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Innovative competences and firm-level productivity in Denmark and Finland

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Abstract
This paper examines how intangible assets affect firm-level productivity in the small open economies Denmark and Finland in 2000–2013. We estimate firms’ total factor productivity and the contribution of intangible assets (ICT, R&D and organizational competencies) to firm productivity. Advanced economies have been under pressure from demand shifts, from increased global competition and from severe conditions due to the financial crisis. We examine whether the role of intangible assets has changed over time, from the period of fairly stable growth prior to the crisis in 2008 to the more difficult period of recovery afterwards. The productivity analysis is conducted in two stages. In the first stage we estimate total factor productivity, while the effects of intangible competencies are estimated in the second stage. Additionally, we explicitly model the company’s decision to invest in these intangible assets. Our approach, which is based on occupational
classifications using linked employer-employee data, constructs measures of three types of intangibles: R&D assets, organizational assets and ICT assets. The findings imply that organizational competences have been higher in Denmark but the benefits from them are growing in Finland, while the elasticity of organizational capital has fallen in the recovery period in Denmark. Firms in both countries had a positive and significant elasticity of R&D assets with respect to productivity, though for both countries, the elasticity of R&D assets is significantly lower in the recovery period. In contrast, elasticities of ICT assets are higher in the recovery period for both countries compared to before the crisis.
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Abstract

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1. Introduction

Manufacturing and service sectors in advanced economies have been under increasing pressure in the last decade. These pressures of global competition have been present and growing over a longer period of time, but have clearly become more acute due to the financial crisis in 2008 and 2009.

A number of studies have focused on ways forward for firms in advanced economies such as Denmark and Finland, with particular focus on manufacturing. Manyika et al. (2012) argues that a new era is emerging for global manufacturing, with an important role for manufacturing in both advanced and developing countries. The report states that “The new era of manufacturing will be marked by highly agile, networked enterprises that use information and analytics as skillfully as they employ talent and machinery to deliver products and services to diverse global markets.” (Manyika et al., 2012, p. 1). This includes taking advantage of IT advances, the capacity to deal with change, risk and uncertainty, and global connectivity, linking capabilities where best and the ability to tailor operations to specific markets. And while declines in manufacturing employment have drawn greater attention to manufacturing, these factors are equally relevant for service sectors. This calls for a holistic understanding of global value chains and the need for ongoing change can also be found in Whitefoot and Donofrio (2015), where in particular the potential of IT and digitalization is highlighted.

This places new demands on manufacturing and service firms in advanced economies in order for them to be competitive. Firms need to be agile, operate on worldwide scale and able to adjust quickly to respond to and take advantage of changing conditions (Wiengarten, 2016). This includes innovation, being able to develop new products or improve on existing products, and also process-oriented innovation. Within the latter, particular focus has been placed on the implementation of ICT-based technologies such as digitalization or automation. Flexibility involves the ability to enter new markets and also the ability to adjust operations to meet changing demand conditions. This requires strong organizational competences.

Mudambi (2008) analyzes the rising share of intangibles in economies worldwide and highlights the crucial role of knowledge-intensive and creative industries in current and future wealth generation. Firms’ value chains can be broadly grouped into three categories, each placing different demands on the firm: the upstream (input) end, the downstream (output or market) end and the middle. R&D is the most important part of activities at the upstream together with design but also requires inputs to the commercialization of creative endeavors. Activities at the other end of the value chain comprise marketing, advertising and brand management and after-sales services. The production is in the middle of the value-chain and may comprise manufacturing and standardized service delivery.

The complicated value chains indicate that returns to R&D and innovation depend on many firm-specific and environmental factors (Hall, Mairesse, & Mohnen, 2010; Syverson, 2011). This raises a number of interesting questions concerning the actual performance of firms. For example, how do innovative competences contribute to firm productivity? What is the role of broader, organizational competences?
And, to what extent is the implementation of new information technologies driving performance for successful firms? Moreover, the technological progress component is seldom known and would, in any case, be only one part of the value chain. Thus, a comprehensive measure of the competences or intangible assets that firms possess is needed when analyzing productivity rather than technological progress (Cucculelli & Bettinelli, 2015).

The focus here is on new type of economic growth along the value chain leaning on intangible assets and market restructuring. C. Corrado, Hulten, and Sichel (2005) have argued that measurement of capital assets should include all investments in human capital, R&D expenditure, and indeed any expenditure in which a business devoted resources to projects designed to increase future rather than current output, whether it is intangible or tangible. Work on the measurement of intangibles has focused on broadening the conceptualization of what constitutes a capital investment, developing measures of intangibles at the macro level and more recently also at the micro level for individual firms. C. Corrado et al. (2005) identify three main categories of intangible assets: economic competencies, innovative property and computerized information. Economic competencies include spending on strategic planning, worker training, redesigning or reconfiguring existing products in existing markets, investment to retain or gain market share and investment in-brand names. Innovative property refers to the innovative activity built on a scientific base of knowledge as well as to innovation and new product/process R&D more broadly defined. Computerized information essentially coincides with computer software.

Denmark and Finland are both small open economies with populations of around 5 million. While there are structural differences between the two countries, for example in terms of industry composition and main trading partners, there are also strong similarities between the two Nordic countries. Both countries suffered large declines in GDP as a result of the financial crisis in 2008, with a 5% decline in GDP in 2009 for Denmark and an 8% decline for Finland. Growth rates prior to the crisis were strongest in Finland, while the fall in GDP was also larger for the Finnish economy, and post-crisis recovery slower.

