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Executive Summary

This paper analyzes innovative growth in firms of different size depending on technical change and market power and how structural capital of R&D and organizational capital (OC) interact with these. Structural capital is assessed from the related labor costs using a full register-based dataset of Finnish firms for the period 1999–2017 from Statistics Finland. Innovation-work biased technical change (IBTC) is analogous to skill-biased technical change and derived from the innovation labor participation weighted by relative returns of innovation labor. In the system estimation market power is found to be an important driver of productivity and profits, and independent of firm size or technology type. Our results suggest that the greatest barriers for good performance are not physical but rather tied to the efficient use of structural capital – especially organizational capacity can cause limits to enhance productivity. Productivity puzzle relates to decreasing markups over time, since IBTC has had opposite trend so that intangibles have become the major drivers of firm performance.

Profitable intangible investments and market power – barriers and opportunities for firms with different size

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1. Introduction

The objective of this study is to analyze how markup and technical change relate to higher productivity and profits. The core innovation inputs, such as research and development (R&D) and organizational capital (OC), are the outcomes of accumulated knowledge, while the quality of innovation work also creates innovation-labor-biased technical change (IBTC), which is our measure of technical change (Piekkola, 2020). The main aim of previous studies has been to explain aspects of firm performance, such as total factor productivity (Polder, Leeuwen, Mohnen, & Raymond, 2010), sales (Evangelista & Vezzani, 2010), value added (Battisti & Stoneman, 2010) or profitability (Cho & Pucik, 2005; Cozza, Malerba, Mancusi, Perani, & Vezzulli, 2012; Prajogo, 2006). Technical change-driven productivity changes, as in Ilmakunnas and Piekkola (2014), are considered here together with the accumulation of intangibles.

IBTC is similar to well-known skill-biased technical change and depends on the recruitment of intangible workers (Ilmakunnas & Piekkola, 2014) and their quality (Piekkola, 2020). In the first stage, quality is proxied by the relative compensation for innovation work. The production function estimates show the quality of innovation work at NACE 4-digit levels after distinguishing the contribution of intangible capital accumulation to productivity.

In addition to IBTC, organizations and technologies, such as proprietary software systems, and structural capital, digitalization and cooperation are considered inputs are part of innovativity. One related study by Polder et al. (2010) used the tripartite design to model OC, R&D 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, Schankerman, and Van Reenen (2013) and Syverson (2011).

Higher shares of innovation workers generate knowledge spillovers that affect growth in industries and regions (Acs, Braunerhjelm, Audretsch, & Carlsson, 2009; Audretsch & Keilbach, 2008; Audretsch, Keilbach, & Lehmann, 2006; Del Giudice, Scuotto, Garcia-Perez, & Petruzzelli, 2019). We consider these as the channels for technical change when the firm itself does have own innovativity. Some analyses follow the CDM tradition, starting from Crepon, Duguet, and Mairessec (1998), who used innovation inputs to determine innovation output and, in turn, productivity growth. The markups, IBTC and firm performance is here analyzed in a system estimation and thus not assuming one-way direction from structural capital to IBTC (innovations) and to production. Markups are separately estimated using production function method of De Loecker, Eeckhout, and Unger (2020) as the major determinant of firm performance. Intangible interact with market shares, create IBTC and have direct role to play in production. We thus analyze a system of markup determination, knowledge creation through R&D-IBTC, OC-IBTC and production which includes all these elements analyzed with cmp method (Roodman, 2011).

We exploit full employer-employee data of the total Finnish economy over the period 1999-2017 and available from Statistics Finland with remote access. We first show that markups have been decreasing over time, while technical change through IBTC has moved forward. A shift from increasing market shares and markups to more technological driven growth is evident. Some of the technology is embedded in the production itself so R&D affect performance at many levels. The puzzle of productivity slowdown is not supported given the major shift of IBTC upwards overtime, or we may rather speak of the puzzle of decreasing markups. R&D work-driven IBTC grew over time until 2017.

Section 2 contains a literature review, and section 3 provides the data analysis with markup and IBTC. Section 4 provides the results. Section 5 concludes.

2. Literature review

Micro- and macroeconomic studies offer strong evidence on intangible capital and productivity growth, see Thum-Thysen, Voigt, Maier, Bilbao-Osorio, and Ognyanova (2017) for a review. Structural capital here covers the organization and technology, such as proprietary software systems, so that R&D and organizational capital (OC) should be considered together. Piekkola (2020) refers to the management and accounting literature finding that intangibles that involve large discretion by management are more valued than others, such as R&D or purchased goodwill. These assets have a shorter technology cycle but may be better recorded in accounts (Wyatt, 2005). It is also clear that organizational capital is oriented toward quality, innovation and care of the environment (F-Jardón & Martos, 2009). The other dimensions of intangibles, such as ICT and cooperation, are linked to structural capital.

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). Caroli and Van Reenen (2001) argue that a higher skill level of the workforce tends to reduce the costs and increase the benefits of decentralization. Organizational innovations may relate to teamwork in production, supply chain management or quality-management systems (Damanpour, 1987; Damanpour & Evan, 1984) or to joint adoption of organizational innovation. Rexhaüser, Hottenrott, and Veugelers (2016), using the Mannheim Innovation Panel, find organizational change to augment the introduction of new environmental technologies. Bresnahan, Brynjolfsson, and Hitt (2002) combine organizational change with ICT use to create product innovation at the firm level.

Intangible workers represent a high share of personnel, approximately 10% in Piekkola (2020), and require decentralized decision-making processes at the level where intangibles are used. Kotey and Slade (2005) equally emphasize the important role of middle management in innovative firms. The literature also finds organizational innovations to be successful responses to the efficient use of product and process innovations (Caroli & Van Reenen, 2001; Damanpour, Szabat, & Evan, 1989; Piva & Vivarelli, 2002). We link these with product rather than process innovations because they are more likely to be radical and because process innovations have more ambiguous performance than product innovation (Bronwyn H. Hall, Mairesse, & Mohnen, 2010). Piekkola and Rahko (2019) find with similar Finnish data that product innovations alone rather than together with process innovations have the greatest effect on productivity growth.

Organizational investments can also support bureaucracy. As the firm grows larger, decision-making can become more efficient. However, entrepreneurial effort may be replaced by professional management that is more interested in following profit margins than innovation (Adams & Brock, 1986; Graves & Langowitz, 1993). There is a risk of the replication of information in the absence of centralized management (Greenan & Guellec, 1994). Therefore, cooperation and ICT are also needed. ICT is considered vital for information spread, which can improve relational capital and trust, and can support the collaboration of dispersed groups (Adamides & Karacapilidis, 2006; Cabrilo, Dahms, Mutuc, & Marlin, 2020). Therefore, ICT services and related development complement the general cooperation of the firm, which we relate here especially to the market relations of the firm.

Digitalization is a notable driving force for SMEs' knowledge-based strategies and can address numerous operational issues (Noori & Lee, 2006). The information and knowledge available online reduce costs for small firms and new entrepreneurs, but we assume that these effects are also captured by R&D.

Structural capital is input to innovations that enhance technological change, alongside market position and being needed in production Piekkola (2020) analyzes innovation-labor biased technical change IBTC separately at firm level and the related knowledge spillover is the average over firms weighted by their size (employment). IBTC is an exact measure on the quality of intangible workers, which also accounts for the shifts in the share of these intangible workers from total workforce. Given that intangible inputs cause high fixed costs there can be asymmetric effects. Existing knowledge spillovers signal large competition on prohibit entrance to the market, while given the decision to participate, incentive to invests large amount relative to existing resources are high with the expectation of larger market shares (Piekkola, 2020). For firms that do not have own innovative activity related to structural capital, it is assumed that industry level knowledge spillovers are rather necessary for knowledge to spread. The innovations used in the firms' principal operating industry have in general favorable effects as they effect the technology level of the industry. Firms are not rivals to knowledge intensive firms but complete them with their action. Thus, knowledge spillovers are included to affect the production facilities, while the absence of own structural capital has a negative effect on their market shares in the market.

Blundell, Griffith, and Van Reenen (1995) and Blundell, Griffith, and Van Reenen (1999) use as the knowledge spillover the count of innovations used in the firms' principal operating industry. Knowledge stock (G) is the depreciated sum of all past innovations of the firms. They argue that knowledge spillovers within industries indeed reflect rivalry of (close) competitors and they indeed find knowledge stock among producers of similar innovation to have negative effects effect.

Therefore, we indeed only measure firm’s own contribution to the industry IBTC, while knowledge spillover are accounted for other firms that do not have structural capital and which are in general a minority about 20% of all firms. Lucking, Bloom, and Van Reenen (2018) indeed separate spillovers which may increase the productivity of other firms that operate in similar technology areas, while the second type of spillover is the product market rivalry effect of R&D.

Our simplification can be justified on the grounds that literature on these two effects is scarce since it has been difficult to distinguish the two types of spillovers using existing empirical strategies. Aghion and Howitt (1992) or Spence (1984). Keller (2004), Klenow and Rodriguez-Clare (2005) and Jones (2005) all have recent surveys of the literature on under-investment in R&D. If product market rivalry effects dominate technology spillovers, the conventional wisdom that there is under-investment in R&D could be overturned. Bloom, Schankerman, and Van Reenen (2013) consider latter as business steeling of rivals. We believe

Market value should be increasing in the size of the pool of R&D spillovers from technologically similar firms and decreasing in the size of the pool of spillovers from product market rivals (SP ILLSIC). There is clearly going to be some feedback mechanism between market power and innovation - a successful innovation is likely to lead to an increase in a firm's market share. In addition, any representative sample of companies is likely to display a wide range of innovative activity. The majority of companies make few innovations while a small group are involved in a high level of activity

Although SMEs lack in financial resources and technical capabilities, SMEs are the largest number of companies in an economy (Gassmann, Enkel, & Chesbrough, 2010), and the source generating the majority of new jobs (Edwards, Franks, & Storey, 1994). Due to its importance, SMEs and entrepreneurial firms are key drivers for national economies (Wolff & Pett, 2006) (Wolff and Pett, 2006). In the European Union, SMEs generate a gross value added share that encompasses about 50% of the European economy (see Eurostat on statistics on small and medium-sized enterprises).

