in Slovenia. However, with weights R&D-IBTC has been increasing at higher rate in Denmark, and also earlier until 2010 in Slovenia. Large firms have hence on average lower R&D-IBTC than SMEs but with rising profile in Denmark.

In what follows, we are going to include MFP and markups in the analysis without revenue weights. We prefer unweighted figures here since MFP is the residual of production function estimation, which for big firms can have large outlier values or determined by monopoly pricing.

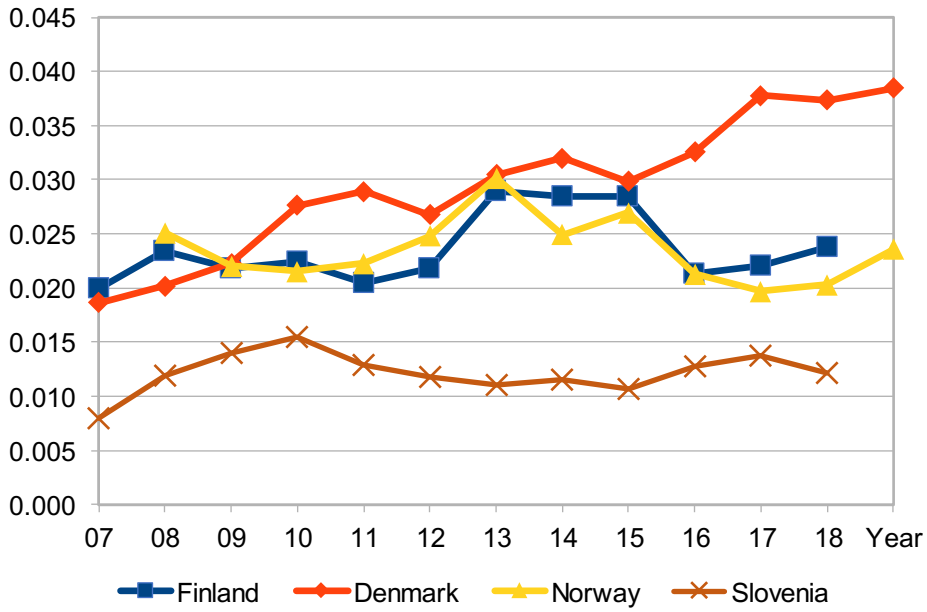
**Figures 1. R&D-IBTC**

[8] Denmark and Finland have data over the whole 2010's. In both alternatives year 2007 figures indicate earlier years 2000-2006 fairly well for these two countries, while most of the variation over the years is observed from the 2008-09 financial crises.

1a) R&D-IBTC

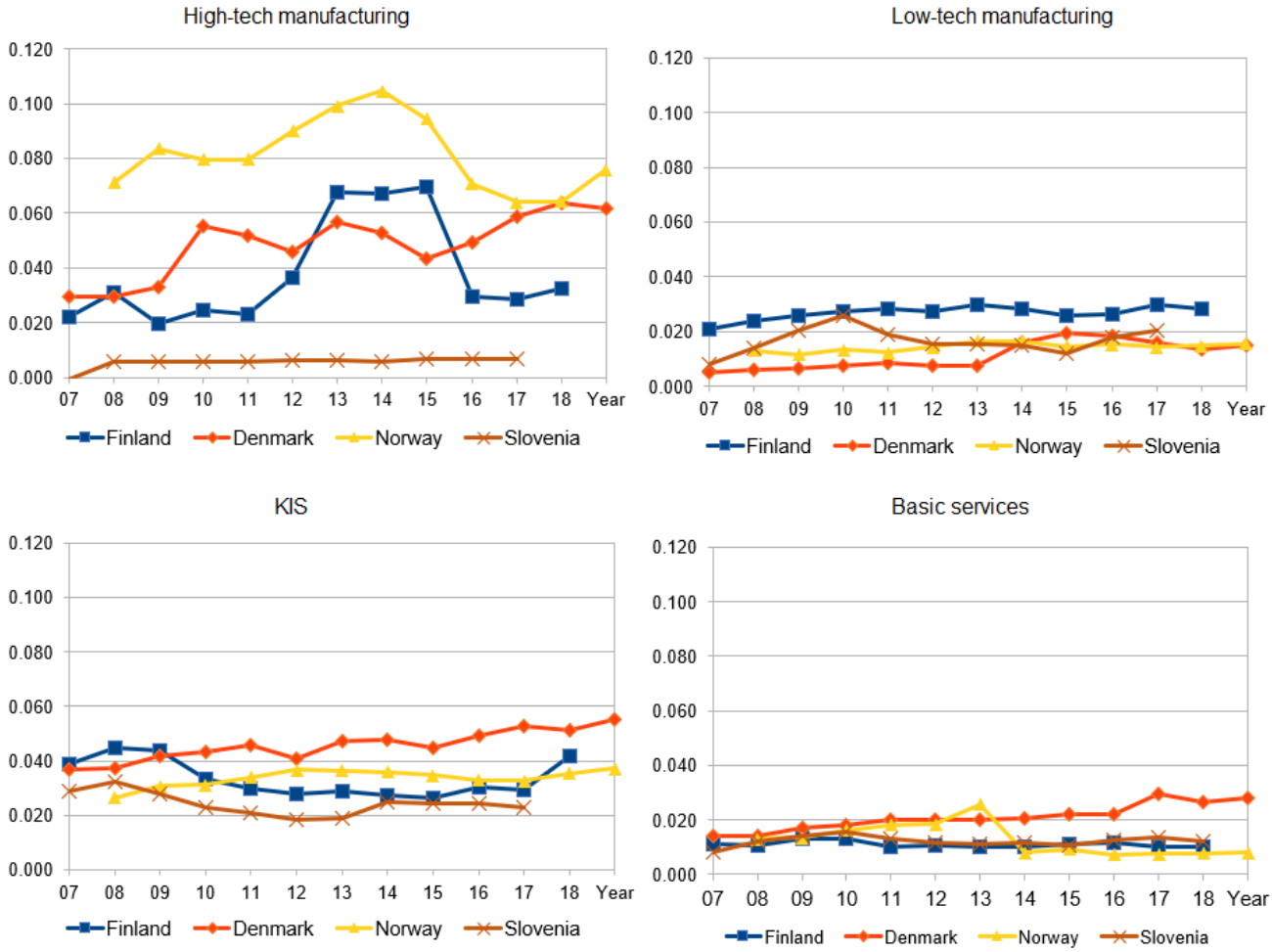



1b) R&D-IBTC weighted




Analysis by technology type can indicate where the different development of large firms (as indicated by revenue weighted figures) compared to the average emerges from. Figure 2 shows R&D-IBTC by technology types: high-tech and low-tech manufacturing, KIS and basic services. We report first the weighted figures with economy wide effects that are much dominated by the largest listed firms. The high-tech includes top high-tech sectors such as pharmacy, computing, electronics, and optical products as the highest technology category. It also includes middle high-tech sectors: chemical, electrical, and machinery equipment, motor vehicles and other transport. Low technology includes other manufacturing (such as oil, rubber, basic metal, metal products, etc.).