This paper examines the link between innovative competences, which are approximated by intangible assets, and productivity for manufacturing and service firms in Finland and Denmark. We draw on the intangible capital approach in measuring firms’ knowledge accumulation. In particular, the analysis will examine the role of intangible assets in facilitating recovery from the financial crisis in 2008 and 2009, and whether investments in intangibles can help explain differences in recovery patterns for Denmark and Finland. It is apparent that the use of intangible capital resources by different firms does not follow conventional industrial classifications; e.g., retail companies may invest either in fixed capital (buildings), labor, or intangible capital. Our analysis covers the period from 2000 to 2013. We employ a productivity

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1 See in particular the extensive work undertaken on intangibles measurement at both the macro and micro level in the EU FP7 project, Innodrive (www.Innodrive.org).
analysis that utilizes a two-stage estimation method, where the total factor productivity (TFP) is estimated in the first stage, while the second stage analyses the relation between TFP and intangible assets.

Here, intangible capital (IC) is divided into three components, namely, organizational capital (OC), R&D assets (RD) and information and communication technology (ICT). We value them at firm-level and rely on occupational data that we link with firm-level balance-sheet data. Organizational capital relates to managerial and marketing capabilities and branding. IT monitors both the relationships among different production units and the dynamics of vertical integration; like Denekamp (1995), Braunerhjelm (1996), Bartel, Ichniowski, and Shaw (2007), Brynjolfsson, Hitt, and Yang (2002) and H. Piekkola (2016) for the monitoring of foreign operations. ICT covers database and software costs, but also maintaining the ICT network requires long-term planning. RD covers R&D activities (as science, engineering and health innovation development). OC, RD and ICT can be used as a measure of innovation capability by their construction that we use in explaining productivity differences.

The next section reviews recent studies to measure intangible assets and estimate their contribution to productivity, with particular focus on firm level analyses. Section 3 describes the data used in this study and our approach to construct firm level measures of intangible assets. Section 4 describes the econometric analysis methods used in the paper while section 5 presents the results of the analysis. The final section concludes.

2. Intangible assets and productivity – a review

Work on the measurement of investments in intangible assets has sought to construct more complete measures of the firms’ value in terms of capital formation. This essentially entailed a broadening of the concept of capital formation to include in the investment in education, training, R&D, software design, marketing, and even certain kinds of expenditures on reorganization of production and marketing aimed at making more efficient use of technology. Early work by Kendrick (1994) on intangible investment in the United States during the 20th century indeed shows a pronounced increase in the proportion of intangible to tangible investment, reflecting the important rise in resources devoted to education, training and especially R&D.

Since then, literature has discussed the effects of intangibles. Niebel, O’Mahony, and Saam (2016) find that manufacturing sectors have a higher share of intangible investment in value added than in service sectors, though using narrower definitions of organizational and ICT asset than those used in this paper. Additionally, they argue this to be partly due to a low depreciation rate of R&D capital. An exception is the UK within business and financial intermediation services. The output elasticity of intangibles is between 0.10 and 0.20, which may be related to narrower data availability and knowledge spillovers than when using macro levels where the share has been around 0.25 or above, see Roth and Thum (2013), C. Corrado, Haskel, Jona-Lasinio, and Iommi (2013). Van Ark, Hao, Corrado, and Hulten (2009), Marrano, Haskel, and
Wallis (2009). C. A. Corrado, Haskel, and Jona Lasinio (2014) highlight the important knowledge spillovers between R&D, organizational and ICT capital. Also, Research in INNODRIVE and COINVEST 7th framework programs found that intangible capital has made considerable contributions to increases in labor productivity in 1995-2005, which was later confirmed by studies using INTAN data; see Piekkola (2011a) and C. Corrado, Haskel, Jona-Lasinio, and Iommi (2014).

However, the question of how intangibles affect survival from financial crises remains unclear. Piekkola and Åkerholm (2013) show that labor productivity growth in Finland improved through market restructuring in the period of 2007–2012 so that high productivity firms increased their market share. However, at the same time intangible investment growth slowed down in Finland. It remained an open question how the intangible and fixed capital input growth and decomposed to internal growth and growth driven by changing market structure is related to lower productivity growth. Moreover, Hannu Piekkola (2016) shows that intangible capital (IC)–driven growth was stalled in European industries during the 2008–2013 financial crisis period. On average, deterioration of intangible asset growth has decreased labor productivity by 1.9% annually. During 2008–2013, product innovation thus appears not by itself to compensate for Europe’s dwindling fixed-capital-intensive manufacturing and job losses. Yet broad-based intangible capital assets offer a roadmap for recovery by relying on an increasing role for intangible-producing services. As indicated above, many of the suggested explanations to the deceleration of productivity growth in Europe allude to intangible investments.

Among firm level analyses, extensive work has been done on the relation between R&D and productivity (for a review, see Hall et al. (2010)) and innovation and productivity, while experience with broader measures of intangibles is more recent. Econometric analyses of the relation between innovation and productivity build to a large extent on work by Griliches (1979) and Pakes and Griliches (1984), who introduced the concept of the knowledge production function to create ‘economically valuable knowledge’, which can then be used in the production of goods and services. Pakes and Griliches (1984) modeled innovation inputs using R&D and innovation outputs using patent counts. The CDM model (Crépon, Duguet, & Mairessec, 1998) was the first to model the relation between innovation inputs, innovation outputs and productivity. In their approach, they take steps to correct both for selection and simultaneity biases, and estimate the full model as a system. Their model includes four equations for: the decision to invest in innovation, the determination of R&D investments, an equation for innovation output, and a productivity equation.

More recent work has analyzed the relation between intangibles and productivity, utilizing a variety of different data sources and categorization of intangible assets. Marrocu, Paci, and Pontis (2012) conduct a firm level productivity analysis of intangibles for six European countries: France, Italy, Netherlands, Spain, Sweden and the United Kingdom. Their measure of intangible capital uses balance sheet information and is based on intangible assets that have been capitalized. They find elasticities in the range of 0.04-0.06.
Bontempi and Mairesse (2015) also relies on balance sheet data of Italian firms, but goes beyond the impact of purely capitalized intangible assets, also including other expenditures. They define two types of intangible capital, intellectual (mainly R&D and patents) and customer intangible capital (mainly advertising, trademarks).