SMEs have generally lower market shares and lower markups, while large firms with usually notable market share have more capacity to introduce new products and services to the market. SMEs that decide to innovate are taking greater risks and therefore can be suggested to be less profitable. The current literature contains a research gap resulting in the inability to fully explain why low-technology rather than high-technology firms gain productivity from process innovations, as described by Bronwyn H. Hall, Lotti, and Mairesse (2009); see also Cohen and Levinthal (1989). One suggested explanation is that research and development (R&D) provides firms the absorptive capacity to recognize the value of new information, assimilate this information, and learn from industry leaders. However, SMEs with a low market share and young firms are also likely to be suppressed by adjustment costs, financing frictions and uncertainties, leading to large fixed costs. Piekkola and Rahko (2019) show that these costs may lead to a "negative selection mechanism" in innovation activity, and firms with low initial productivity and profitability invest only in innovations with the highest productivity growth. Large fixed costs imply that these innovations are not necessarily profitable. SMEs are indeed heterogeneous and not all high-growth SMEs promote growth and knowledge spillovers in a large scale.

Innovation-based SMEs are faced with Schumpeterian growth, where firms need market power to reap profits from future innovations. The innovation of SMEs has positive relation between organizational performance (Oke, Burke, & Myers, 2007; Rosenbusch, Brinckmann, & Bausch, 2011). Innovations are performed to earn abnormal profits but are also subjected to creative destruction (Schumpeter, 1942, 1947). Innovations lead to out-of-equilibrium conditions that increase profitability above the average or result in failure (Antonelli & Scellato, 2011).

Register-based data are particularly important for analyzing SMEs and low-market-share small firms, which are not entirely covered in R&D survey data. Broad R&D and other ICs are thus also evaluated based on innovation work using the methodology from the Innodrive 7th framework project (FP7); see Piekkola et al. (2011), Piekkola (2016), and the Organization for Economic Cooperation and Development (OECD) study by Squicciarini and Le Mouel (2012). This is consistent with Hall et al. (2009), who argue that a broader set of ICs is important for smaller firms because formal R&D inputs provide a very incomplete picture of their innovation efforts. These authors consider training, technology adoption and sales of products new to the market or firm essential components of downstream ICs. Here, organizational capital (OC) includes marketing, advertising and brand management, and some of these after-sales services are used to apply innovations in the market; see Corrado, Haskel, Jona-Lasinio, and Iommi (2014).

3. Data analysis with markups and IBTC

Markup estimation

It is expected that innovation inputs such as intangibles are firm-specific capital that affects competitive positive through markups. We first derive sector specific markups and how they vary over time. The production function method by De Loecker, Eeckhout, and Unger (2020); (De Loecker & Warzynski, 2012) is fairly straightforward. The idea is that the gap between output effects and value added share of employment costs of flexible workers gives a good estimate of markup. Parikka (2021) develops the method further by excluding from flexible work intangible work. Intangibles include fixed costs rather than being flexible and returns materialize over longer period (intangible work relates here to OC (management, marketing), R&D and ICT occupations listed in Box A.1 in Appendix A). The markup is given by

$$\gamma_{it} = \frac{\beta}{(\frac{P^L_{it}L_{it}}{P_{it}Y_{it}})}, \qquad (1)$$

where β denotes the output elasticity of non-innovative labor input using real values and $P^L_{it}L_{it}/P_{it}Y_{it}$ is the nominal share of expenditures on non-innovative labor input in value added (i.e. labor costs net of those for innovative work in current production per value added). The output elasticity is allowed to vary by nine technology types of industries and over time with moving average of seven years in 1995-2017 (technology types are based closely on EUROSTAT classification of technology types: production: high technology, high middle-technology, low middle-technology, low technology, services: KIS, ICT, R&D, OC, other). The elasticity of labor is calculated using moving average of time over seven periods using GMM estimation of log form of production function with lagged explaining variables as instruments. The excluded innovation work is 40% of management and marketing work and respective shares increase to 70% for R&D work and 60% for ICT work (see Table 1 later). Time allocation to intangible work is then about 10-15% of all work. Bronwyn H Hall and Mairesse (1995); Schankerman (1981) similarly show that IC work should be excluded from the employment figures to avoid double accounting. The expenditures share of labor varies by firm as well as the output elasticities by technology type and over years (the estimation period is 1995-2017).

We follow Blundell et al. (1999) and market share as one determinant of markups is the company's sales divided by total industry sales, which we apply here at 4 digit level. Market share also with interactions to intangibles are the major determinants of markup that in turn affects firm performance.

IBTC estimation

Structural capital also promotes new innovation that create technical change. However, innovation data is based on survey data, we want to compare widely firms of different size and by technology type. Technical change is evaluated from production function estimation. The “final” good of consumers is produced here by perfectly competitive firms using inputs: quality adjusted labor $A(L_O, L_R)L$, R&D and OC with the Cobb-Douglas production technology (Piekkola, 2020).

$$Y_t = (A(L_{OC}, L_{R\&D})L_Y)_t^{\alpha_L} \; K_t^{\alpha_K} R_t^{\alpha_{R\&D}} O_t^{\alpha_{OC}}, \qquad (2)$$

where Y_t is the value added in period t, A_t is a parameter that reflects the productivity of the OC and R&D labor inputs in that period and $\alpha_L = 1 - \alpha_L - \alpha_{R\&D} - \alpha_{OC}$. AL_{Yt} refers to the economy's effective labor supply of labor L_{Yt} engaged in production (excluding time spent on intangible investment), where the quality A_t creates IBTC depending on the time spent in intangible investment. K_t is the sum of the stock of buildings and machinery and equipment (accumulated value of respective investment with 10% depreciation of machinery and equipment and 3% depreciation of buildings).

The improved quality of innovation work increases the returns to innovation relative to the returns of other firms in the industry. IBTC depends on the share of workers engaged in innovation labor in addition to the gap between the existing skills of innovation workers and all workers an average so that the first term in production function (1) is written as:

$$A(L_{OC}, L_{R\&D})L_Y = \left(\left(\frac{a_{R\&Dt} L_{R\&Dt}}{\bar{a}_{Lt} L_t} + \frac{a_{OCt} L_{OCt}}{\bar{a}_{Lt} L_t} \right) + \frac{L_{Yt}}{L_t} \right) L_t, \qquad (3)$$

where $a_{R\&Dt}$, a_{OCt} are the quality of innovation workers relative to the average quality $\bar{a}_{Lt}$ of all workers in the firm (subindex for firm i is not shown here) and $L_t = L_{Yt} + L_{R\&Dt} + L_{OCt}$ is the total labor force including the time spent on intangibles. High investment in research not only affects output but also brings the firm more qualified researchers with a higher probability of successful innovation.

Successful innovation depends on the share of workers engaged in innovation labor and on the gap between the existing skills of innovation workers and all workers, on average, following the Schumpeterian growth proposed by Aghion, Harris, Howitt, and Vickers (2001).

We are interested in IBTC for total workforce L_t, and the terms in the brackets can be rewritten as:

$$\frac{a_{R\&Dt}L_{R\&Dt}}{\bar{a}_{Lt}L_t}+\frac{a_{OCt}L_{OCt}}{\bar{a}_{Lt}L_t}+\frac{L_{Yt}}{L_t}=\left(\frac{a_{R\&Dt}}{\bar{a}_{Lt}}-1\right)\frac{L_{R\&Dt}}{L_t}+\left(\frac{a_{OCt}}{\bar{a}_{Lt}}-1\right)\frac{L_{OCt}}{L_t}+1 \qquad (4)$$

$(A(L_{OC},L_{R\&D})L_Y)_t^{\alpha_L}$ in (1) using (3) is then in log form approximated by

$$\alpha_L \ln L_t+\alpha_L\left((a_{Rt}/\bar{a}_{Lt}-1)L_{Rt}/L_t+(a_{Ot}/\bar{a}_{Lt}-1)L_{Ot}/L_t\right), \qquad (5)$$

where the approximation in log form is $ln\left((a_{R\&Dt}/\bar{a}_{Lt}-1)L_{R\&Dt}/L_t+(a_{OCt}/\bar{a}_{Lt}-1)L_{OCt}/L_t+1\right)\approx$ $(a_{R\&Dt}/a_{Lt}-1)L_{R\&Dt}/L_t+(a_{OCt}/a_{Lt}-1)L_{OCt}/L_t$ given that the first two terms are not too far from zero. IBTC increases depending on the improvement in the quality of labor and the increase in the share of IA workers. The concept of "fishing out" states that good ideas are used first, so improved relative quality of innovation workers $a_{IAt}/\bar{a}_{Lt}$, $IA=R\&D,OC$ is needed to produce new innovations.

The estimation follows the preferred method in Piekkola (2020), using relative wages as first-stage proxies for relative quality, while earlier studies, such as those of Hellerstein, Neumark, and Troske (1999) and Ilmakunnas and Piekkola (2014), proxy the relative productivity of various worker types by their labor shares alone, thus holding $a_{IAit}/\bar{a}_{Lit}$ as an unknown parameter. More precisely, IBTC is first approximated, proxying the relative quality of work $a_{IAit}/\bar{a}_{Lit}$ by wage shares $w_{IAit}/\bar{w}_{Lit}$, with w_{IAit} as the average compensation for innovation work of type IA in firm i and $\bar{w}_{Lit}$ as the average compensation for all work in the firm. Wages for IA workers and wages for all workers are measured from the sum of regular hourly earnings divided by the number of workers in each firm i and year t.