**Figure 2. R&D-IBTC by technology type, revenue weighted**




Figures reveal that R&D-IBTC in Norway is the highest in high-tech, whereas in Denmark and Finland high-tech and KIS have equal average levels of R&D-IBTC. Slovenia has highest technological progress (around 0.025) in KIS. Denmark had most prominent R&D-IBTC in Figure 1, which is spread across all technology sectors. From Figure 2 we see that Denmark had a decrease in technological change in high-tech since 2017, but this high R&D-IBTC sector has expanded with 50% increase in value added in the period 2008-2021. At the same time, rationalization led to a cut-down of jobs by 13% to 228,300 persons by 2021. These industries create value added of 31 billion € in 2021, which is about double more than in Finland or Norway. Slovenia has also relatively high 20% share of high-tech manufacturing in the investigated sample, however its R&D-IBTC is the lowest among the investigated countries and also without improvement. The weighted results for Slovenia should be interpreted in view of a very small number of large firms (around 400 in total) which generate about a third of revenue.

In Norway, the decrease in oil prices in 2015 had negative effect on R&D-IBTC both in high-tech sector and basic services, while low-tech manufacturing and KIS were unaffected. The overall decrease in R&D-IBTC since 2015 in Figure 1 is caused mainly by high-tech manufacturing.

Finland has a manufacturing technological focus according to Sanandaji et al. (2022). Finland performs fairly well around 0.025% in low-tech manufacturing. Low-tech manufacturing such as material technology, product technology and other low-tech manufacturing technology continued to have high R&D-IBTC, and they operate largely outside Helsinki region.

KIS industries are important producers of purchased intangibles to other industries and in global value chains (Tsakanikas et al., 2020) and in 2017 its value added share of private sector was 16% in Denmark, 14.2 in Finland, 12.9% in Norway and 6.5% in Slovenia. Denmark has performed well in KIS. The Copenhagen region can be said to be a leading European innovation center. IT platforms are a relatively new business sector, where the key concept is to set up online platforms to facilitate a particular service. Basic services include here NACE N (administrative and support service activities) and is also besides KIS important producers of purchased intangibles to other industries. These include rental and leasing activities and travel agency, reservation services and related activities. In Denmark KIS including NACE N and without the IT sector employs about 94,000 persons, which is more than 73,000 in Norway and 64,000 persons in Finland (and with an annual rise by 1.6% since 2008).

IT industries as part of KIS could also include telecommunication and manufactures of computers, electronic and optical products). The IT sector in this broad sense is about the same size in all Nordic countries, creating 10 billion € value added in 2021. However, the ICT sector including computer programming and information sectors (excluding telecommunication and NACE 25 electronic industry) is highest 7.3% in Finland in the considered industries followed by Norway 4.7%, Denmark 4% and Slovenia 2.5%, see Appendix A. The Helsinki area is digitally focused innovation region concentrated on the field of consumer services, digital infrastructure/platform and software. Relative to other Nordic regions, the Copenhagen area together with Zealand have special focus on the platform sector, digital meetings and software innovation. Oslo focuses on finance/real estate, marketplace/trade and transportation. Figure 3 shows R&D-IBTC without revenue weights.

R&D-IBTC without revenue weightsis is two- to three-times lower in manufacturing. These differences show that only large firms have been able to maintain to improve technological change in manufacturing. At the same time there appears to be large share of small firms with fairly modest R&D-IBTC. The situation is the opposite in services, where the R&D-IBTC is instead double higher when unweighted. Thus, when turning the focus to large firms, manufacturing appears to perform better leading the economy and being more efficient. When all firms are considered with equal weights, services with large amount of small firms appear to have much higher technological change.

The contrast is sharpest in basic services where SMEs are leading the technological change that is in most countries developing faster than in KIS (with the exception being Norway).