Polder, Leeuwen, Mohnen, and Raymond (2009) extend the CDM framework by including investment in ICT, and analyze the implementation of product, process and/or organizational innovations on productivity. In particular, they analyze the role of implementation of product and/or product innovations in combination with organizational innovations. They find strong complementary effects for process and organizational innovations – similar to those found in the context of intangibles.

Crass and Peters (2014) utilize innovation data to construct and analyze measures of intangibles. They utilize innovation survey data for the German Mannheim Innovation Panel to create measures of intangibles within three categories: innovative capital, human capital and branding capital. Innovative capital is measured by R&D, design and licenses, and patent stocks, human capital by training and shares highly skilled labor, and branding capital by marketing expenditures and stocks of trademarks. In addition, dummy variables concerning organizational innovations function as proxies of organizational capital.

Another approach used by Ilmakunnas and Piekkola (2014) measures intangibles investments with employees of Finnish firms. Worker shares proxy intangible capital for three categories: organizational, RD and ICT. We follow this line of literature and the measurement approach further developed in the INNODRIVE project (Görzig, Piekkola, & Riley, 2010), where linked employer-employee data (LEED) are used to measure investments in intangibles at the firm level. Intangible capital assets (IC) is classified into three categories:

- Organizational capital asset (OC)
- Research and development asset (RD)
- Information and communication asset (ICT)

Organizational asset is the accumulated through investments in management and marketing activities, where it is assumed that these result in a build-up of organizational knowhow for the firm. R&D asset is accumulated through the technical activities of the firm, and thus are broader than measures of R&D expenditures based on the Frascati definition of R&D (OECD, 2015). ICT asset represents the accumulated knowhow based on in-house activities to manage, develop and implement ICT activities in the firm.

In our approach, we assume that organizational and technical knowhow in the three categories is accumulated through the work of personnel in occupations that are relevant to each of the three types. Measures of investments in intangibles are constructed from the wage incomes of employees within selected occupations that are related to each of the three types of intangibles. Occupations within the top
three major groups in the International Standard Classification of Occupations\(^2\) (Managers, Professionals and Technicians and Associate Professionals) are assumed to engage in activities that contribute to the accumulation of knowhow within the firm. Actual list of occupational classifications used in the measurement of intangible investments is shown in the appendix. The investment calculations consist of wage income, and a multiplier accounting for investment share (not all work activities contribute to knowledge creation) and that non-labor expenditures also constitute intangibles investments. H. Piekkola (2016) provides the value of a combined multiplier \(A^\text{IC}_i\) in equation (1), which is time invariant in the expenditure-based approach.

This expenditure approach allows a much broader coverage of the role of intangibles than many of the other recent approaches described above. Our approach is not limited to expenditures that are formally capitalized in balance sheets, allowing us to a broader measure of investment. This is particularly the case for organizational capital, which has typically proved difficult to measure using firm level data. In addition, the use of LEED data allows widespread coverage of Danish and Finnish firms.

3. Data and variables
This study utilizes register data for Danish and Finnish firms in the period 2000-2013. The datasets include all firms\(^3\) having at least ten employees on average. The samples cover all manufacturing and a broad range of market services\(^4\). Firm-level financial data is linked with employee data in order to construct measures of investments in intangibles. The main variables for firms are value-added, labor (number employees), physical capital (total fixed assets) and investments, exports, imports and firm age. Data for employees include annual wage income for each employment, type of occupation, and education level and field.

Intangible (capital) assets are constructed from intangible producing employees and used intermediates as follows. First, we divide intangible (IC) employees into organizational capital (OC) employees (e.g. management and marketing), R&D employees (RD) and information and communication technology (ICT) employees. Managerial and technical staffs contribute partly to daily operations and partly to the accumulation of intangible capital. The working shares spent on producing IC are assumed to be 20% for OC workers, 70% for RD workers and 50% for ICT (appendix, table A.1) following the work within the Innodrive project.

Following Görzig et al. (2010) and H. Piekkola (2016) we include the costs of intermediates and tangible capital originated to the intangible production. These intangible goods are evaluated based on how labor


\(^3\) The resulting final sample used includes all firms the selected industries with over 10 employees and where data for key variables are available and positive (as the log values of these variables will be used in regressions).

\(^4\) The sample include all market service industries with the exception of construction and financial services; in terms of NACE Rev. 2 2-digit code, the sample includes industries 10 to 33 (ie. all manufacturing) and 45 to 74 with the exception of 64-66.
costs, intermediate input, and tangible capital combine into value added in business services. Appendix A shows the details surrounding the construction of expenditure-based measures of intangible assets at the firm level. These figures are linked to how labor, capital and intermediate inputs costs are combined to produce intangible (IC) assets in benchmark industries which are IC-producing business services. Real expenditure-based investments $N_{it}^{IC}$ of type IC=OC, RD, ICT are as follows:

$$P^N_{jt}N_{it}^{IC} = A^{IC}W_{it}^{IC},$$

In equation 1, $W_{it}^{IC}$ represents labor costs of IC (OC, RD or ICT) worker in firm i. The labor costs are multiplied by the factor multiplier $A^{IC}$. $P^N_{jt}$ is the industry (j) deflator proxied by the IC producing business services deflator at a two-digit NACE level when assessable\(^5\). The intangible assets $R_{it}^{IC}$ follow the standard accumulation of capital stock, where the depreciation rate is 20% (25%) of the previous organizational asset in manufacturing (services), 15% for the previous RD, and 33% for the previous ICT. Using the expenditure-based measure of intangible investment from equation 1, the real stock of old capital $R_{it}^{IC}$ for IC of type OC, RD, ICT is as follows:

$$R_{it}^{IC} = N_{it}^{IC} + (1-\delta_{it})R_{it-1}^{IC},$$

with $R_{11+0}^{IC} = \frac{N_{11+0}^{IC}}{l} (\delta_{it} + g)$

The initial IC investment $N_{11+0}^{IC}$ is defined as the average growth-adjusted investment over a three-year period of the industry in the first year of the data coverage. $R_{11+0}^{IC}$ is calculated from intangible investments using the geometric sum formula, with the depreciation rate of $\delta_{IC}$ and the growth rate of the intellectual asset $g$. The growth rate $g$ is set at 2% for all IC, which follows the sample average growth rate of real wage costs for IC-related activities. Nominal variables are deflated using industry-level producer price indexes for firm financial variables. As noted above, measures of intangible investments are deflated using the producer prices index for the business service industry, as it was viewed that price developments in this industry better reflected developments in intangibles costs than price level in respective industries.

Much of these assets, such as purchased organizational, R&D and ICT assets, are unaccounted for in national accounts. Additionally, standard measures of value-added do not account for these intangible investments, which are treated as expenditures. As we treat intangibles as investments, we adjust the measures of value-added used in the analysis for intangibles investments.

The full sample consists of 28,506 firms and 225,843 observations for Denmark and 14,986 firms and 96,720 observations for Finland. Table 1 shows descriptive statistics for the sample. The share of firms with

\(^5\) Service industries in Denmark are using consumer price index as we didn’t find deflators ranging from 1999 to 2013 (the first year is consumed in intangible formulation, equation 2).
RD assets is fairly similar in the two countries, while shares with organizational assets are higher in Denmark and shares with ICT assets higher in Finland. Hence, there would appear to be some structural differences in firm compositions for the two countries.

Table 1. Descriptive statistics of Denmark and Finland.

<table>
<thead>
<tr>
<th></th>
<th>Denmark</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value-added per employee</td>
<td>63,258</td>
<td>79,962</td>
</tr>
<tr>
<td>Physical capital per employee</td>
<td>130,606</td>
<td>131,095</td>
</tr>
<tr>
<td>Inputs per employee</td>
<td>165,741</td>
<td>220,275</td>
</tr>
<tr>
<td>% obs. with RD assets</td>
<td>68.4%</td>
<td>67.8%</td>
</tr>
<tr>
<td>% obs. with Org. assets</td>
<td>86.4%</td>
<td>80.6%</td>
</tr>
<tr>
<td>% obs. with ICT assets</td>
<td>29.7%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Number observations</td>
<td>225,843</td>
<td>73,758</td>
</tr>
<tr>
<td>Number firms</td>
<td>28,506</td>
<td>13,223</td>
</tr>
</tbody>
</table>

4. Analysis method

The framework of most previous studies is the production function approach using a Cobb-Douglas production function\(^6\). We follow this path and estimate the production function utilizing a two-stage approach. In the first stage, we estimate a standard Cobb-Douglas production function consisting of physical capital and labor, and save the residual as our measure of total factor productivity (TFP). Then, the second stage tests the explanatory power of intangible assets. In addition, we examine whether the effects of intangibles assets differs in the strong growth period prior to the 2008 financial crisis compared to the post-crisis recovery period. The empirical strategy primarily builds on Bontempi and Mairesse (2015), Piekkola (2011b) and Crass and Peters (2014).

4.1 First Stage: Production Function Estimation

We assume that the production function follows Cobb and Douglas (1928) as in eq. 3 where \(Q\) denotes value added, \(L\) labor, \(K\) Capital, \(\eta\) is an error term, and where small letters denote logarithms. However, firms choose their capital and labor accounting for following periods. Here, they use their knowledge of forthcoming shocks \(v_{it}\) that are a part of the error term \(\eta\) in equation (3). In a micro level analysis, we need an approximation of these firm specific shocks (or asymmetric observation of shocks) that affect the firms’ dynamic optimization (Parrotta, Pozzoli, & Pytlikova, 2014).

\(^6\) An exception here is Bontempi and Mairesse (2015) who use a constant elasticity of substitution function.
\[ q_{it} = a + \alpha \cdot l_{it} + \beta \cdot k_{it} + \eta_{it} \]  \hspace{1cm} (3)

We follow Olley and Pakes (1996), henceforth OP, and assume that firm specific shocks are a strictly increasing function of investments (Van Beveren, 2010; Yasar, Raciborski, & Poi, 2008). The OP method is chosen over Levinsohn and Petrin (2003), henceforth LP, method using intermediate inputs as a proxy variable, because of practical reasons. First, we lack some years in intermediate inputs and, second, investments had more non-zero values than the inputs in our sample.

OP and LP model the investment decision as a function of capital, labor and the shock. Assuming that investments are strictly increasing in productivity, we can take the inverse of the investment function and write shock \( v_{it} \) defined as a non-parametric function. Thus, the object function of the firm becomes:

\[ v_{it} = f^{-1}(k_{it}, l_{it}, \text{inv}_{it}) \]
\[ \rightarrow q_{it} = a + \alpha \cdot l_{it} + \beta \cdot k_{it} + v_{it} + \epsilon_{it} \]  \hspace{1cm} (4)

Ackerberg, Caves, and Frazer (2015, p. 2423), henceforth ACF, detect a functional dependence problem associated with labor optimization and investment/input decisions affecting the resulting coefficients from OP and LP. They slightly modify the assumptions by allowing labor to affect future profits in addition to current ones (hiring and firing costs) and change the timing of input decisions to the previous period. This makes the hiring decision a part of the dynamic firm optimization problem (Ackerberg et al., 2015, p. 2428) like the capital stock. Moreover, ACF use a more conditional input decision function than in the original OP model. Thus, we employ the ACF correction into the production function estimation. Another advantage in the OP (and LP) model is the attrition correction for the exit effect thus we avoid one selection problem. From here we get the total factor productivity TFP that is used to estimate the effects of intangible assets in the second stage of the analysis.