Part-time workers' labor input is assumed to be 2/3 that of full-time workers. The compensation ratio $w_{IAit} / \overline{w}_{Lit}$ of each firm is also set within the 1st and 99th percentiles of the overall distribution in the data. The industry production functions are estimated in each NACE-3 digit industry j in the following log form using (2) and (5):

$$\ln Y_{it} = \alpha_{Lj} \ln L_{it} + \sum_{IA,i\in j} \alpha_{IBTC,IAj} (w_{IAit} / \overline{w}_{Lit} - 1) \frac{L_{IAit}}{L_{it}} + \alpha_{IAi} \ln IA_{it} \\ + \alpha_{Kj} \ln K_{it} + \alpha_{Zj} \ln Z_{it} + \ln e_{it} \quad , \qquad (6)$$

where Z_{it} represents the controls (industry and year dummies), e_{it} is the residual. From (6) $\alpha_{IBTC,IAj} (w_{IAit} / \overline{w}_{Lit} - 1) = \alpha_{Lj} (\hat{a}_{IAit} / \hat{\overline{a}}_{Lit} - 1)$, so the adjusted relative productivity is $\hat{a}_{IAit} / \hat{\overline{a}}_{Lit} = \alpha_{IBTC,IAj} (w_{IAit} / \overline{w}_{Lit} - 1) / \alpha_{Lj} + 1$. If α_{IAj} is found to differ from α_{Lj}, we know from (6) that the difference must be because relative wages $w_{IAit} / \overline{w}_{Lit}$ do not reflect true productivity differences. Thus, we calculate a new $\hat{a}_{IAit} / \hat{\overline{a}}_{Lit}$ given that $\alpha_{IBTCj} = \alpha_{Lj}$. Here, $\partial \hat{a}_{IAit} / \hat{\overline{a}}_{Lit} / \partial \alpha_{IBTC,IAj} = \left(w_{IAit} / \overline{w}_{Lit} - 1 \right) / \alpha_{Lj}$, where the quality of innovation labor increases with relative compensation in firm $\hat{a}_{IAit} / \hat{\overline{a}}_{Lit}$. IBCT is, thus, firm- and time-varying.

We also analyze knowledge spillovers that are industry specific. "Fishing out" of existing ideas may lead to negative spillovers since the technology is already used by others. The estimations are performed separately in each three-digit industry. The respective knowledge spillovers created by firms through IBTC in IA in industry j are given by

$$Spill_{IAjt} = \sum_{i\in j} \frac{L_{it}}{L_{jt}} (\frac{L_{IAit}}{L_{it}} (\hat{a}_{IAit} / \hat{\overline{a}}_{Lit} - 1) , \qquad (7)$$

where $\hat{a}_{IAit} / \hat{\hat{a}}_{Lit}$ was from the estimation of (6). Aggregation uses each firm's labor share in industry j as weights. The contribution to knowledge spillovers thus depends on the relative size of the firm.

The EU Horizon 2020 Globalinto 2019-2022 project identifies the structural capital of R&D and OC using occupational data. ICT is from ICT-related services and experts. After elaboration of the IA labor input from the related occupations, the second task is to evaluate the worktime share spent on innovative work. Finally, overheads should cover other factor inputs, such as intermediate and tangible inputs used in the construction of IA investment. These own-account IAs are assumed to be produced with a similar share of factor inputs as in IA-producing industries, such as O-producing business services (Legal and accounting activities M69, Head office M70, Architectural and engineering activities M71, Advertising and market research M73). The factor multiplier includes half of the intermediate inputs and all capital inputs per unit of labor costs given that IA-producing industries are more intermediate input-intensive than other industries, on average. The method is analogous for measuring "overheads" in OECD (2010), a method applied to evaluate "software and database expenditures" in ICT from related labor costs. [1] Real expenditure-based investment N_{IA}^{Y} of type IA = OC, R&D, ICT is given by (firm i, industry j and year t suppressed):

$$P^N N_{IA}^{Y} \equiv z^{IA} l^{IA} P^{IA} W^{IA}, \tag{7}$$

[1] The Office for National Statistics (ONS) evaluates ICT factor input from 72.2. industry (Research and experimental development on social sciences and humanities) and not from J62-J63 (Computer programming, consultancy and related activities and information service activities), as done here. Intermediates are further deducted by those used for resale without further processing, road transport, computer services, advertising and marketing costs and depreciation of vehicles. They are added by total taxes and levies and total depreciation. Estimation of the rate of return on capital is excluded. This yields a nonlabor cost share of 80%, which is close to that observed by (Chamberlin, Clayton, & Farooqui, 2007).

where z^{IA} is the time invariant factor multiplier, l^{IA} is the innovation labor share of type IA and W^{IA} is the labor cost investment of type IA (total annual earnings per employee including performance-rated pay, extra for overtime hours, etc.). The benchmark factor multipliers follow Globalinto to represent the entire EU27 area from IA-producing upstream industries. The shares l^{IA} are considered the same in all countries, and the combined multiplier $z^{IA}l^{IA}$ is 1.55 for OC wage expenses, 1.53 for R&D wage expenses, and 1.7 for ICT wage expenses. Table 1 summarizes the combined multiplier $z^{IA}l^{IA}$ (the product of the share of effort devoted to IA production and the factor multiplier).

Table 1. Combined multipliers for OC, R&D and ICT

	OC	R&D	ICT
Employment shares l^{Y}	30%	50%	50%
Factor multiplier z^{IA}	1.55	1.53	1.7
Combined multiplier $z^{IA}l^{IA}$ (rounded)	45%	77%	85%

Appendix A provides a detailed description of the innovative work coding in IA work. Depreciation is 20% for OC, 33% for ICT and 15% for R&D. The initial value of IA stock is determined according to the geometric formula IA investment (the average over the first three years) divided by the sum of depreciation + 2% (the assumed annual increase in IA investment per year).

System estimation of firm performance

Our model differs from stepwise estimation like CDM introduced by Crépon, Duguet, and Mairesse (1998) by using a system estimation. Markup and profitability equations are estimated as a system with cmp command in Stata (Roodman, 2011). CDM is an empirical structural model that analyzes the innovation patterns of firms. In the context of the Porter hypothesis, Marin (2014) and Van

Leeuwen and Mohnen (2017) have applied the CDM model. The system estimates the firm's decision regarding improving markups. We measure R&D using labor costs, which are more widely available in 84% of firms than reported R&D investments, see Box A.1 in Appendix A.

Our first explained variable in the system are markups over flexible labor costs, R&D- and OC-IBTCs as described above, while the ultimate goal is to improve productivity and generate profits. Productivity is measured by labor productivity and profitability by operating profits per employee as described below. Net incomes would not be used since it would include one-time expenses and gains, which makes it harder to compare a company's performance with its competitors at any single period. Operating profit includes user costs of R&D, OC and ICT (which does not substantially affect the results). We also do not evaluate amortization but include net financial costs. Our measurement is hence about value added created in the economy and to the degree that it will generate revenue for shareholders. It still does not cover the (uncertain) depreciation of intangibles but which justifies the high enough markups in innovative business, as will be evident also here.

The modeling of the innovation value chain and the literature on organizational innovations linked to other innovations lead to the following hypotheses for our empirical analysis:

1. Structural capital, such as R&D and OC, are important drivers of market power and productivity irrespective of firms size.

2. IBTC is the other source of innovativity through high-quality innovation work, which is needed to avoid "fishing out" and improves both productivity and profitability irrespective of firms size

3. Innovation activity such as investment into structural capital and quality of worker that improves productivity also lead to higher profitability irrespective of firms size.

The first hypothesis concerns the importance of the accumulation of innovation inputs for productivity growth. Firms may cooperate, e.g., when they are part of a group, have a large amount of OC, or use digital tools to spread and receive information. The second hypothesis is about the need to have a new high-quality innovative input when the best innovations have already been fished out. Here, IBTC measures the relative quality of innovation work in the firm to the average knowledge available. The third hypothesis concerns the innovation value chain. The third hypothesis measures the independency between productivity, and profitability, again by firms size.

4. **Results**

Analysis covers private sectors except for finance, construction, public administration, health, other services (Nace S, T, U, X). In IBTC estimation based on (6) an important part of the approach is to check for outliers since the wage ratio can vary from zero to infinity. We restricted in data to firms having at least some structurally intangible capital (OC or R&D in any year) (155 thousand firm-year observations with an average around 6500 firms per year). In addition, in small firms R&D workers are not necessarily the better paid, in which case these observation with relative lower R&D wages are ignored. For all firms it can also be the case that intangible capital workers are les paid than average workers, in which case we use as the average wage ration existing in Nace 4-digit industries. Even after this correction the wage ratios are set to be within 5th and 95th percentile of the overall distribution. The data include additional estimations for the relevant two-digit industry if the NACE 4 observations are too few in the first run (with less than 1000 observations). Knowledge spillovers are calculated as the employment-weighted sum of IBTC of all firms in the industry (except the firm's own effect).

Table 1 shows the summary of variables and the equivalent by firm size are reported in appendix.