**Figure 3. R&D-IBTC by technology type, unweighted**

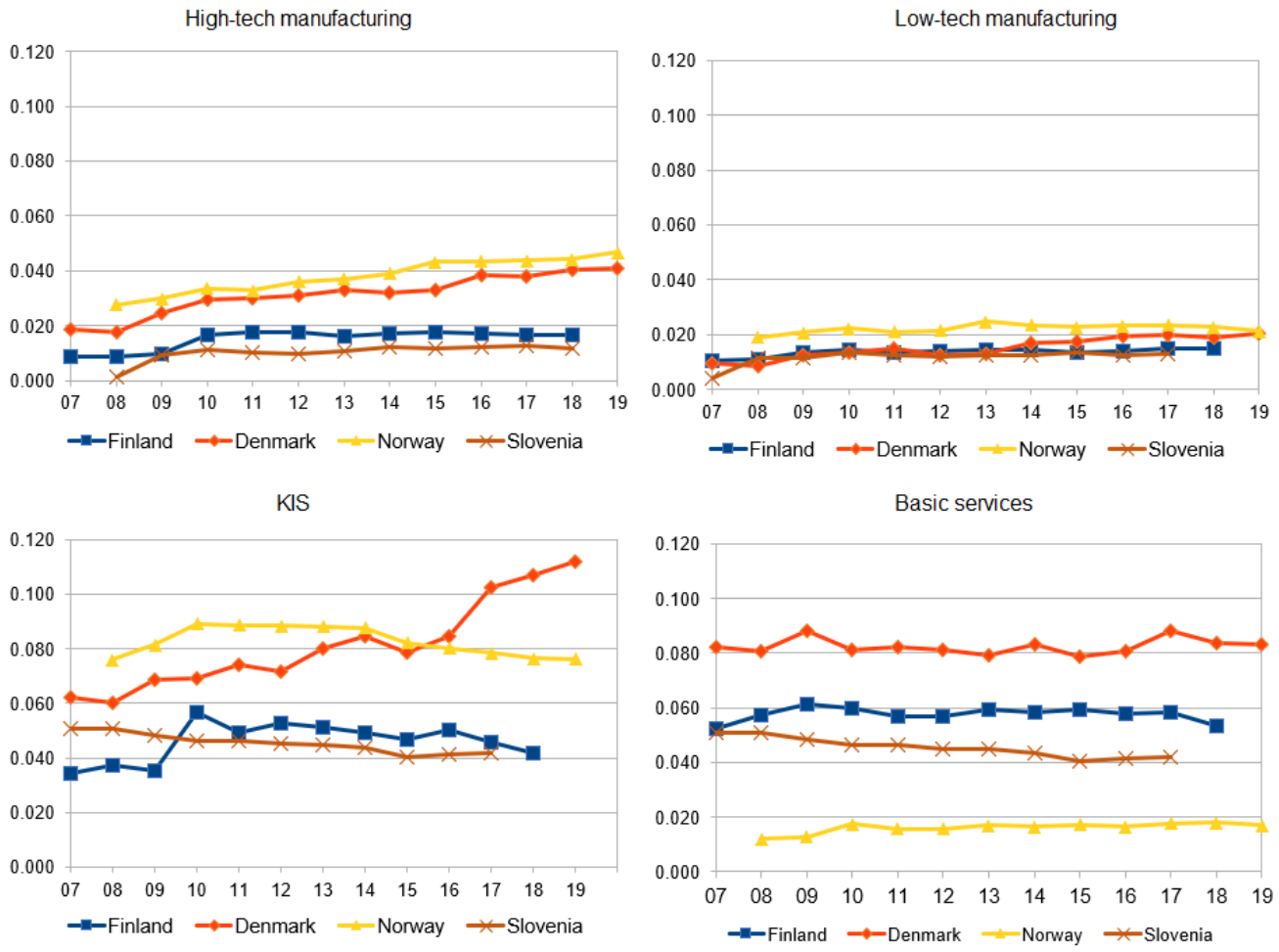
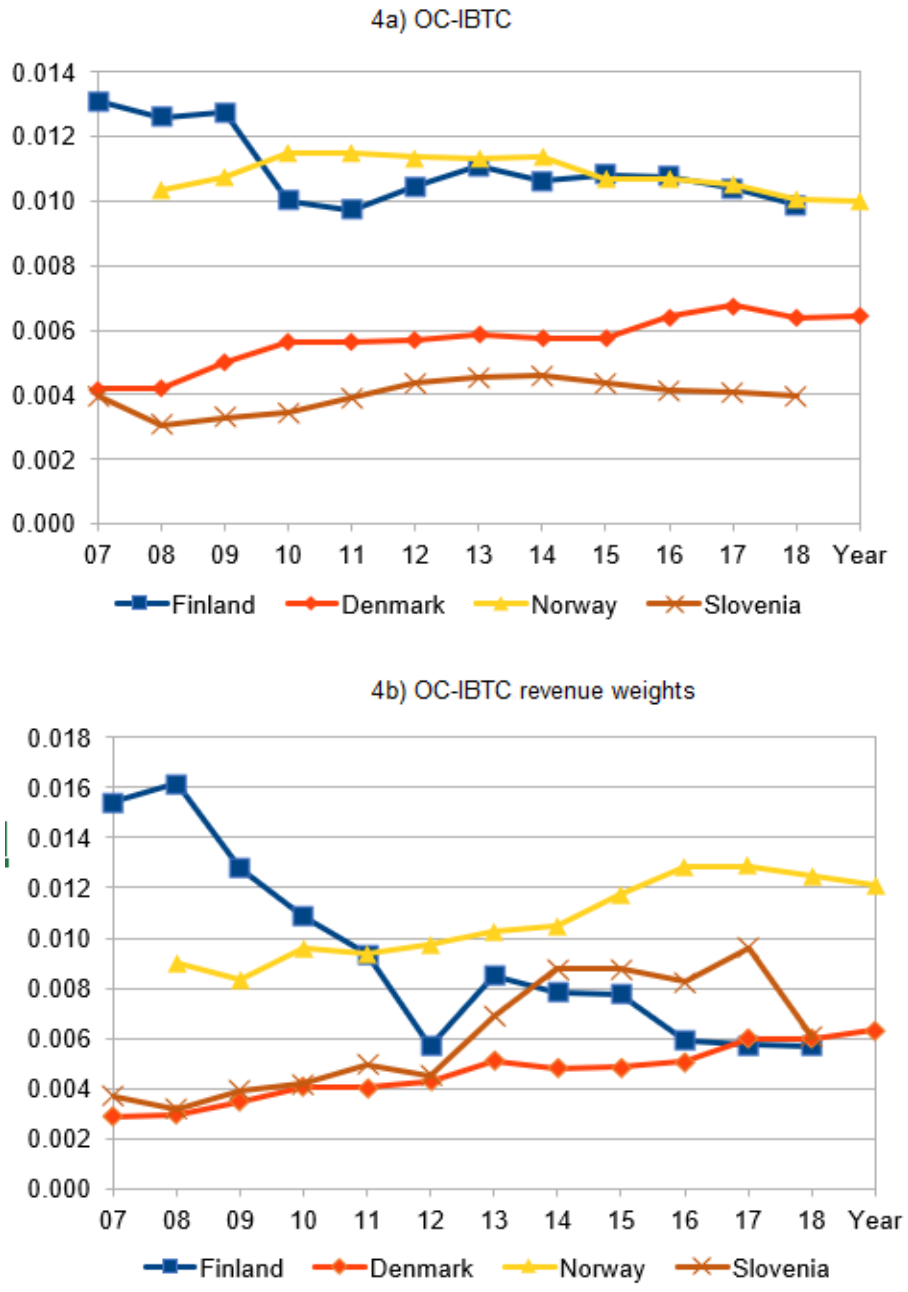



Figure 4 shows OC-IBTC for Finland, Norway, Denmark, and Slovenia. On average, OC-IBTC is about one fourth of R&D-IBTC and is around 0.01 in Finland, Norway and 0.005 in Denmark and Slovenia. With revenue weights OC-IBTC rises to about half of R&D-IBTC and hence 1/3 of overall IBTC in the economies. Its overall economic technological impact to GDP is hence about the same as its share of intangible capital (i.e. the sum of R&D and OC). Large firms were much behind the slowdown in OC-IBTC in Finland and growth since 2016 in Norway. For OC-IBTC, firm size matters less as unweighted and weighted figures are more alike. However, OC-IBTC appears to be an important driver for large high-tech manufacturing firms in Finland and for KIS in Denmark (figures are available upon request).

Denmark does not stand out as a high OC-IBTC Nordic country. Bloch et al. (2021a) relates the moderate level of OC jobs to the expansion of non-OC jobs such as low-paid jobs in services given the

demand boom and increase in public services. However, we will show that organizational change is more positively related to MFP there than in the other countries.

**Figure 4. OC-IBTC by technology type**



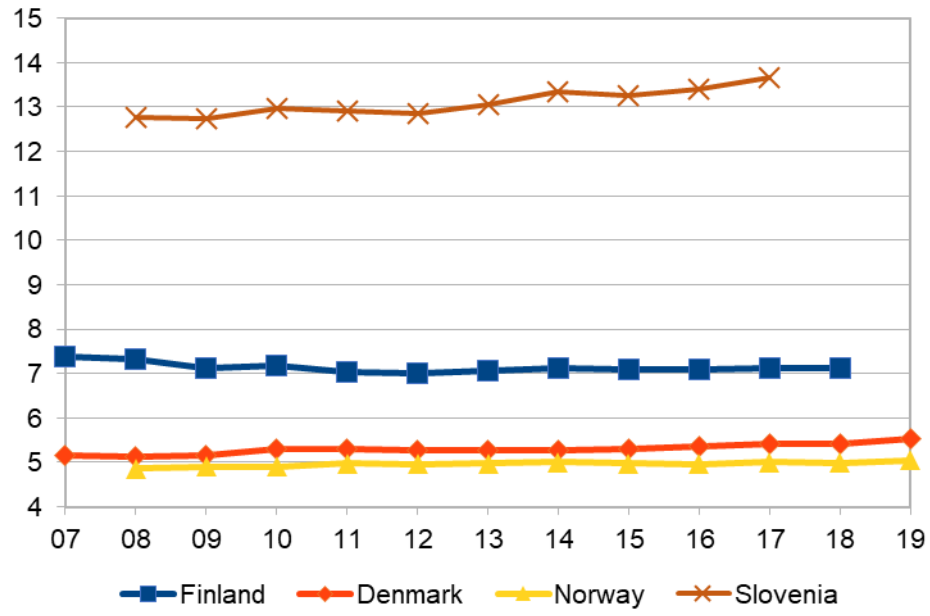

Industrial structure in Norway is prevailed by basic private services, followed by low-middle technology and KIS (see Table B.1). Such structure differs from other Nordic nations, where innovative firms concentrate on consumer and business services and digital infrastructure/platforms. Both in RD- and OC-IBTC sector differences are lowest in Norway.