4.2 Second Stage: From Intangible Assets to Productivity

We explain TFP from the first stage with beginning of year values of intangibles in order to avoid endogeneity problems as Hall and Mairesse (1995, p. 278). This simultaneity problem results from possibility that firm knows the period’s productivity when choosing the investments in intangible assets. Lagging the assets makes the problem of endogeneity less severe but does not eliminate it. The regression is presented in (5) where TFP denotes total factor productivity, \( rd_{it} \) lagged logarithm of RD assets, and \( oc_{it} \) and \( ict_{it} \) similarly for organizational and ICT assets. \( X_{it} \) includes controls, year and firm size dummies. Year dummies correct the macroeconomic changes from the error term whereas the size dummies control partly

\footnote{The firm’s exit decision can be a function of unobservable productivity shocks in an unbalanced panel like ours.}
for the communication environment and other size related advantages and are statistically significant. RD, ICT and organizational assets are constructed from linked employer-employee data, FLEED for Finland and IDA for Denmark, and described both above and in appendix A. Shortly, organizational occupations include (non ICT) management, administrative and marketing positions, RD includes mostly positions related to natural science and ICT includes ICT-professionals and managers. Second, we model the structural break for the financial crises. The underlying assumption is that the crisis introduced a changed business environment notably because of new tight situation in access to finance and changes in demand. The crisis period tests firms capabilities to act agile and to be flexible when needed or even capacity to innovate their way out under pressure. The structural break helps to test our hypothesis that the financial crisis affects the productivity gains from intangible assets and these can explain why Denmark has recovered better from the crisis than Finland.

\[ tfp_{it} = \beta_0 + \beta_1 \cdot rd_{it} + \beta_2 \cdot oc_{it} + \beta_3 \cdot ict_{it} + \beta_4 \cdot rd_{it} \cdot A + b_3 \cdot oc_{it} \cdot A + \beta_6 \cdot ict_{it} \cdot A + X_{it} + e_{it}, \]  

(5)

Equation 5 is the second stage regression, where \( A \) is a dummy for after periods getting value 1 when year>2008 and structural break is included, being zero otherwise.

A high share of firms has organizational assets while smaller shares also have other types of intangible assets, particularly for ICT assets. Hence, while it is problematic to restrict the sample to firms with organizational assets, the sample of firms with all three types of assets may be less representative of the full population. At the same time, setting missing values equal to zero for ICT intangibles may introduce downwards bias for coefficient estimates. A simple solution is to include a dummy for all observations where the missing value has been set to zero. This alternative is suggested by Cohen et al. (2003), Cohen, Cohen, West, and Aiken (2013) and Palia (2001). Therefore we apply a dummy for missing values of ICT & RD assets. As these assets have the most missing observations, inclusion of them gains us the most observations. We employ fixed effect with these to deal with firms' heterogeneity following Hall and Mairesse (1995, p. 269). The following section presents the results.

5. Results
In this section, we present results from the analysis. First, we discuss production function estimates of both countries. We report the OP production model although the LP model has also been tested: it gives similar results. Second, we present the results of the second stage estimation where TFP is explained with intangible assets.

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8 We tried to set the break starting at 2008 and 2009 and this seemed to make no difference.

9 Intangible assets are included in logs in the regressions, so technically, missing values of intangible assets are set equal to one, which then results in log value of zero.
5.1 Production Functions

Table 2 presents the estimates of OP for Denmark and Finland. We are aware that using the number of employees is problematic but the using the number of hours worked might be correlated with our intangible assets estimation. We first used ACF correction for both firms but as it returned unreasonable estimates for Finnish employees (2.8) and strictly increasing returns to scale, we decided to not to use the correction for Finland\textsuperscript{10} before going through the data once more.

<table>
<thead>
<tr>
<th>Value added</th>
<th>DK</th>
<th>FI</th>
</tr>
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<tbody>
<tr>
<td>Log(employees)</td>
<td>0.790***</td>
<td>0.930***</td>
</tr>
<tr>
<td>(2.14e-6)</td>
<td>(0.00161)</td>
<td></td>
</tr>
<tr>
<td>Log(capital)</td>
<td>0.239***</td>
<td>0.0925***</td>
</tr>
<tr>
<td>(6.5e-6)</td>
<td>(0.00058)</td>
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</tr>
<tr>
<td>Avg. years per firm</td>
<td>7.9</td>
<td>6.5</td>
</tr>
<tr>
<td># Firms</td>
<td>28,506</td>
<td>14,986</td>
</tr>
<tr>
<td># obs.</td>
<td>225,843</td>
<td>96,720</td>
</tr>
<tr>
<td>ACF correction</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

\textsuperscript{10} The inclusion or exclusion of acf correction mostly affects the coefficients of dummy variables

The coefficient of capital is larger in Denmark than in Finland. For both countries, the sum of coefficient estimates for labor and capital are significantly greater than one, at 1.03 for Denmark and 1.02 for Finland. Hence, the results indicate slight increasing returns to scale for both countries. From this first stage we save the residuals as a measure of (the logarithmic) total factor productivity (TFP).

5.2 Results of second stage estimation

Based on the approximation of TFP above, we obtain the following results for Denmark and Finland (table 3). The model is estimated using fixed effects with year and size dummies. Capital lettered intangibles denote lagged logarithmic values. In order to examine whether elasticities are different before and after the crisis, each of the intangible assets are interacted with a dummy that is zero before 2008 (OCafter, RDafter, and ICTafter). We present three samples that include firms having all three types of assets (table 3); both RD and OC assets (table 4); and at least OC assets (table 5).