Table 1. Summary

	Mean	Q1	Median	Q3	Standard deviation	Observation
Value added	309	43.6	62.6	89.3	6679	183455
Operating profit/L	51.7	14	31.4	58.1	88.1	183455
Markup	1.26	0.826	1.13	1.56	0.632	170125
Market share	0.0294	0.00112	0.00342	0.014	0.0963	182503
R&D-IBTC	0.0452	0.000426	0.00338	0.0171	0.141	132202
OC-IBTC	0.00311	2.07E-05	0.000369	0.00211	0.012	104425
Employee	63.2	13	21	41.7	235	183455
Employee not IA	58	12.3	19.8	38.8	217	183455
R&D/L	68.6	15.4	33.9	72.2	312	132973
OC/L	27.5	8.13	15.9	30.3	74	105123
ICT/L	17.6	2.03	4.77	11.6	73.7	48318
K/L	201	11.9	73.9	214	1547	183455
Export/Sales	0.0769	0	0	0.00507	1.3	183455
R&D subsidy dummy	0.0216	0	0	0	0.145	183455
R&D wage/ Avg wage	2.01	1.58	2.16	2.34	0.464	81472
OC wage/ Avg wage	2.21	1.62	2.28	2.75	0.641	78405
R&D work relative proo	1.12	1.01	1.05	1.12	0.246	81466
OC work relative prod.	1.04	1	1.02	1.05	0.182	78393

The focus on the sample data is on small firms with 126065 firm-year observation and median firms with 54152 firm-year observations, while large firms consist of 6990 firm-year observations in the estimation sample. The median number of employees in the firm is 21 (473 in large firms, 55 in median firms with 30-249 employees, 16 in small firms).

The average markup is 26% (26% for large firms, 42% for median firms and 25% for small firms from Appendix A) The median markup up is 13% (30% for large, 14% for median and 12% for small firms from Appendix A). The median value of operating profit per employee is 22.5 thousand € per employee (€2015 producer prices). The median value of value added per employee is 62.6 thousand € per employee. The median value of R&D is about 34 thousand € per employee in firms and over 80% of firms have it, while OC per employee is 16 thousand € per employee. Median ICT per employee is 4.8 thousand € per employee, but median value is 9.5 thousand € per employee in small firms. At median values small firms are more intangible intensive than larger firms.

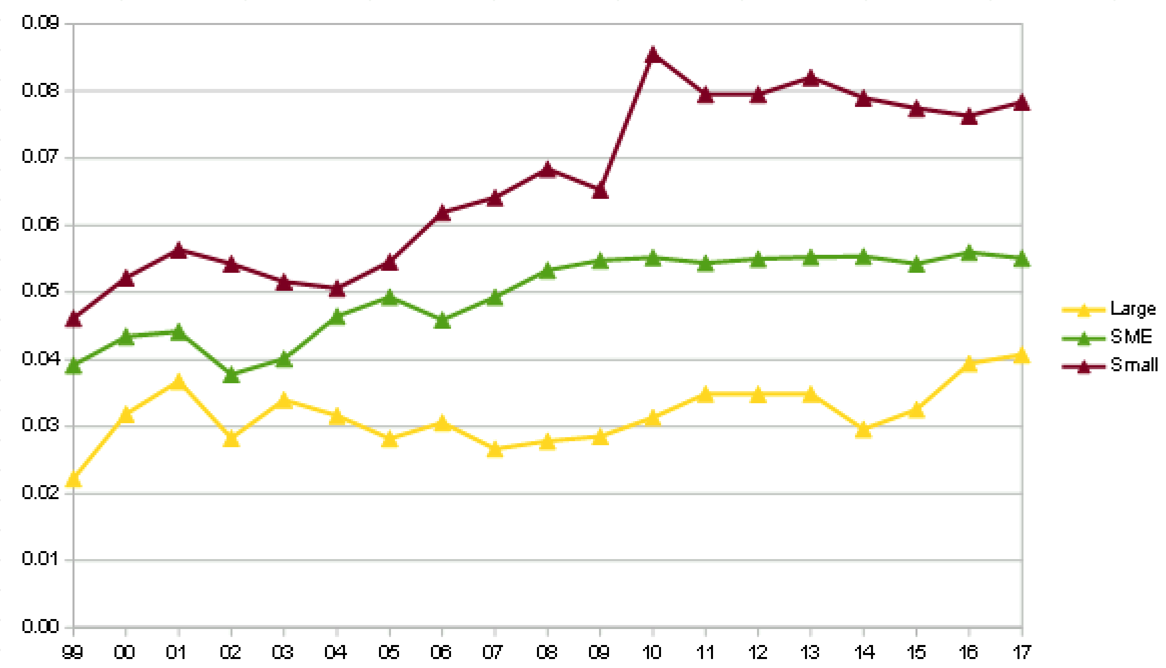
Organizational capital and ICT investments are usually even larger subcategories of intangible investment in macrolevel analysis (Van Ark et al. 2009, Bloom and Van Reenen 2010, Piekkola 2016). About 80% of large firms and half of median have either OC or R&D so R&D-IBTC and/or OC-IBTC can be estimated. Only 20% of small firms have either one. Proxying R&D-IBTC by 4-digit industry R&D spillover by in the firms that do not have R&D seems to work nicely as coefficients are must the same for small firms than in other firm size classes. Median R&D-IBTC is then also increasing in firm size (Appendix A Table A.1-A.3). Median OC-IBTC is instead decreasing in firm size and therefore found more important factor for performance in other than small firms. It should be noted in measuring IBTC we had to polish from the data the low-skill R&D employees that have very low wages compared to the average level in the small firms.

IBTC is performed separately in each 218 NACE 4-digit industries and for firms with at least 10 employees, on average (270 thousand firm-year observations in the original data extending to years 1995-2017). The initial relative quality of innovation workers relied on the relative wages of innovation workers. In the sample the median OC worker is paid 2.2 times and R&D worker 2.1 more than average workers. These ratios are based on annual earnings per employee adjusted for part time employment.[2] In Table 1 the estimated relative quality of innovation workers varies roughly around unity, but with noticeable standard deviation of around 1.6-1.9 and a positive trend overtime, as seen later in figure xx. IA accumulation already captures much of the average effect on the quality of intangibles.

[2] IBTC is evaluated separately in each Nace 3-digit industry in longer period 1995-2017. The median output elasticity of employment is approximately 61%. The median output elasticities are approximately 5-7% for R&D and 6-8% for OC.

The average value of R&D-IBTC is 4.5% and two times standard deviation is 24% so productivity effect varies a lot across firms. Figure 1 shows the development of R&D-IBTC and related spillovers in the full sample. Spillover is the employee weighted average of R&D-IBTC over the firms in each Nace 3-digit industries (around 180 industries)

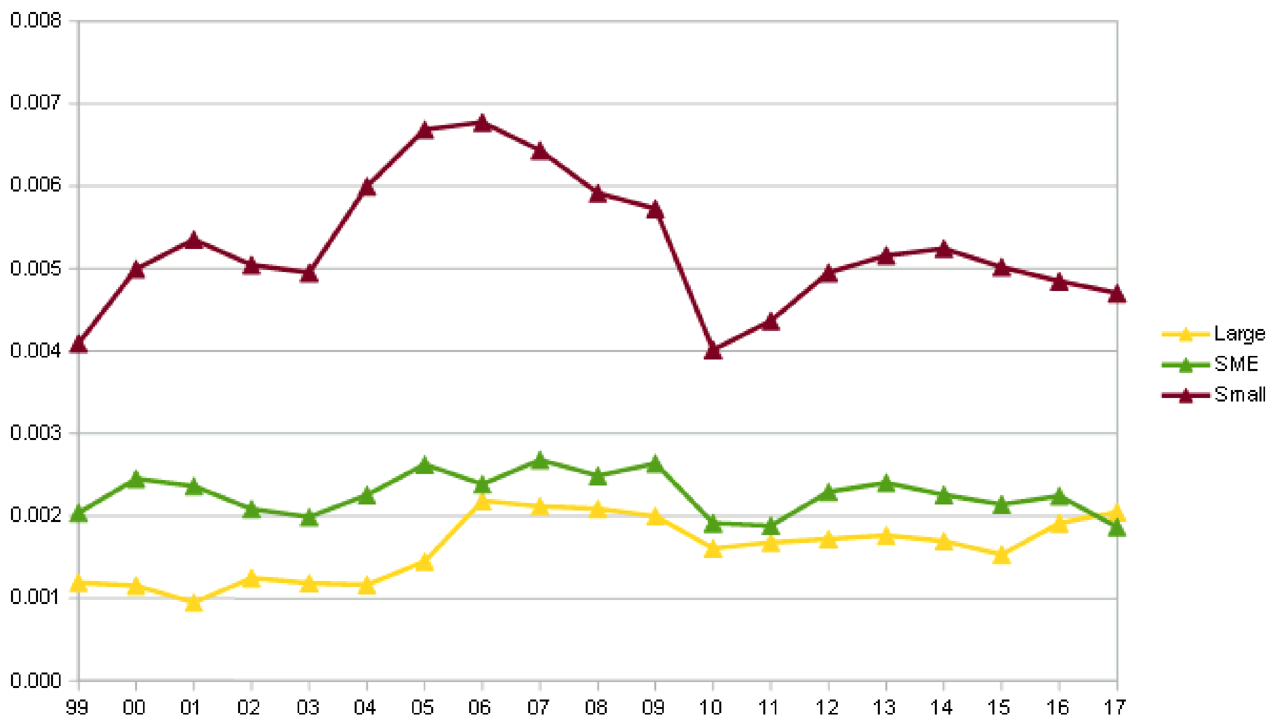
Figure 1 R&D-IBTC 1999-2017



The average R&D-IBTC has increased until 2008 or until 2010 for small firms (the rise would be less steep for R&D spillovers, which are firm size weighted average of the firms). These results show that especially small firms with less than 30 employees and median firms in the range 30-249 employees have become relatively more innovative over time; at least those that have R&D capital. One possible explanation for the revival of R&D-IBTC in small firms since 2010 is the digitalization and new small firms established after the sizing down of Nokia operations and staff in Finland. Moreover, R&D-

IBTC was relative stagnant in 2004-2015 for large firms. The average value of OC-IBTC is 4.5% and two times standard deviation is 24% so productivity effect varies a lot across firms.