# 4. Intangibles, IBTC and firm performance

It is of considerable interest on how intangible expenditures are valued in the firms and how IBTCs relate to multi-factor productivity (MFP) and profitability/markups. MFP is estimated applying Wooldridge (2009). State variables are intangible intangibles covering R&D and OC. Flexible variables are flexible workers excluding intangible capital work and ICT, which is hence considered to be general purpose technology. Proxy for productivity shock is intermediate investment (Levinsohn and Petrin, 2003). Summary B.3 in Appendix B shows that average and median markups in the estimation sample are around 10%-14% with being lowest in Denmark and highest in Finland. R&D-IBTC is on average around 2% GDP share of technical change but the median value is zero. Similarly, OB-IBTC is on average around 8%-9% in Finland and Norway, and around 0.3 in Denmark.

Figure 5 shows estimates for MPF, which is residual in explaining log of value added by flexible variables (employment of non-IC workers, ICT) and state variables (tangible capital, R&D and OC). Estimation is provided by the Woolridge (2009) method where intermediate input is used as an instrument. Figure 5 shows the development of MFP over time.

**Figure 5. MFP estimates**

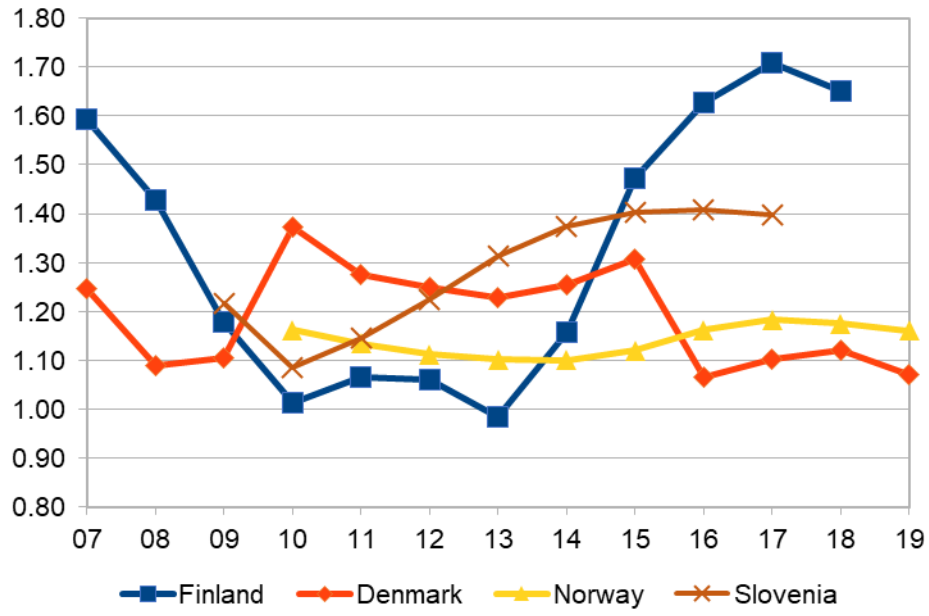



MFP level is highest in Slovenia followed by Finland. It is seen that MFP has been growing over time in Slovenia and to some extent in Denmark and Norway. MFP annual growth rate has been 4.2% in Slovenia followed by 1.5% in Denmark, 0.9% in Norway. Finland is an exception with negative growth given the initial high level in 2007-2008 due to the boom in Nokia mobile phones and paper and pulp products. The strong Slovenian performance might be explained by the catch-up process on the one

hand, while on the other hand, it might be also impacted by the strong position of Slovenian firms in international value chains, where these firms can be niche players. National economy size and strong market position of larger firms in Slovenia impacts the markup as well.[9]

Profitability is analyzed through markups following the production function method by De Loecker and Warzynski (2012) and De Loecker et al. (2020). Their main idea is that the gap between the productivity and employment costs of flexible workers gives a better estimate of markups than any estimate for intangible capital work, where fixed costs are prominent and private returns may gradually materialize over a longer period and intangibles are indeed correctly valued based on our results above. Our approach is novel in specifying flexible work by work not related to generating intangible assets, which is prominent among management, marketing, R&D, and ICT 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. The estimation of markups and basic results are shown in greater detail in Appendix C. Markup is estimated within three year overlapping blocks, so that output elasticity of flexible labor can change over time. Figure 6 shows the development of markups over time.

**Figure 6. Markups development between 2007 and 2019**




In general, markups have stayed out between 0-20% decreasing in Denmark and increasing in Norway. Finland has a high variation of markups and even recover close to the high level of 60% in

[9] By Slovenian standards, the average firm has 4-5 employees, with only 400 large firms (250+ employees), and around 1.2 thousand with 50 to 249 employees and another 6 thousand small. The remaining 190 thousand companies are micro companies. These firms have been largely excluded from this analysis due to the selection of firms with at least 5 employees. Such selection criteria might impact the mfp estimates as well.

the boom period 2007-2008 (until burst of financial crises in September 2008) and in the last years 2016-2018. Finland is hence both characterized as country with high MFP, but also the highest varying markups. In Slovenia, markups have plunged during the crisis and increased with economic boom, which can be explained by firm performance and competition and demand impact in international and national markets. In the crisis, primarily exporters were impacted heavily due to fierce international competition, while the recovery saw improvement in prices due to demand.

Tables 3 shows the results of the random effects production function estimates of using IBTCs to explain MFP. The production function is also assessed separately by main technology sectors: high-tech manufacturing, low-tech production, KIS, and basic private services.

**Table 3.** Random effect estimation of MFP

| | | Manufacturing | | Services | | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All | High-Tech | Low-Tech | KIS | Basic | All | High-Tech | Low-Tech | KIS | Basic |
| | **Finland** | | | | | **Norway** | | | | |
| R&D-IBTC | 1.32*** | 1.14*** | 1.463*** | 1.49*** | 1.30*** | 1.40*** | 1.13*** | 1.06*** | 1.43*** | 1.42*** |
| | (0.089) | (0.303) | (0.212) | (0.120) | (0.205) | (0.072) | (0.237) | (0.211) | (0.101) | (0.157) |
| OC-IBTC | -0.86*** | -1.33 | -3.52*** | -0.41 | 0.33 | -0.24 | -0.96 | -0.88 | -0.31 | 0.35 |
| | (0.239) | (0.800) | (0.694) | (0.370) | (0.379) | (0.247) | (0.85) | (0.774) | (0.435) | (0.337) |
| Constant | 5.86*** | 6.11*** | 6.34*** | 5.55*** | 5.80*** | 4.39*** | 4.28*** | 4.00*** | 4.55*** | 4.38*** |
| | (0.014) | (0.034) | (0.028) | (0.025) | (0.022) | (0.008) | (0.028) | (0.018) | (0.014) | (0.012) |
| Obs | 32394 | 5667 | 6510 | 9947 | 10270 | 52884 | 6521 | 7453 | 20306 | 18604 |
| $R^2$ within | 0.025 | 0.034 | 0.039 | 0.036 | 0.03 | 0.005 | 0.001 | 0.002 | 0.012 | 0.003 |
| $R^2$ between | 0.028 | 0.03 | 0.113 | 0.044 | 0 | 0.016 | 0.033 | 0.013 | 0.007 | 0.011 |
| $R^2$ all | 0.034 | 0.021 | 0.13 | 0.05 | 0.003 | 0.016 | 0.044 | 0.011 | 0.005 | 0.008 |
| Rho | 0.855 | 0.808 | 0.842 | 0.861 | 0.861 | 0.737 | 0.701 | 0.679 | 0.741 | 0.756 |
| | **Denmark** | | | | | **Slovenia** | | | | |
| R&D-IBTC | 1.92*** | 1.67*** | 3.38*** | 1.79*** | 1.69*** | 1.66*** | 1.17* | 1.81*** | 1.04 | 1.19* |
| | (0.067) | (0.164) | (0.19) | (0.116) | (0.118) | (0.235) | (0.498) | (0.322) | (0.695) | (0.496) |
| OC-IBTC | 4.55*** | 3.69*** | 8.46*** | 4.11*** | 4.12*** | -0.95 | -0.36 | -7.74*** | 5.73** | 3.82 |
| | (0.471) | (1.045) | (1.145) | (1.105) | (0.721) | (0.956) | (2.394) | (1.242) | (2.135) | (2.374) |
| Constant | 4.81*** | 4.79*** | 4.76*** | 4.84*** | 4.82*** | 12.00*** | 12.20*** | 12.00*** | 11.43*** | 12.21*** |
| | (0.008) | (0.016) | (0.018) | (0.017) | (0.013) | (0.02) | (0.043) | (0.028) | (0.057) | (0.043) |
| Obs | 29293 | 7172 | 6118 | 6186 | 9817 | 11923 | 2289 | 5591 | 1161 | 2882 |
| $R^2$ within | 0.019 | 0.01 | 0.036 | 0.023 | 0.016 | 0.052 | 0.074 | 0.034 | 0.092 | 0.212 |
| $R^2$ between | 0.102 | 0.072 | 0.198 | 0.1 | 0.077 | 0.031 | 0.009 | 0.058 | 0.048 | 0.089 |
| $R^2$ all | 0.09 | 0.053 | 0.19 | 0.103 | 0.06 | 0.023 | 0.017 | 0.03 | 0.041 | 0.091 |
| Rho | 0.668 | 0.629 | 0.744 | 0.628 | 0.686 | 0.851 | 0.873 | 0.877 | 0.875 | 0.774 |