Table 3 shows estimation results when restricting the sample to firms having all three intangible types (which we refer to as the restricted sample). While the sample is still very large, with 42,617 observations in Denmark and 24,283 in Finland, the restricted sample only includes around a third of firms in the total populations with 10 or more employees in the selected sectors.
If we consider first the results for the whole period (the first columns for both countries), we see that RD elasticities are very similar for Denmark and Finland. The elasticity is approximately 0.04 for both. These values correspond well with values found in previous studies. Note though, that our measure of RD assets is somewhat broader than the measures based on R&D expenditures. This would thus suggest that the returns of other technical innovation activities (that are not formally R&D according to the Frascati definition by OECD (2015)) are similar to that for formal R&D investments.

In contrast, elasticities vary greatly for organizational assets, where the elasticity is from 0.07 to 0.08 and significant in Denmark while it is much smaller (0.01) and insignificant at the 5% level for Finland. Additionally, the elasticity of ICT is positive and significant only for Denmark. Meanwhile, management and marketing (OC) seem like one of the most important drivers of Danish growth.

The results show that, in almost all cases, elasticities are significantly different before and after the crisis, though typically these changes are not large in size. Elasticities for organizational assets in the recovery period are insignificant for Finland and lower for Denmark. On the other hand, elasticities increase for ICT assets, particularly for Finland.
The restricted sample of firms includes only a fraction of firms. For Denmark, there is a high correspondence between organizational and R&D assets (i.e. most firms have both types), while only a small share of these firms also has ICT assets. In Finland, correspondence between R&D and organizational assets is not quite as high while a slightly larger share of firms has ICT assets. When we include firms without ICT assets, the sample size grows for Denmark to 107,089 and doubles for Finland to 42,835 (table 4). When we allow firms without ICT and RD, the sample in Denmark is 156,326 and in Finland 55,763 (table 5). Hence, Denmark gets half more data points but Finland one fifth.

Next, we include a dummy for ICT to observations with the missing ICT assets value set to zero. The tables below show results for this second approach. Table 4 reports results of firms with organizational and RD assets and table 5 includes all observations with organizational assets.

All intangibles have positive and significant effect in Denmark. When adding a structural, the significant differences become visible in before and after the crisis for elasticities of RD & ICT assets, while the elasticity of organizational assets declines after the crisis. These Danish results are thus largely similar to those for the restricted sample, though with a couple of exceptions. First, the elasticities for after RD &ICT are insignificant for the restricted sample but significant for this larger sample of firms with RD and organizational assets. Second, the elasticities for organizational assets are smaller in this larger sample than for the restricted sample. One possible interpretation is that the organizational assets are more productive in combination with ICT assets, leading to a higher elasticity than in the restricted sample. However, we are unable to find support for the latter argument.

For Finland, the ICT dummy is insignificant unlike for Denmark. The elasticity of RD in Finland is higher than in Denmark by 0.01. Meanwhile, organizational & ICT assets are still insignificant in Finland for the full period. Yet, OCafter and ICTafter have a statistically positive coefficient. The dummy inclusion raised R squared.

As opposed to Finland, the returns from organizational competencies have come down (by 0.02) during the financial crises in Denmark. This is in line with the results of the restricted sample, though the elasticity here is very small. In Denmark, lagged ICT stock has a significant and positive contribution to productivity both before and after the crisis.

---

11 We also tried organizational dummy with Danish data, i.e., sample without restrictions. Yet, unlike other dummies, the dummy was statistically insignificant, did not gain many observations and made the coefficients absurd.
Table 4. Results for sample including all firms with organizational and RD assets

<table>
<thead>
<tr>
<th></th>
<th>DK</th>
<th>FI</th>
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<tbody>
<tr>
<td>Lagged log(RD)</td>
<td>0.0412***</td>
<td>0.0360***</td>
</tr>
<tr>
<td></td>
<td>(0.00197)</td>
<td>(0.00205)</td>
</tr>
<tr>
<td>Lagged log(OC)</td>
<td>0.0540***</td>
<td>0.0616***</td>
</tr>
<tr>
<td></td>
<td>(0.00202)</td>
<td>(0.00211)</td>
</tr>
<tr>
<td>Lagged log(ICT)</td>
<td>0.0177***</td>
<td>0.0151***</td>
</tr>
<tr>
<td></td>
<td>(0.00178)</td>
<td>(0.0018)</td>
</tr>
<tr>
<td>Lagged log(RDafter)</td>
<td>0.00915***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0013)</td>
<td>(0.00267)</td>
</tr>
<tr>
<td>Lagged log(OCafter)</td>
<td>-0.0178***</td>
<td>0.0170***</td>
</tr>
<tr>
<td></td>
<td>(0.00157)</td>
<td>(0.00297)</td>
</tr>
<tr>
<td>Lagged log(ICTafter)</td>
<td>0.00431***</td>
<td>0.00199**</td>
</tr>
<tr>
<td></td>
<td>(0.00043)</td>
<td>(0.000738)</td>
</tr>
<tr>
<td>ict_dummy</td>
<td>0.195***</td>
<td>0.186***</td>
</tr>
<tr>
<td></td>
<td>(0.0222)</td>
<td>(0.0223)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.793***</td>
<td>-1.750***</td>
</tr>
<tr>
<td></td>
<td>(0.0349)</td>
<td>(0.0335)</td>
</tr>
</tbody>
</table>

Next, we allow firms without RD assets to the sample if they still have organizational capital. This leaves us with almost 50% more data points for Denmark and 20% for Finland. For Denmark, the coefficients of RD, OC and ICT are the same as in table 4 at two decimals’ accuracy. However, the RDafter and ICTafter coefficients differ in size, but not in sign, from the previous ones. When the requirement of having RD assets is loosened, the after coefficient drops from 0.009 to 0.003, while also the negative coefficient of OCafter approaches zero (from -0.018 to -0.014) in Denmark. However, ICTafter rises from 0.0043 in the sample of RD and OC asset restricted to 0.0046 in OC asset restricted.