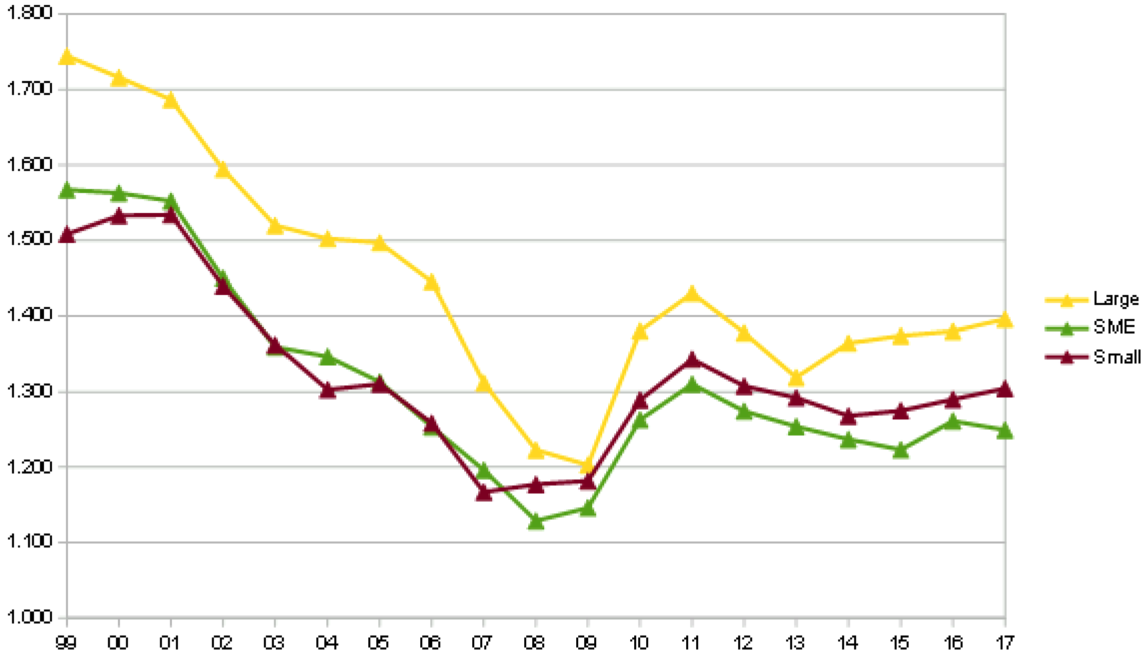
Figure 2 OC-IBTC in full data from 1995-2017



It is seen that OC-IBTC decreases in firm size and is most volatile for small firms. One reason for the difference is that managerial positions are relative more important than in larger firms, where organizational competence can be distributed more widely in administration and are also more likely owners of the firm. The drastic drop for small firms in 2010 may also be partly measurement error as occupational coding changed in 2010, so that part of workers in OC were reclassified by ICT workers.

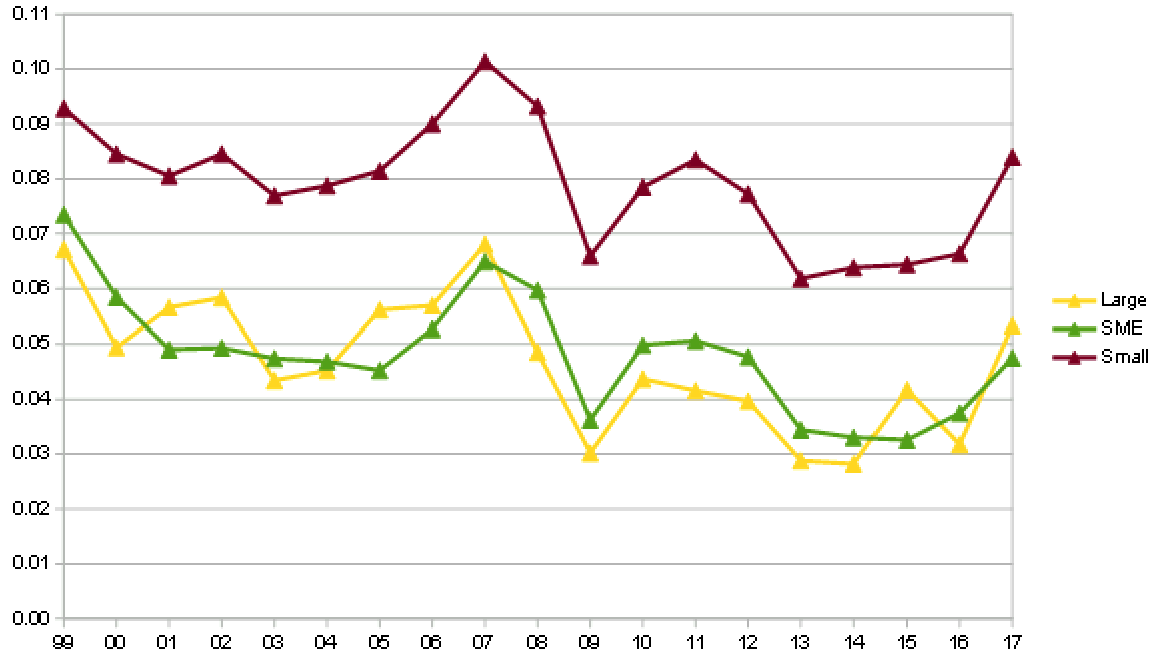
Following figures shows the development of average markups in our sample firms

Figure 3. Markups by firm size



Markups were very high in 1999 especially for large firms, but dropped during the depths of fiscal crisis in 2009 to 12-20%. The economy is described by a deep drop in profitability in the financial crises year 2009 as GDP dropped in Finland by 8%. It is of interest to contrast these figures to the development of marginal net returns, where the denominator is value added instead of sales to better reflect the value creation ability of the firm based on intangibles. It is also seen that markups are one period ahead of shifts in R&D and OC-IBTC. Changes in market shares are expected to precede this and lagged with one period. Following Figure 4 shows that operating profits per employee have had a decreasing trend s over the time, but with recent recovery.

Figure 4. Operative profit per employee by firm size



In our analysis small firms have the highest operating profit per employees that also variates over the business cycle more than for other firms. The recovery since 2009 has been heterogeneous and we can also see the decrease in operating profits per employee at its lowest level since 2012.

In what follows, we analysis markups, IBTCs and labor productivity in a system, where markups are explained also be independent factors and work as one determinant of marginal net incomes. The instruments for identifying markups from IBTC and productivity are exports per sales. Additional identifying factor is market shares which is also interacted with interaction to structural capital. Firms with strong structural capital such as R&D and OC should be more able to sustain competition or can be the leaders in the introduction of new technology in the industry. ICT per employee is also considered as general purpose technology affecting markups, since it helps to build relations to customers, to get market information and to introduce new products and services to market. All of this affects can affect the price of products sold and services provided so the decrease in producer prices would be lower.

R&D-IBTC and OC-IBTC are identified by respective intangible inputs and related innovative work. Moreover, R&D-IBTC is identified by R&D subsidy dummy and further from OC-IBTC by including tangible capital per employee. R&D activity helps in more efficient production, which can lower physical capital investment costs. As discussed, R&D or OC spillovers can also imply that rivals are relatively competitive. We have these to be still the source of technological knowledge when firm has not own R&D or OC activity if only available at the considered 3-digitu industry level. For other firms the possible negative rivalry effect via R&D and OC spillover lead to its omission (and also subject to multicollinearity). Table 2 shows the system estimation of the four equations that includes productivity equation.

Table 2. System estimation of markups, IBTCs and productivity by firm size

Markup	All	Large	Median	Small
Market share t-1	-0.5204***	-0.8922**	-0.8263***	-0.3222
	(0.1272)	(0.2851)	(0.2042)	(0.2301)
ICT/L	0.1465***	0.1447	0.2039***	0.1642**
	(0.0418)	(0.1167)	(0.0601)	(0.0616)
Market share, R&D/L t-1	0.2532***	0.2484***	0.2499***	0.2063***
	(0.0314)	(0.0611)	(0.0582)	(0.0541)
Market share, OC/L t-1	0.0390***	0.0706***	0.0574***	0.0169***
	(0.0033)	(0.0119)	(0.0053)	(0.0043)
K/L	0.0463***	0.0218	0.0397***	0.0457***
	(0.0021)	(0.0148)	(0.0038)	(0.0025)
Employee	-0.0811***	-0.0595*	-0.0375***	-0.2083***
	(0.0042)	(0.0257)	(0.0095)	(0.0073)
Export sales share	-0.0138***	-0.0197***	-0.0150***	-0.0116***
	(0.0005)	(0.0026)	(0.0009)	(0.0006)
Trend	-0.0463***	-0.1119***	-0.0400***	-0.0461***
	(0.0035)	(0.0202)	(0.0068)	(0.0042)
Financial crises 2008-09	0.0471***	0.0573***	0.0441***	0.0490***
	(0.0034)	(0.0161)	(0.0060)	(0.0042)
Sovereign debt crise 2012-14	1.4924***	1.8294***	1.3589***	1.8026***
	(0.0163)	(0.1752)	(0.0428)	(0.0241)

OC-IBTC	All	Large	Median	Small
OC/L production	0.0023***	0.0014*	0.0013***	0.0014***
	(0.0001)	(0.0007)	(0.0002)	(0.0001)
OC/L services	0.0035***	0.0019***	0.0017***	0.0022***
	(0.0001)	(0.0006)	(0.0002)	(0.0001)
OC employee	0.0001**	0.0001**	0.0004***	0.0029***
	(0.0000)	(0.0000)	(0.0001)	(0.0002)
Financial crises 2008-09	-0.0001	0.0002	0	-0.0002
	(0.0001)	(0.0003)	(0.0001)	(0.0001)
Sovereign debt crises 2012-14	0.0002	0.0006*	0.0004*	0.0002
	(0.0001)	(0.0003)	(0.0001)	(0.0002)