*** significant at 1% level, ** significant at 5% level, * significant at 10% level

All countries have invested in the quality of R&D that generates technological change. The findings are strong in all countries and sectors except for KIS in Slovenia, where R&D-IBTC trend has also been downward sloping. Norway has highest technological gain on R&D in services than in manufacturing. Bloch et al. (2021a) find that R&D has a greater effect on TFP in Denmark than in

Finland, which is also holds for MFP in manufacturing and KIS. High and low-tech manufacturing have benefitted equally from R&D-IBTC, although with much stronger R&D input in high-tech manufacturing.

In OC-IBTC Denmark has also performed well in contrast to the other countries. Danish firms have used managerial ability to apply new types of technology. Organizational and marketing abilities are clearly one of the cornerstones of the economy to remain a leader in technological change, which can also be an outcome of the highest degree of digitalization of the countries. In this respect, Finland stands out as the worst performer in organizational abilities and especially in manufacturing. OC-IBTC also stands as important factor for technological change in Slovenian KIS. Finally, Slovenia has the largest constant so we cannot explain highest MFP in Slovenia and its highest growth based on IBTC.

We next analyze the relation of IBTC to the much more volatile markups. An analogy applies between skill-biased technological change and IBTC as described in Acemoglu (1998). A large increase in the supply of intangible capital workers (like skilled workers in Acemoglu) first moves the economy along a short-run (constant technology) relative demand curve, reducing the innovation premium. The relative supply change also increases the size of the market for technologies complementary to innovativeness, and induces a change in the direction of technological progress and a shift of the relative demand curve. Hence, intangible-work-biased technological change could benefit the profitability with some lag because there is a greater number of technologies that benefit from intangible capital workers. The first direct effect on markups can be negative and evidence already showed that intangible investment did not decrease in the low growth period 2011-2015 while markups decreased especially in Finland. Higher returns from overall shifts in the economy are reaped in the longer term.

The power struggle or "winner takes all" is likely to affect the top markup firms. Hence the market power explains the pace for high profitability rather than R&D or OC capacities. Results are more significant when dropping top 90$^{th}$ decile of firms in the overall distribution of markups in the country. In Finland and Slovenia, the overall R squared increase to over 30% in the random effects estimation. In these countries, R&D-IBTC and OC-IBTC have both positive effects for markups. In Denmark we instead apply this restriction to high-tech manufacturing since most of the high markup firms come from there nearly half of forms are dropped if exclude the top 90$^{th}$ decile of firms. Table 4 shows the markup effects.

**Table 4**. Random effect estimation of markups

| | | Manufacturing | | Services | | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All | High-Tech | Low-Tech | KIS | Basic | All | High-Tech | Low-Tech | KIS | Basic |
| | **Finland** | | | | | **Norway** | | | | |
| R&D-IBTC | 0.41*** | 0.15 | 0.03 | 0.21*** | -0.01 | 0.24*** | -0.01 | 0.024 | 0.198*** | -0.003 |
| | (0.040) | (0.199) | (0.976) | (0.049) | (0.077) | (0.023) | (0.085) | (0.056) | (0.029) | (0.028) |
| OC-IBTC | 0.62** | -1.03** | -199 | 0.51*** | 0.16 | -0.21** | 0.86** | -0.94*** | -0.93*** | 0.48*** |
| | (0.118) | (0.0340) | (0.241) | (0.174) | (0.135 | (0.073) | (0.315) | (0.174) | (0.115) | (0.056) |
| Constant | 1.49*** | 1.50*** | 1.47*** | 1.48*** | 1.44*** | 1.16*** | 1.19*** | 1.04*** | 1.25*** | 1.16*** |
| | (0.005) | (0.016) | (0.008) | (0.010) | (0.007) | (0.003) | (0.012) | (0.005) | (0.005) | (0.003) |
| Obs | 31198 | 4302 | 9456 | 7779 | 9661 | 41176 | 4467 | 9760 | 12652 | 14297 |
| $R^2$ within | 0.603 | 0.548 | 0.72 | 0.365 | 0.816 | 0.057 | 0.029 | 0.126 | 0.189 | 0.149 |
| $R^2$ between | 0.193 | 0.58 | 0.297 | 0.05 | 0.17 | 0.042 | 0.035 | 0.061 | 0.033 | 0.01 |
| $R^2$ all | 0.37 | 0.547 | 0.66 | 0.132 | 0.574 | 0.041 | 0.031 | 0.092 | 0.048 | 0.024 |
| Rho | 0.608 | 0.207 | 0.285 | 0.713 | 0.729 | 0.2 | 0.353 | 0.2 | 0.17 | 0.067 |
| | **Denmark** | | | | | **Slovenia** | | | | |
| R&D-IBTC | 0.013 | 0.15* | 0.68*** | 0.41*** | -0.10* | 0.32** | -0.43* | -0.13 | 1.38** | 0.66*** |
| | (0.052) | (0.062) | (0.17) | (0.1) | (0.043) | (0.101) | (0.199) | (0.122) | (0.425) | (0.163) |
| OC-IBTC | -0.50 | -0.81 | 2.44** | -1.54 | 0.26 | 1.72*** | -0.26 | 1.09* | 4.97*** | 4.82*** |
| | (0.359) | (0.453) | (0.828) | (0.95) | (0.259) | (0.425) | (1.054) | (0.487) | (1.456) | (0.856) |
| Constant | 1.15*** | 1.17*** | 1.23*** | 0.99*** | 1.14*** | 1.36*** | 1.38*** | 1.34*** | 1.53*** | 1.34*** |
| | (0.008) | (0.007) | (0.014) | (0.022) | (0.007) | (0.007) | (0.017) | (0.008) | (0.04) | (0.014) |
| Obs | 31467 | 4639 | 8463 | 6027 | 9805 | 9707 | 1622 | 4879 | 847 | 2359 |
| $R^2$ within | 0.088 | 0.377 | 0.111 | 0.074 | 0.325 | 0.433 | 0.485 | 0.635 | 0.309 | 0.229 |
| $R^2$ between | 0.011 | 0.21 | 0.05 | 0.025 | 0.033 | 0.243 | 0.346 | 0.443 | 0.104 | 0.337 |
| $R^2$ all | 0.041 | 0.295 | 0.075 | 0.032 | 0.1 | 0.300 | 0.426 | 0.475 | 0.142 | 0.276 |
| Rho | 0.275 | 0.13 | 0.301 | 0.321 | 0.108 | 0.607 | 0.357 | 0.591 | 0.549 | 0.429 |