For Finland, ICT remains insignificant and RD remains statistically significant while OC gains significance. In addition, after the start of financial crises, organizational assets and ICT assets have contributed to the total factor productivity development in Finland. Unlike in Denmark, after crises organizational asset have a positive (and significant) coefficient (0.02). After crises ICT assets have a coefficient of a fourth of the size in Denmark. As previously, ICT dummy is insignificant for Finland as opposed to Denmark.
To summarize, recently the productivity gains from ICT and organizational competencies have developed in Finland, and are most apparent in the period after the beginning of financial crisis. Simultaneously, the high contribution of RD to Finnish productivity has been lower in the period after the crisis. Meanwhile, elasticities for ICT have also increased in the recovery period for Danish firms though for organizational competences the opposite is true. Hence, the results indicate that intangible assets have been important for the post-crisis recovery, though RD competencies influence positively to Denmark, OC competencies to Finland. The results support the discussion of growing ICT benefits.

6. Conclusion
This paper has examined the role of intangible assets for firm level productivity in two Nordic countries. While there is now a fairly extensive amount of evidence on the contribution of intangibles to growth at the macroeconomic level, only a relatively small set of analyses have examined the impact of intangibles at the firm level. A key barrier to these important analyses is lack of data availability, particularly concerning broader measures of intangibles. This paper contributes to this emerging strand of work. An important

<table>
<thead>
<tr>
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<th>DK</th>
<th>FI</th>
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<tbody>
<tr>
<td>Lagged log(RD)</td>
<td>0.0352***</td>
<td>0.0326***</td>
</tr>
<tr>
<td></td>
<td>(0.00155)</td>
<td>(0.00158)</td>
</tr>
<tr>
<td>Lagged log(OC)</td>
<td>0.0566***</td>
<td>0.0625***</td>
</tr>
<tr>
<td></td>
<td>(0.00153)</td>
<td>(0.00162)</td>
</tr>
<tr>
<td>Lagged log(ICT)</td>
<td>0.0201***</td>
<td>0.0178***</td>
</tr>
<tr>
<td></td>
<td>(0.00159)</td>
<td>(0.00161)</td>
</tr>
<tr>
<td>Lagged log(RDafter)</td>
<td>0.00262***</td>
<td>0.00689</td>
</tr>
<tr>
<td></td>
<td>(0.000355)</td>
<td>(0.000610)</td>
</tr>
<tr>
<td>Lagged log(OCafter)</td>
<td>-0.0141***</td>
<td>0.0144***</td>
</tr>
<tr>
<td></td>
<td>(0.00120)</td>
<td>(0.00240)</td>
</tr>
<tr>
<td>Lagged log(ICTafter)</td>
<td>0.00459***</td>
<td>0.00179**</td>
</tr>
<tr>
<td></td>
<td>(0.000379)</td>
<td>(0.000650)</td>
</tr>
<tr>
<td>ict_dummy</td>
<td>0.205***</td>
<td>0.204***</td>
</tr>
<tr>
<td></td>
<td>(0.0197)</td>
<td>(0.0197)</td>
</tr>
<tr>
<td>rd_dummy</td>
<td>0.422***</td>
<td>0.395***</td>
</tr>
<tr>
<td></td>
<td>(0.0199)</td>
<td>(0.0202)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.750***</td>
<td>-1.793***</td>
</tr>
<tr>
<td></td>
<td>(0.0335)</td>
<td>(0.0349)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>DK</th>
<th>FI</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>156326</td>
<td>156326</td>
</tr>
<tr>
<td>r2_w</td>
<td>0.0985</td>
<td>0.100</td>
</tr>
<tr>
<td>r2_b</td>
<td>0.384</td>
<td>0.382</td>
</tr>
<tr>
<td>r2_o</td>
<td>0.314</td>
<td>0.312</td>
</tr>
<tr>
<td>sigma_e</td>
<td>0.333</td>
<td>0.333</td>
</tr>
<tr>
<td>sigma_u</td>
<td>0.527</td>
<td>0.528</td>
</tr>
</tbody>
</table>

To summarize, recently the productivity gains from ICT and organizational competencies have developed in Finland, and are most apparent in the period after the beginning of financial crisis. Simultaneously, the high contribution of RD to Finnish productivity has been lower in the period after the crisis. Meanwhile, elasticities for ICT have also increased in the recovery period for Danish firms though for organizational competences the opposite is true. Hence, the results indicate that intangible assets have been important for the post-crisis recovery, though RD competencies influence positively to Denmark, OC competencies to Finland. The results support the discussion of growing ICT benefits.

6. Conclusion
This paper has examined the role of intangible assets for firm level productivity in two Nordic countries. While there is now a fairly extensive amount of evidence on the contribution of intangibles to growth at the macroeconomic level, only a relatively small set of analyses have examined the impact of intangibles at the firm level. A key barrier to these important analyses is lack of data availability, particularly concerning broader measures of intangibles. This paper contributes to this emerging strand of work. An important
contribution of this work is the construction of intangible assets’ measures based on linked employer-employee data and its use in firm level productivity analysis. The approach follows occupational-based measure of intangibles as done in Squicciarini and Le Mouel (2012) that of the INNODRIVE project, though our paper is the first to utilize this approach in firm level regression analysis of intangibles and productivity. The advantages of this approach are that the data allows a broad-based measurement of intangible assets and that it also allows for extensive coverage of firms across industries. And while, the method is very data-intensive and requires further validation work to evaluate comparability across countries, it can in principle be applied in any country with linked employer employee data (LEED) and international occupation classification of employees. An additional novel element of our analysis is the examination of the role of intangibles in the economic recovery after the crisis, also set in relation to the role of intangibles in the period of fairly stable growth prior to the crisis. Our data covers the period from 2000 to 2013.