R&D-IBTC	All	Large	Median	Small
R&D/L	0.0402***	0.0169***	0.0198***	0.0202***
	(0.0013)	(0.0032)	(0.0017)	(0.0011)
K/L	-0.0083***	-0.0049	-0.0063***	-0.0073***
	(0.0006)	(0.0032)	(0.0008)	(0.0006)
R&D employee	0.0003***	0.0002*	0.0035***	0.0189***
	(0.0001)	(0.0001)	(0.0002)	(0.0007)
R&D subsidy dummy	-0.0077*	-0.0224*	-0.0157**	0.0119*
	(0.0031)	(0.0102)	(0.0055)	(0.0048)
Financial crises 2008-09	0.0004	-0.0006	0.0014	0.0004
	(0.0008)	(0.0025)	(0.0012)	(0.0010)
Sovereign debt crises 2012-14	0.0009	-0.0025	-0.0015	-0.0041**
	(0.0010)	(0.0024)	(0.0013)	(0.0013)
Observations	179177	6976	53255	118946
Log pseudolikelihood	228000	20300	120000	109000
rho_12	0.12	0.14	0.14	-0.04
rho_13	0.04	0.04	0.04	0.03
rho_14	0.03	0.01	0.02	0.03
rho_23	-0.01	0.11	0.07	0.00
rho_24	0.53	0.51	0.20	0.50
rho_34	-0.51	-0.28	-0.45	-0.18

VA/L	All	Large	Median	Small
Markup	0.6174***	0.7098***	0.7287***	0.7657***
	(0.0184)	(0.0460)	(0.0371)	(0.0287)
R&D-IBTC t-1	-3.3040***	-2.3585**	-1.1678***	-2.1605***
	(0.4440)	(0.7578)	(0.1079)	(0.1185)
OC-IBTC t-1	35.9877***	11.6310*	28.4354***	7.2701***
	(4.3367)	(5.5097)	(4.6386)	(1.1031)
R&D/L	0.1500***	0.0839***	0.1122***	0.1697***
	(0.0185)	(0.0185)	(0.0087)	(0.0089)
Import sales share	0.0028	-0.021	0.0012*	0.1260***
	(0.0017)	(0.0179)	(0.0006)	(0.0249)
Service input/L	0.0236***	0.0180**	0.0219***	0.0316***
	(0.0020)	(0.0062)	(0.0037)	(0.0029)
Employee	0.0362***	-0.0035	0.0083	0.1603***
	(0.0061)	(0.0165)	(0.0115)	(0.0135)
Trend	0.0090***	0.0162***	0.0123***	0.0087***
	(0.0007)	(0.0019)	(0.0011)	(0.0011)
Financial crises 2008-09	0.0444***	0.0688***	0.0402***	0.0457***
	(0.0056)	(0.0137)	(0.0072)	(0.0071)
Sovereign debt crises 2012-14	-0.0660***	-0.0620***	-0.0769***	-0.0957***
	(0.0068)	(0.0143)	(0.0076)	(0.0083)

Analysis shows that structural capital (R&D, OC) per employee and the size of innovative work pool both increases chances of IBTC, while are clearly related to market shares and how they improve market position and hence markups. R&D/L interaction with market share has the same effect irrespective of firm size, while OC/L interaction with markets share has most positive effect in large and median size firms.

ICT per employee has also clear positive effect on markups and a bit more in large firms. ICT per employee is probably more important for access to the market and to contact customers so the effect when associated with other cooperative measures that are not considered here.

Financial crises had a negative, and sovereign debt crises a positive effect on markups. This hints that also labor costs were driven down together with lowering producer prices. Sovereign debt crises was instead in the time when producer prices were not at fall any more. The access to finance became initially more difficult and there was not oversupply of goods in the market so that markups even improved.

R&D-IBTC is positively related to R&D per employee for all firms and to the number of R&D employees, but negatively for R&D subsidy dummy for median and small firms. One reason can be that subsidies have been given for limited period and thus have not led to permanent technological change. For large firms R&D subsidies are always one instrument among others also given their limited size. After controls there is no substantial increase during financial or sovereign debt crises. Firms invest into new technology in bad times which may make those investment to look worse than what they actually are as profits accrue more in good times (which is not the case for OC-IBTC). OC-IBTC is similarly positively related to own OC/L and the number of OC employees. The relation is stronger in small and median firms although OC-IBTC was decreasing in firm size.

Our main interest is on what happens to firm performance. Markups as well as R&D per employee increase productivity in all firms. R&D-IBTC has instead a negative effect, while OC-IBTC is significant positive. Piekkola and Norkio (2021) find organizational competence and thereby OC-IBTC to be the most significant factor for explaining variable for high growth in production (cover manufacturing and low-tech production also includes D sector: electricity, gas, steam; E sector: water supply, sewerage, waste management). This also strengthens the theory of smiling curve in innovation value chain of median firm sector. Organizational competence is needed after the structural capital has been associated with an improvement in growth. R&D-IBTC helps in median firm new goods and services also in bad times so that productivity does not necessarily increase. Service inputs from other firms also improve productivity. There is also clear trend growth of 1.3% per year in productivity. Financial crises period 2008-09 indicated a positive growth in productivity, while sovereign debt crises period has opposite effect. This is opposite to the development of markups. Financial crises appear hence to include a clear adjustment towards more efficient production by layoffs and other way to cut costs (but cause also fixed costs in short run as seen later when analyzing return on asset). Situation was opposite for Finland during sovereign debt crises, where improving technology cause higher return on asset at the same or lower level of labor productivity, see later analysis.

R&D-IBTC as measured is also required in the middle manufacturing stage of smiling curve (Mudambi, 2008), which may explain the decrease in productivity before the products and services are brought to the market. OC-IBTC is instead concentrated in the upstream and downstream phases with more immediate effect on productivity.

Markups and operating profit per employee by firm size

We have already analyzed the determinants of markups, R&D-IBTC and OC-IBTC and Tables 2 and 3 show that these coefficients remain about the same when explaining return on asset instead of productivity in the fourth equation. Our interest in Table 3 are then the effects on the operating profit per employee.

Table 3 System estimation of markups, IBTCs and operating profit per employee by firm size

	All	Large	Median	Small
Markup				
Market share t-1	-0.4830***	-0.9172**	-0.7899***	-0.3049
	(0.1259)	(0.2919)	(0.2055)	(0.2301)
ICT/L	0.1507***	0.1523	0.1863**	0.1576*
	(0.0421)	(0.1132)	(0.0596)	(0.0613)
Market share, R&D/L t-1	0.2220***	0.2486***	0.2471***	0.2035***
	(0.0315)	(0.0622)	(0.0578)	(0.0540)
Market share, OC/L t-1	0.0357***	0.0731***	0.0616***	0.0194***
	(0.0035)	(0.0119)	(0.0053)	(0.0043)
K/L	0.0464***	0.0216	0.0395***	0.0457***
	(0.0022)	(0.0149)	(0.0038)	(0.0025)
Export sales share	0.0314	0.0397	0.0197	0.1843***
	(0.0194)	(0.0206)	(0.0128)	(0.0374)
Trend	-0.0792***	-0.0630*	-0.0384***	-0.2080***
	(0.0042)	(0.0259)	(0.0095)	(0.0073)
Financial crises 2008-09	-0.0137***	-0.0201***	-0.0150***	-0.0116***
	(0.0005)	(0.0026)	(0.0009)	(0.0006)
Sovereign debt crises	-0.0461***	-0.1119***	-0.0399***	-0.0462***
2012-14	(0.0035)	(0.0201)	(0.0067)	(0.0042)
R&D-IBTC				
R&D/L	0.0422***	0.0168***	0.0199***	0.0201***
	(0.0013)	(0.0032)	(0.0017)	(0.0011)
K/L	-0.0086***	-0.0049	-0.0064***	-0.0073***
	(0.0008)	(0.0033)	(0.0008)	(0.0006)
R&D employee	0.0002**	0.0002*	0.0035***	0.0189***
	(0.0001)	(0.0001)	(0.0002)	(0.0007)
R&D subsidy dummy	-0.0105*	-0.0178	-0.0187***	0.0128*
	(0.0046)	(0.0110)	(0.0056)	(0.0052)
Financial crises 2008-09	0.0001	-0.0006	0.0014	0.0004
	(0.0008)	(0.0025)	(0.0012)	(0.0010)
Sovereign debt crises	0.001	-0.002	-0.0017	-0.0041**
2012-14	(0.0010)	(0.0024)	(0.0013)	(0.0013)
Observations	179177	6976	53255	Err:509
Log pseudolikelihood	200000	17459.689	114000	98253.426
rho_12	0.12	0.14	0.14	-0.04
rho_13	0.04	0.04	0.04	0.03
rho_14	0.03	0.01	0.02	0.03
rho_23	-0.01	0.11	0.07	0.00
rho_24	0.53	0.51	0.20	0.50
rho_34	-0.51	-0.28	-0.45	-0.18