Top markup firms above 90th percentile of overall distribution are excluded in Finland, Slovenia and Norway, and for high-tech manufacturing in Denmark.

*** significant at 1% level, ** significant at 5% level, * significant at 10% level

R&D-IBTC is generally positively related to markups in all counties and in all firms irrespective of technology type. The only significant negative effect is found for basic services in Denmark. In all countries, markup effects are highest in KIS, while also basic services have performed well in Slovenia. It can be indeed expected that the lags in raising profitability with new innovations are shorter in KIS than in manufacturing, i.e. in providing new services rather than new products. The recent improvement in markups in Slovenian manufacturing from R&D-IBTC has instead been negative.

OC-IBTC is the other cornerstone of better profitability for all countries but has general positive effect only in Finland and Slovenia, but not irrespective of the sector. This suggests that there has been also important reallocation of resources away from manufacturing to services that are not observed when considering changes in profitability within each sector. KIS industries have indeed increased at the rate of 6% per year in Finland since 2007.

Similar to R&D-IBTC, OC-IBTC drives markups in Slovenian services and including low-tech manufacturing. OC-IBTC can indeed be expected to be even more important in Central Europe, where the service sector has been traditionally larger than in Nordic countries. Denmark is more strongly

attached to than other Nordic countries to Central Europe (Piekkola, 2018), but does not stand out here as doing relatively better in improving profitability than other Nordic countries. It is also noteworthy that Norway and Finland also have on average larger OC-IBTC than Denmark or Slovenia. It is thus interesting to find that Denmark is the clear lead in how R&D improves markups but not at all when it comes to profitability. This suggests that there is some unexplained technological change that is not due to large investment in intangibles, which on the other hand does not show up in large markups.

All of these observations indicate that the Nordic countries and Slovenia are intangibles-driven economies and R&D- and OC-IBTC also have positive spillovers to MFP. IBTCs cause significant markups that can also explain the relatively good level of profitability made by their companies. Denmark appears efficient in IBTC in improving technological change but it does not materialize in higher profits.

# 5. Conclusion

Building on a recently developed occupation-based method for measuring intangible assets at the firm level, this paper examines how intangible capital work creates technological change measured by IBTC. Development in intangibles capital stocks per employee varies across the four countries. Both R&D and organizational capital have increased in Norway and Slovenia, while organizational capital has fallen over time in Finland and R&D capital has declined in Denmark.

MFP has grown moderately on average at highest rate 4.2% in Slovenia followed by 1.5% in Denmark, 0.9% in Norway and stayed about the same or decreased in Finland. However, this development hides in itself positive trends in R&D- and OC-IBTC when adjusting growth for firm size, indicating higher returns from intangible capital work. Technological change related to the improvement in the quality of intangible capital work has been the key to improved productivity in all countries where Norway takes the lead in high-tech and Denmark in organizational and marketing innovations. However, most of the R&D-IBTC is driven by large firms in manufacturing, indicating increases in productivity dispersions, whereas SMEs are usually the technological leaders in services. Goodridge and Haskel (2022) found a rapid decline in intangible capital deepening and TFP in UK since the financial crises, which may also relate to the relatively poor performance of SMEs in manufacturing.

The Nordic countries have been able to maintain their relatively strong competitive position also by investing in KIS, which continues to give growth opportunities. Slovenia is following this track of the Nordic countries well, but its KIS sector is still relatively small. Denmark is the clear leader in OC-IBTC in raising MPF. This suggest that OC-IBTC captures the possible advantages that Denmark has in organizational and marketing abilities especially in low markup firms. Finland has highest MFP, which is less backed by OC-IBTC over the years. R&D capital has also decreased.

All this shows the very heterogeneous way in which total factor productivity observed in many studies have decreased or varied across years after financial crises, whereas MFP has rather moderately increased. An additional reason is also the decrease in intangible capital stocks and markups in economic downturns. Innovation policy should clearly focus on the sector level technological change and on the reallocation of resources between them.

As countries mature in intangible investment, R&D-IBTC can be expected to play a stronger role in technological change and is consistently positive related to MFP. Moreover, OC-IBTC plays important role in technological change being about one half to that of R&D-IBTC on average. New innovations require organizational skills (management and marketing) and good access to markets. OC-IBTC growth proceeds less rapidly than R&D-IBTC, but was an important indication of technological change and important especially in Denmark, while rather improving the profitability of Slovenian services.

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# Appendix A. Measuring intangibles

Following Box A. 1 shows the intangible capital work in bold: **OC**=organizational capital occupation, **R&D**=R&D occupation, and **ICT**= ICT occupation

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

| | |
|---|---|
| 1 Managers<br>**112 OC** Managing Directors and Chief Executives<br>**12 OC** Administrative and Commercial Managers<br>**121 OC** Business Services and Administration Managers<br>122 Sales, Marketing and Development Managers<br>**1221 OC** Sales and Marketing Managers<br>**1222 OC** Advertising and Public Relations Managers<br>**1223 R&D** Research and Development Managers<br>13 Production and Specialized Services Managers<br>**131 OC** Production Managers in Agriculture, Forestry, and Fisheries<br>**132 OC** Manufacturing, Mining, Construction, and Distribution Managers<br>**133 ICT** Information and Communications Technology Services Managers<br>**134 OC** Professional Services Managers<br>14 Hospitality, Retail, and Other Services Managers<br>2 Professionals<br>21 Science and Engineering Professionals<br>**211 R&D** Physical and Earth Science Professionals<br>**212 R&D** Mathematicians, Actuaries, and Statisticians<br>**213 R&D** Life Science Professionals<br>**214 R&D** Engineering Professionals (excluding Electrotechnology)<br>**215 R&D** Electrotechnology Engineers<br>2151 Electrical Engineers<br>**2152 R&D** Electronics Engineers R&D<br>**2153 ICT** Telecommunications Engineers | **216 R&D** Architects, Planners, Surveyors, and Designers<br>22 Health Professionals<br>**221 R&D** Medical Doctors<br>**222 R&D** Nursing and Midwifery Professionals<br>223 Trad. and Complementary Medicine Professionals;<br>224 Paramedical Practitioners<br>**226 R&D** Other Health Professionals<br>23 Teaching Professionals<br>24 Business and Administration Professionals<br>**241 OC** Finance Professionals<br>**242 OC** Administration Professionals<br>243 Sales, Marketing, and Public Relations Professionals<br>**25 ICT** Information and Communications Technology Professionals<br>26 Legal, Social, and Cultural Professionals<br>3 Technicians and Associate Professionals<br>31 Science and Engineering Associate Professionals<br>**311 R&D** Physical and Engineering Science Technicians<br>312 Mining, Manufacturing, and Construction Supervisors;<br>313 Process Control Technicians<br>**314 R&D** Life Science Technicians and Related Associate Professionals<br>315 Ship and Aircraft Controllers and Technicians<br>32 Health Associate Professionals<br>**321** R&D Medical and Pharmaceutical Technicians<br>33 Business and Adm. Associate Professionals;<br>34 Legal, Social, Cultural Associate Professionals;<br>**35 ICT** Information and Communications Technicians |