	All	Large	Median	Small
OC-IBTC				
OC/L production	0.0022***	0.0015*	0.0014***	0.0014***
	(0.0002)	(0.0007)	(0.0002)	(0.0001)
OC/L services	0.0033***	0.0020***	0.0018***	0.0022***
	(0.0002)	(0.0006)	(0.0002)	(0.0001)
OC employee	0.0001***	0.0001**	0.0004***	0.0029***
	(0.0000)	(0.0000)	(0.0001)	(0.0002)
Financial crises 2008-09	-0.0001	0.0002	0.0000	-0.0002
	(0.0001)	(0.0003)	(0.0001)	(0.0001)
Sovereign debt crises	0.0002	0.0006*	0.0004*	0.0002
2012-14	(0.0001)	(0.0003)	(0.0001)	(0.0002)
Operating profit/L				
Markup	1.0028***	1.0774***	1.0645***	1.0942***
	(0.0318)	(0.0755)	(0.0365)	(0.0332)
R&D-IBTC	-0.7805	-2.9324**	-1.4035***	-2.1495***
	(0.4573)	(1.1064)	(0.1170)	(0.1396)
OC-IBTC	3.1846	22.9924*	35.6122***	11.9067***
	(3.9280)	(11.5740)	(8.2906)	(1.5078)
R&D/L	0.2233***	0.2117***	0.2441***	0.3097***
	(0.0203)	(0.0265)	(0.0128)	(0.0111)
Import sales share	0.0023	-0.0103	0.0006	0.0745***
	(0.0013)	(0.0290)	(0.0004)	(0.0217)
Service input/L	0.0195***	0.0166	0.0048	0.0247***
	(0.0029)	(0.0099)	(0.0042)	(0.0039)
Employee	-0.0015	0.0104***	0.0006	-0.0011
	(0.0010)	(0.0030)	(0.0013)	(0.0014)
Trend	0.0516***	0.0816**	0.0645***	0.0371***
	(0.0068)	(0.0262)	(0.0101)	(0.0108)
Financial crises 2008-09	-0.1256***	-0.0969***	-0.1406***	-0.1325***
	(0.0081)	(0.0254)	(0.0116)	(0.0131)
Sovereign debt crises	1.8313***	1.6609***	1.5939***	1.3343***
2012-14	(0.0529)	(0.1415)	(0.0606)	(0.0553)

Operating profits per employee are also positively related to markups and the output elasticity is about 60%-points large than for productivity. R&D-IBTC decreases and OC-IBTC increases profitability as before for productivity. R&D per employee has also very similar effects. negative effects in median firms although in sectors the effect is negative except in low-tech production. The distinctive difference is the positive trend of operating profits per employee with an increase about 9-10% per year except somewhat smaller 7% per year in small firms. Financial crises had a strong negative shock on the trend, while opposite holds during the sovereign debt crises.

Most of our observations are from the service sectors, where the average size of firms is also smaller. Table A.2 in the appendix shows the estimation result in four different sectors. The results are quantitatively the same across all sectors, except R&D-IBTC has no more significant negative effects on profitability in production. Why are recent years 2012-2014 good for profitability and not for productivity? One reason can be that firms had history of cost cutting that

Blundell et al. (1995) argue that ex ante market power can facilitate innovation and productivity: uncertainty may be lower in concentrated markets and new innovations may be complements to old ones. Ex post market power is less controversially regarded as a necessary incentive to innovate in the presence of spillovers. This is why there are patent law. The negative effect of markups on return on asset in other services could then be explained that high markups are ex ante and do not lead to high innovativity.

We cannot instead identify the positive effects of IBTC in any particular sectors, except that other service firms have benefitted greater from OC-IBTC, while R&D-IBTC has had negative effect. Thus, important OC-IBTC holds with respect to median firms in services in particular. Positive R&D-IBTC effects in large and small firms seem to apply in other industries than other services and particularly in production R&D intensity is rather a sign of large fixed costs if not associated with R&D-IBTC. But our results show that structural capital has always on important role in improving markup the more the large is the market share of the firm. Implicitly this implies that intangible intensive firms with high market shares have negotiation power in the markets but at least in production this does not guarantee that also return on asset is higher.

4. Conclusion

Intangibles are firm-specific structural capital as a natural source of markups and corporate performance. Markups are always positively related to both productivity and return asset. We can finally review our proposed hypotheses.

Hypothesis 1 that structural capital increases market power and productivity is valid both for R&D and OC capital in all firms of different size and technology type. We do not find the effect to be decreasing in firm size here. It is noteworthy that we consider ICT as general knowledge increasing markups.

Hypothesis 2 regarding improved productivity and profitability via R&D-IBTC and OC-IBTC holds only for OC-IBTC. Organizational capital is the key to competitiveness as it is not exchangeable, it cannot be sold, and hence competitors are unlikely to be able to copy it. Howeer, OC-IBTC is decreasing in firm size and therefore found more important factor for performance in other than small firms. Median R&D-IBTC is increasing in firm size but R&D has direct positive effect on performance, while R&D-IBTC in excess of this has negative effect especially service sector. This all suggests that the quality variation of R&D workers across firms are less vital than for OC workers or in services the quality requirement of R&D work differ from production; maybe as not closely tied to advance of new products and services.

Hypothesis 3 of joints effects of innovation activity to productivity and profitability hold. Management expenditures are not considered as a mere cost but also as an asset. R&D has many effects: with high market shares increasing markus, R&D labor cause R&D-IBTC and improving directly productivity. R&D-IBTC equation also suggest heavier investment into new technology in bad times such as during financial or sovereign debt crises (which is not the case for OC-IBTC).

In recent decades, well-performing firms in the Finnish economy have engaged in organizational reform and investment in the quality of organizational workers. Product innovations are combined with organizational innovations, and organizational innovations are further associated with marketing innovations. We thus find a clear innovation value chain from product to organizational innovation, as observed in previous literature, while increased competition has led to decreasing markups. Productivity puzzle relates to decreasing markups over time, since IBTC has had opposite trend although is inferiot to R&D as a whole in improving productivity.

The labor productivity decrease is thus explained primarily by a decrease in markups. This in turn is explained by decreasing trend in producer prices relative to labor costs. Understanding technological change is clearly bound to the efforts to succeed in the use of structural capital creating IBTC and thus to the employment of innovative labor with the best quality. Our results show that intangibles are widely used irrespective of firms and technology type.

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Appendix A. Measurement of intangible capital (IC) and tables

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

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

Table A.1 Summary Large firms

	Mean	Q1	Median	Q3	Standard deviation	Observation
Value added	422	52.9	74.8	105	6585	6983
Operating profit/L	71.6	22.1	43.3	78.2	108	6983
Markup	1.42	0.956	1.3	1.79	0.654	6495
Market share	0.215	0.0377	0.106	0.294	0.249	6918
R&D-IBTC	0.0293	3.41E-05	0.000795	0.00703	0.12	6894
OC-IBTC	0.0016	-1.47E-05	8.79E-05	0.000452	0.0111	6858
Employee	762	320	476	796	945	6983
Employee not IA	694	289	437	710	876	6983
R&D/L	92.5	7.7	41.5	97.4	576	6901
OC/L	22.5	5.41	11.4	21.4	161	6857
ICT/L	11.7	0.632	1.76	4.44	145	6389
K/L	530	75.9	188	377	7025	6983
Export/Sales	0.238	0	0.00722	0.394	0.63	6983
R&D subsidy dummy	0.0967	0	0	0	0.296	6983
R&D wage/ Avg wage	1.81	1.21	2.06	2.27	0.552	6249
OC wage/ Avg wage	2.2	1.67	2.06	2.7	0.626	6677
R&D work relative proo	1.07	1	1.02	1.06	0.2	6249
OC work relative prod.	1.02	0.998	1.01	1.03	0.158	6677

Table A.2 Summary Median firms

	Mean	Q1	Median	Q3	Standard deviation	Observation
Value added	381	47.4	67.2	95.5	8577	53765
Operating profit/L	60.2	16.4	34.5	64.2	102	53765
Markup	1.25	0.843	1.14	1.56	0.603	49163
Market share	0.0471	0.00368	0.011	0.0352	0.113	53381
R&D-IBTC	0.0395	0.000253	0.00231	0.0095	0.139	47373
OC-IBTC	0.00209	9.4E-06	0.000259	0.00123	0.00979	43813
Employee	76.7	37	55	94	65	53765
Employee not IA	70.4	34.2	50.9	86.3	59.2	53765
R&D/L	69.7	12.4	29.5	62.6	446	47512
OC/L	25.1	6.53	13.2	26.2	80.8	43956
ICT/L	14.9	1.74	3.54	7.52	62.9	25623
K/L	291	32.8	142	340	1133	53765
Export/Sales	0.129	0	0	0.0776	2.36	53765
R&D subsidy dummy	0.0325	0	0	0	0.177	53765
R&D wage/ Avg wage	2.02	1.76	2.18	2.34	0.462	33150
OC wage/ Avg wage	2.21	1.64	2.19	2.75	0.631	36096
R&D work relative proo	1.11	1.01	1.03	1.11	0.243	33150
OC work relative prod.	1.03	1	1.01	1.04	0.14	36093

Table A.3 Summary Small firms

	Mean	Q1	Median	Q3	Standard deviation	Observation
Value added	272	41.7	59.9	85.6	5657	122707
Operating profit/L	46.8	12.6	29.4	54.6	79.5	122707
Markup	1.25	0.812	1.12	1.55	0.642	114467
Market share	0.0112	0.000778	0.00198	0.00577	0.0479	122204
R&D-IBTC	0.05	0.000789	0.00403	0.0231	0.143	77935
OC-IBTC	0.00414	7.99E-05	0.000653	0.00282	0.0136	53754
Employee	17.5	11	16	22	9.48	122707
Employee not IA	16.5	10.5	15	21	9.04	122707
R&D/L	65.8	17.9	36	75.8	124	78560
OC/L	30.1	10.4	18.8	34.9	45	54310
ICT/L	24.1	5.31	9.52	21.2	40	16306
K/L	143	8.76	46	150	440	122707
Export/Sales	0.0452	0	0	3.09E-06	0.221	122707
R&D subsidy dummy	0.0126	0	0	0	0.112	122707
R&D wage/ Avg wage	2.02	1.66	2.16	2.35	0.445	42073
OC wage/ Avg wage	2.22	1.57	2.44	2.75	0.653	35632
R&D work relative proo	1.13	1.02	1.06	1.15	0.253	42067
OC work relative prod.	1.05	1	1.03	1.08	0.218	35623