GLOBALINTO estimates factor multipliers from Eurostat national accounts based on production activities in certain knowledge-intensive industries (KIS) to determine how value added is divided into labor costs, capital, and intermediate inputs. Factor multipliers are calculated as the average of

EU countries. The nominal value of intangible capital investment of type *IC* for firm *i* in year *t* is given by

$$P_{it}^{N} N_{it}^{IC} = A^{IC} M_{it}^{IC}, \text{ for } IC = \{R\&D, OC, ICT\}, \qquad \text{(a.1)}$$

where labor costs, $M_{it}^{IC}$, are multiplied by a total multiplier, $A^{IC}$ (0.7 in OC, 1.1 in RD and 0.9 in ICT), to obtain total investment expenditure on intangibles. Total multiplier demonstrates also the innovative share of IC occupations (0.4 in OC, 0.7 in RD and 0.6 in ICT) and not only the use of capital and intermediate inputs for one unit of IC occupation labor costs (1.76 in OC, 1.55 in RD and 1.48 in ICT). The parameter, $P_{it}^{N}$, is the price of each of the three types of intangibles. To estimate fixed values, we use the investment deflator for R&D, the innovation property investment deflator (which includes R&D, software, and database) for ICT and the labor costs weighted average of the producer price deflator over business services (NACE 69–73) for OC. The real stock, $R_{it}^{IC}$, of intangible capital is given by

$$R_{it}^{IC} = R_{it-1}^{IC}(1-\delta_{IC}) + N_{it}^{IC},\ R_{i}^{IC}(0) = N_{i}^{IC}(0)/(\delta_{IC} + g_{IC}), \qquad \text{(a.2)}$$

where $N_{i}^{IC}(0)$ is the initial investment, $R_{i}^{IC}(0)$ is the initial intangible capital stock, $\delta_{IC}$ is the depreciation rate, and $g_{IC}$ is the growth of the intangible capital stock of type IC (R&D, OC, and ICT) using the geometric sum formula. The initial investment, $N_{i}^{IC}(0)$, is the first 3-year average for the corresponding type of investment and the growth rate of all intangibles, $g_{IC}$, is set at 2%. The depreciation rate for organizational investments $\delta_{OC}$ is set at 20% following the survey by Lev et al. (2016) and paper by Squicciarini and Le Mouel (2012). Recent estimates of R&D depreciation rates are closer to the 15% relied on here than to the 20% figure used in Corrado et al. (2014). ICT investments are assigned a 33% depreciation rate.

# Appendix B. Industries by technology type and summaries

**Table B.1 Industries by technology type (firms with at least 5 employees on average in the selected industries)**

| Technology type | Main industries | Other | Value added shares in 2017, % | | | |
|---|---|---|---|---|---|---|
| | | | FIN | NOR | DEN | SLO |
| Top High technology manufacturing | Electronics 21 and pharmacy 26 | | 4.5 | 1.5 | 12 | 6 |
| High-middle technology manufacturing | Chemical 20, electrical equipment 27, machinery and equipment 28 | Motor vehicles 29, other transport 30 | 10.5 | 5 | 11 | 13.6 |
| 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 | 14.9 | 19.7 | 9 | 25.1 |
| 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 32 | 10.8 | 5.8 | 10 | 8.1 |
| 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 | 12.0 | 14.1 | 9 | 7.5 |
| ICT services | Computer programming, consultancy 62, information service activities 63 | | 7.3 | 4.7 | 4 | 2.5 |
| R&D services | Architectural, engineering 71, R&D 72 | | 3.8 | 4.5 | 8 | 2.2 |
| OC services | Legal 69, head office 70, advertising, market research 73 | | 3.1 | 3.7 | 4 | 1.8 |
| Basic private services | Wholesale trade 45-47, land transport 49, warehouse 52, accommodation, food and beverages 56, real estate 68 | Rental and leasing 77, travel agency 79 | 33.1 | 41.1 | 33 | 33.4 |

**Table B.2 Summary and IBTC**

| | Mean | Median | Std | N | Mean | Median | Std | N |
|---|---|---|---|---|---|---|---|---|
| | | | **Finland** | | | | **Norway** | |
| Value added/L | 81.2 | 58.7 | 531.0 | 106.9 | 108.0 | 80.5 | 386.0 | 228.0 |
| Employee | 38.4 | 11.0 | 227.0 | 106.9 | 44.6 | 12.9 | 241.0 | 228.0 |
| Total Capital/L | 247.0 | 127.0 | 1226.0 | 106.9 | 515.0 | 128.0 | 4037.0 | 228.0 |
| Output elasticity of employment (excl. IC work) | 0.767 | 0.803 | 0.139 | 89.9 | 0.887 | 0.899 | 0.130 | 228.0 |
| Output elasticity of capital | 0.175 | 0.149 | 0.105 | 44.4 | 0.148 | 0.125 | 0.098 | 228.0 |
| Output elasticity of relative quality of R&D work | 1.030 | 1.020 | 0.934 | 106.9 | 1.540 | 1.060 | 1.740 | 95.5 |
| Output elasticity of relative quality of OC work | 1.310 | 1.320 | 0.629 | 106.9 | 0.676 | 0.510 | 0.741 | 154.2 |
| Initial relative quality (wages) of R&D work | 1.340 | 1.270 | 0.420 | 21.4 | 1.320 | 1.300 | 0.217 | 106.3 |
| Initial relative quality (wages) of OC work | 2.010 | 1.910 | 0.580 | 21.4 | 1.570 | 1.520 | 0.240 | 184.4 |
| Relative quality of R&D work | 1.120 | 1.040 | 0.269 | 21.4 | 1.080 | 1.030 | 0.157 | 81.5 |
| Relative quality of OC work | 1.170 | 1.100 | 0.240 | 21.4 | 1.060 | 1.030 | 0.108 | 152.2 |
| R&D-IBTC | 0.027 | 0.004 | 0.057 | 21.4 | 0.045 | 0.003 | 0.086 | 81.5 |
| OC-IBTC | 0.022 | 0.007 | 0.035 | 106.9 | 0.011 | 0.003 | 0.019 | 152.2 |
| | | | **Denmark** | | | | **Slovenia** | |
| Value added/L | 122.0 | 81.9 | 4258.0 | 224.7 | 36.3 | 26.3 | 90.4 | 101.2 |
| Employee | 64.2 | 18.3 | 347.0 | 224.7 | 39.5 | 11.0 | 198.4 | 101.2 |
| Total Capital/L | 165.0 | 61.2 | 838.0 | 224.7 | 57.1 | 22.1 | 408.3 | 101.2 |
| Output elasticity of employment (excl. IC work) | 0.830 | 0.876 | 0.305 | 224.7 | 0.736 | 0.001 | 0.000 | 101.2 |
| Output elasticity of capital | 0.119 | 0.110 | 0.326 | 108.5 | 0.233 | 0.000 | 0.000 | 101.2 |
| Output elasticity of relative quality of R&D work | 0.894 | 0.834 | 0.561 | 88.0 | 0.843 | 0.001 | 0.002 | 35.4 |
| Output elasticity of relative quality of OC work | 0.352 | 0.338 | 0.295 | 109.1 | 0.219 | 0.000 | 0.001 | 50.5 |
| Initial relative quality (wages) of R&D work | 1.530 | 1.480 | 0.263 | 224.7 | 1.491 | 1.453 | 0.296 | 42.5 |
| Initial relative quality (wages) of OC work | 2.010 | 1.920 | 0.517 | 87.7 | 1.969 | 1.894 | 0.546 | 56.9 |
| Relative quality of R&D work | 1.120 | 1.060 | 0.182 | 87.7 | 1.060 | 1.041 | 0.341 | 35.3 |
| Relative quality of OC work | 1.040 | 1.020 | 0.067 | 108.5 | 1.038 | 1.005 | 0.524 | 50.4 |
| R&D-IBTC | 0.052 | 0.007 | 0.093 | 87.7 | 0.023 | 0.003 | 0.055 | 35.3 |
| OC-IBTC | 0.005 | 0.002 | 0.008 | 108.5 | 0.004 | 0.000 | 0.017 | 50.4 |