Table A.4 System estimation of markups and productivity by technology type

Markup	High tech	Low tech	KIS	Services other
Market share t-1	-1.3154***	-0.3182	-2.2251***	0.2408
	(0.3731)	(0.1897)	(0.4149)	(0.1926)
ICT/L	0.1537*	0.081	0.5151***	0.1331
	(0.0735)	(0.0590)	(0.1420)	(0.1056)
Market share, R&D/L t-1	0.3223***	0.2215***	0.6294***	0.2332*
	(0.0699)	(0.0466)	(0.1158)	(0.0940)
Market share, OC/L t-1	0.0418***	0.0488***	0.0741***	-0.0163*
	(0.0121)	(0.0086)	(0.0047)	(0.0080)
K/L	0.0259***	0.0431***	0.0493***	0.0416***
	(0.0069)	(0.0043)	(0.0042)	(0.0032)
Employee	-0.0269*	-0.0966***	-0.0122	-0.1483***
	(0.0119)	(0.0083)	(0.0094)	(0.0065)
Export sales share	-0.0254***	-0.0128***	-0.0040***	-0.0158***
	(0.0017)	(0.0009)	(0.0012)	(0.0007)
Trend	-0.1427***	-0.0498***	-0.0166	-0.0366***
	(0.0115)	(0.0068)	(0.0088)	(0.0050)
Financial crises 2008-09	0.0819***	0.0483***	0.0330***	0.0465***
	(0.0115)	(0.0064)	(0.0084)	(0.0050)
Sovereign debt crise	1.7066***	1.4895***	1.0193***	1.7703***
2012-14	(0.0499)	(0.0311)	(0.0337)	(0.0254)

OC-IBTC	High tech	Low tech	KIS	Services other
OC/L production	0.0030***	0.0015		
	(0.0005)	(0.0008)		
OC/L services			0.0060***	0.0027***
			(0.0003)	(0.0002)
OC employee	0	0	0.0002***	0
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Financial crises 2008-09	0.0001	-0.0001	-0.0004	-0.0004**
	(0.0002)	(0.0001)	(0.0002)	(0.0001)
Sovereign debt crises	-0.0001	0.0002	0.0011***	-0.0007***
2012-14	(0.0002)	(0.0002)	(0.0003)	(0.0001)

R&D-IBTC	High tech	Low tech	KIS	Services other
R&D/L	0.0249***	0.0213***	0.0862***	0.0083***
	(0.0019)	(0.0021)	(0.0026)	(0.0004)
K/L	-0.0017***	0.0010*	-0.0110***	-0.0003*
	(0.0005)	(0.0004)	(0.0013)	(0.0002)
Emp R&D	-0.0000**	0.0001	0.0006***	0.0001*
	(0.0000)	(0.0000)	(0.0002)	(0.0001)
R&D subsidy dummy	0.0006	-0.0108***	0.0046	0.0012
	(0.0024)	(0.0023)	(0.0082)	(0.0021)
Financial crises 2008-09	0.0032**	0.0004	0.0077*	-0.0002
	(0.0011)	(0.0008)	(0.0031)	(0.0004)
Sovereign debt crises	0.0029*	-0.0002	0.005	0.0008
2012-14	(0.0014)	(0.0008)	(0.0037)	(0.0006)
Observations	17298	45021	38412	74667
Log pseudolikelihood	45900	101000	36100	141000
rho_12	0.11	0.01	0.10	0.13
rho_13	0.06	0.01	0.05	0.07
rho_14	-0.28	0.05	-0.37	-0.18
rho_23	-0.01	0.01	-0.02	0.01
rho_24	0.48	0.06	0.35	0.60
rho_34	-0.46	0.03	-0.52	-0.40

VA/L	High tech	Low tech	KIS	Services other
Markup	0.6611***	0.6546***	0.6020***	0.7459***
	(0.0396)	(0.0409)	(0.0425)	(0.0272)
R&D-IBTC t-1	-0.6298	-0.1478	-1.9691***	-14.5873***
	(.)	(.)	(0.3901)	(3.8491)
OC-IBTC t-1	3.1484	3.495	19.0559***	51.1701***
	(7.9699)	(29.6616)	(2.4228)	(4.3751)
R&D/L	0.0233	0.0657***	0.2156***	0.1506***
	(0.0157)	(0.0185)	(0.0348)	(0.0336)
Import sales share	0	0.0173	0.2141**	0.0016
	(0.0005)	(0.0222)	(0.0682)	(0.0011)
Service input/L	0.0385***	0.0186***	0.0444***	0.0143***
	(0.0046)	(0.0030)	(0.0047)	(0.0033)
Employee	0.0236*	0.0276*	0.0289**	0.0734***
	(0.0092)	(0.0109)	(0.0103)	(0.0076)
Trend	0.0280***	0.0082***	-0.0078***	0.0159***
	(0.0016)	(0.0010)	(0.0014)	(0.0011)
Financial crises 2008-09	0.1026***	0.0229***	-0.0096	0.0895***
	(0.0121)	(0.0064)	(0.0121)	(0.0112)
Sovereign debt crises	-0.0876***	-0.0839***	-0.0117	-0.0578***
2012-14	(0.0123)	(0.0070)	(0.0135)	(0.0137)

Table A.5 System estimation of markups and operating profit per employee by technology type

	High tech	Low tech	KIS	Other services
	Markup			
Market share t-1	-1.3154***	-0.2615	-1.8164***	0.2291
	(0.3674)	(0.1920)	(0.4551)	(0.1886)
ICT/L	0.1537	0.081	0.4658**	0.1277
	(0.0823)	(0.0565)	(0.1420)	(0.1052)
Market share, R&D/L t-1	0.3223***	0.2108***	0.5412***	0.2351*
	(0.0699)	(0.0470)	(0.1174)	(0.0930)
Market share, OC/L t-1	0.0418**	0.0485***	0.0783***	-0.0194*
	(0.0139)	(0.0085)	(0.0045)	(0.0080)
K/L	0.0259**	0.0433***	0.0520***	0.0406***
	(0.0085)	(0.0041)	(0.0042)	(0.0032)
Export sales share	0.0141	0.1691***	0.1067	0.0053
	(0.0104)	(0.0341)	(0.0558)	(0.0060)
Trend	-0.0269*	-0.0942***	-0.0083	-0.1498***
	(0.0118)	(0.0083)	(0.0094)	(0.0065)
Financial crises 2008-09	-0.0254***	-0.0130***	-0.0044***	-0.0157***
	(0.0021)	(0.0009)	(0.0012)	(0.0007)
Sovereign debt crises	-0.1427***	-0.0499***	-0.0163	-0.0366***
2012-14	(0.0116)	(0.0068)	(0.0088)	(0.0050)
		R&D-IBTC		
R&D/L	0.0249***	0.0205***	0.0855***	0.0083***
	(0.0029)	(0.0020)	(0.0026)	(0.0004)
K/L	-0.0017	0.0014**	-0.0098***	-0.0005*
	(0.0035)	(0.0005)	(0.0015)	(0.0003)
Emp R&D	0	0.0001	0.0007***	0.0002*
	(0.0000)	(0.0000)	(0.0002)	(0.0001)
R&D subsidy dummy	0.0006	-0.0065**	0.0037	-0.0006
	(0.0372)	(0.0025)	(0.0093)	(0.0028)
Financial crises 2008-09	0.0032**	0.0005	0.0082**	-0.0003
	(0.0012)	(0.0008)	(0.0032)	(0.0004)
Sovereign debt crises	0.0029	-0.0001	0.0051	0.0008
2012-14	(0.0041)	(0.0008)	(0.0037)	(0.0006)
Observations	17298	45021	38412	74667
Log pseudolikelihood	41048	90147	32471	132000
rho_12	0.10	0.13	0.31	0.22
rho_13	0.01	0.01	0.08	0.04
rho_14	-0.01	-0.07	0.19	-0.02
rho_23	0.04	0.03	0.02	0.04
rho_24	0.00	-0.09	0.54	0.24
rho_34	-0.05	-0.74	-0.38	-0.62

	High tech	Low tech	KIS	Other services
			OC-IBTC	
OC/L production	0.0030***	0.0016***		
	(0.0008)	(0.0003)		
OC/L services			0.0059***	0.0026***
			(0.0003)	(0.0002)
OC employee	0	0	0.0002***	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Financial crises 2008-09	0.0001	-0.0001	-0.0004	-0.0004**
	(0.0002)	(0.0001)	(0.0002)	(0.0001)
Sovereign debt crises	-0.0001	0.0002	0.0011***	-0.0007***
2012-14	(0.0002)	(0.0002)	(0.0003)	(0.0001)
	Operating profit/L			
Markup	0.9274*	0.9990***	1.1401***	1.0749***
	(0.3665)	(0.0307)	(0.0686)	(0.0349)
R&D-IBTC	-0.7532	1.5340*	-1.7203***	-7.9734**
	(48.7062)	(0.7740)	(0.4888)	(3.0601)
OC-IBTC	5.4994	88.7101***	25.4501***	68.6738***
	(32.9018)	(13.7171)	(2.9945)	(6.0273)
R&D/L	0.2823	0.1110***	0.3651***	0.1648***
	(1.1236)	(0.0204)	(0.0441)	(0.0312)
Import sales share	0	0.0139	0.0981	0.0016**
	(0.0033)	(0.0192)	(0.0739)	(0.0006)
Service input/L	0.0276***	0.0136**	0.0234***	0.0115**
	(0.0076)	(0.0042)	(0.0058)	(0.0044)
Employee	0.0214*	0.0049**	-0.0168***	0.0004
	(0.0109)	(0.0015)	(0.0019)	(0.0016)
Trend	0.1277	0.0473**	-0.0214	0.0933***
	(0.1135)	(0.0146)	(0.0161)	(0.0153)
Financial crises 2008-09	-0.126	-0.1532***	-0.0473*	-0.1155***
	(0.1912)	(0.0183)	(0.0185)	(0.0182)
Sovereign debt crises	1.2232	2.9691***	1.2754***	1.7483***
2012-14	(2.8200)	(0.0874)	(0.0975)	(0.0663)