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

## Table B.3 Summary in MFP and markup estimation

| | Mean | Median | Std | N | Mean | Median | Std | N |
|---|---|---|---|---|---|---|---|---|
| | | | **Finland** | | | | **Norway** | |
| MFP | 6.2 | 6.1 | 1.0 | 32.4 | 4.5 | 4.5 | 0.8 | 52.9 |
| Markup | 1.4 | 1.4 | 0.7 | 32.1 | 1.3 | 1.2 | 0.4 | 43.9 |
| Value added/L | 102.0 | 70.9 | 280.0 | 32.4 | 121.0 | 95.5 | 249.0 | 52.9 |
| Employee | 166.0 | 44.0 | 555.0 | 32.4 | 95.3 | 26.4 | 310.0 | 52.9 |
| Employee excluding IC (Lnoic) | 141.0 | 36.3 | 493.0 | 32.4 | 76.8 | 19.3 | 269.0 | 52.9 |
| RD/L | 68.0 | 38.8 | 145.0 | 32.4 | 146.0 | 70.7 | 284.0 | 52.9 |
| OC/L | 28.5 | 18.0 | 44.0 | 32.4 | 41.2 | 29.3 | 43.2 | 52.9 |
| ICT/L | 15.3 | 4.7 | 37.2 | 17.2 | 38.8 | 11.3 | 58.0 | 23.0 |
| Tangibles/L | 286.0 | 226.0 | 419.0 | 32.4 | 480.0 | 30.0 | 3728.0 | 52.9 |
| Output elasticity of Lnoic | 0.550 | 0.558 | 0.054 | 32.4 | 0.563 | 0.538 | 0.041 | 52.9 |
| RD-IBTC | 0.022 | 0.000 | 0.002 | 32.4 | 0.031 | 0.000 | 0.002 | 52.9 |
| OC-IBTC | 0.008 | 0.000 | 0.002 | 32.4 | 0.009 | 0.000 | 0.002 | 52.9 |
| | | | **Denmark** | | | | **Slovenia** | |
| MFP | 4.9 | 4.9 | 0.6 | 29.0 | 1.4 | 1.4 | 0.6 | 84.2 |
| Markup | 1.1 | 1.0 | 0.4 | 28.7 | 32.8 | 16.4 | 25.5 | 105.7 |
| Value added/L | 112.0 | 90.4 | 187.0 | 29.0 | 36.8 | 10.4 | 187.0 | 119.0 |
| Employee | 166.0 | 49.0 | 681.0 | 29.0 | 34.4 | 9.8 | 177.0 | 119.7 |
| Employee excluding IC (Lnoic) | 136.0 | 39.4 | 591.0 | 29.0 | 2.7 | 0.0 | 0.0 | 105.7 |
| RD/L | 129.0 | 74.4 | 419.0 | 24.9 | 16.2 | 0.0 | 0.0 | 106.2 |
| OC/L | 19.9 | 15.4 | 19.7 | 23.3 | 8.6 | 0.0 | 1.7 | 106.2 |
| ICT/L | 21.6 | 7.0 | 41.1 | 10.1 | 3.1 | 0.0 | 0.0 | 106.2 |
| Tangibles/L | 74.9 | 10.3 | 392.0 | 29.0 | 32.9 | 0.0 | 4.2 | 106.2 |
| Output elasticity of Lnoic | 0.785 | 0.764 | 0.039 | 29.0 | 0.6 | 0.6 | 0.1 | 110.2 |
| RD-IBTC | 0.030 | 0.001 | 0.005 | 29.0 | 0.0 | 0.0 | 0.0 | 25.7 |
| OC-IBTC | 0.004 | 0.000 | 0.001 | 29.0 | 0.0 | 0.0 | 0.0 | 29.4 |

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

# Appendix C. Estimation of markups

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

$$\ln Y_{it} = \ln b_{0i} + b_{noIC} L_{noIC.it} + b_{IA} \ln\left(\sum_{IA} R_{it}^{IC}\right) + b_K K_{it} + b_Z' \ln Z_{it} + \ln e_{it}, \qquad \text{(b.1)}$$

where flexible workers $L_{noICit}$ are simply other than workers engaged in intangible capital work, and the estimation is done over about 63 NACE 2-digit industries. Following De Loecker and Warzynski (2012), the markup is given by

$$\gamma_{it} = \frac{b_{noIC}}{P_{it}^L w L_{noICit} / P_{it}^L Y_{it}}, \qquad \text{(b.2)}$$

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

Markup estimations use an instrumental variable GMM regression, where instruments are lagged values of the explanatory variables and productivity shocks are controlled by tangible investment lagged by up to two periods. The estimations are made separately on about 90 NACE 2-digit industries.

Figure 1 shows the development of markups over time with revenue-based weights on the firm level. The investigated period differs somewhat across countries. “Markup IC” denotes markups for intangibles labor, while “Markup noIC” denotes markups estimated by not separating any intangible labor costs from total costs, and not including the unmeasured IC investment in value added. “Markup noIC” is the approach of De Loecker et al. (2012) that uses total labor costs and non-time-variant output elasticities. While using the latter approach, the markups would exceed the markups observed in the USA by De Loecker et al. (2020) in Finland and Slovenia by being 1.6–1.7 over the period, but would be lower and below 1 in Denmark and Norway. In all countries, the true markup is much higher when excluding intangible capital work from flexible work labor costs and when unmeasured IC investment is included in value added.

The output elasticity of flexible work is estimated separately in 3-year periods (the last year uses data from the current and past 2 years etc. and in the estimation tangible investment is lagged up to 2 years). Finland has the longest observation period beginning in 1995, while the observations for the rest are for 1999–2019 in Demark, for 1999–2017 in Slovenia, and for 2008–2019 in Norway.