Based on occupational data, intangible assets are classified into three categories: organizational, research and development (RD) & information communication technology (ICT) assets. Organizational assets are accumulated through investments in management and marketing activity, where we assume that these activities result in a build-up of organizational knowhow for the firm. RD assets are accumulated through the technical activities of the firm, and thus are broader than measures of R&D expenditures based on the Frascati definition of R&D (OECD, 2015). ICT assets represent the accumulated knowhow based on in-house activities to manage, develop and implement ICT activities in the firm.

Our main results are the following. First, productivity elasticities of RD found for Denmark and Finland are typically in the range of 0.04-0.06. These results are thus quite comparable with those found in other recent analyses using different measurement approaches (such as Marrocu et al. (2012), Bontempi and Mairesse (2015), Crass and Peters (2014)). This is also interesting given that our measure of R&D assets is much broader than measures based on formally defined R&D expenditures and likely also innovation expenditures, which include non-R&D activities that are directly related to innovation development and implementation (OECD & Eurostat, 2005). For example, based on our measure, around two thirds of all firms (with 10 or more employees) have R&D assets, while shares of firms with R&D or with innovation activities are typically much lower. This comparability in elasticity estimates despite these measurement differences suggests that broader ‘non-R&D’ activities in related tasks are equally important in building technical knowhow that contributes positively to firm performance.

Our method in particular offers an approach to measure organizational assets, which has proven very elusive for firm level analysis. We in general find that positive, significant elasticities of organizational assets, in some cases larger than R&D assets for Denmark. However, the differences in results for Denmark and Finland are somewhat larger than would be expected for two fairly similar countries. The share of firms with organizational assets is lower in Finland and results are much weaker for Finland concerning the productivity effects of organizational assets. More in-depth analysis of the data is needed in order to assess
the comparability of the LEED data across the two countries. While we have utilized the same approach in both countries, further analysis is needed to assess whether there are differences in data quality or perhaps in reporting practices concerning occupational classifications. This would allow us to better discern to what extent cross-country differences reflect actual firm differences (for example, that Danish firms have greater focus on managerial, organization and non-technical aspects of innovation than Finnish firms) as opposed to differences in the data.

RD assets are positive and significant before the financial crises for both countries but the RD elasticities are lower in the recovery period in Denmark and higher in Finland. A similar pattern is found for organizational assets, where elasticities decreased in Denmark and increase in Finland, where organizational assets has statistically insignificant effect, during the before period.

The role of ICT assets is interesting, particularly when examining differences in the post-crisis recovery: the elasticities of ICT assets are significantly larger in the recovery period. This is particularly the case for Finland, where ICT assets are actually insignificant pre-crisis but strongly significant in the post-crisis recovery period. The results thus suggest an important role of ICT assets in firm efforts to adapt and compete after the start of financial crisis in 2008.
References


### Appendix A. Intangible capital measurement

IC-related employees are classified according to the following occupational coding (based mainly on two or three digit codes) based on ISCO2008 (ISCO1988 in parenthesis)

#### Organizational work

- Managing Directors and Chief Executives 112 (112)
- Administrative and Commercial Managers 12 (123 all)
  - Business Services and Administration Managers 121, Sales, Marketing and Development Managers 122
• Managing, mining, construction and distribution managers 13, 131 (122)
• Manufacturing, mining, construction and distribution managers 132 (122)
• Professional services managers 134 (122)
• Teaching Professionals 23 (23)
• Business and Administration Professionals 24 (241 all)
• Finance Professionals 241, Administration Professionals 242, Sales, marketing and public relations professionals 243
• Legal, Social, Cultural and Related Associate Professionals 34 (all) (242)
• Legal, social and religious associate professionals 341 (343), Sport and fitness workers 342 (347), Artistics, cultural and culinary artist professionals, 343 (347)
• Business and Administration Associate Professionals 33 (excluding 335):
  • Financial and Mathematical Associate Professionals 331 (343), Sales and Purchasing Agents and Brokers 332 (342), Business Services Agents 333 (342)
• Administrative and Specialized Secretaries 334 (332)
• Otherwise R&D work and education field in social sciences and business and 2, 21, 22, 3, 31, 32

RD work
• Technical and mathematical work professional R&D managers 1223 (1237)
• Science and Engineering Professionals 21 (excluding telecommunication engineering 2153)
  • Physical and earth science professionals 211 (211), Engineering Professionals 212 (212)
  • Mathematicians, Statisticians, Life-science professionals 213 (212), 214 (212), Electrical, Electronics Engineering 2151, 2152 (212), Architects, Planner 216 (212)
• Health professionals 22
  • Medical doctors 221 (222), Nursing and Midwifery Professionals 222 (223), Other Health Professionals 226 (223), 22 (isco3 not available)
• Science and Engineering Associate Professionals 31
  • Physical and Engineering Science Technicians 311 (311), Life Science Technicians and Related Associate Professionals 314 (321)
• Otherwise OC work and education field not in social sciences and 1, 12, 13, 23, 24, 34

ICT work
• ICT managers 133 (1236)
• Telecommunication engineering 2153 (213)
• Information and Communications Technology Professionals 25
• Information and Communications Technicians 35 (312)
• Nursing and Midwifery Associate Professionals 226 (322)
Employees with other classifications in the top three major groups are classified into ICT if their education is ICT-related and Organizational is their education is within the social sciences. For employees where occupation data is not available in a given year, occupation data was imputed using the past year’s occupation. If this is not available, employees are assumed to contribute to one of the three types of intangibles investments if their education level is a bachelor’s degree or higher and if their education field is within a relevant area.

Calculations are made based on wage income and a multiplier that takes account first that not all work activities contribute to knowledge creation and second that non-labor expenditures also constitute intangibles investments. H. Piekkola (2016) provides the value of a combined multiplier $M^C$ in (1), which is time invariant in the expenditure-based approach. The share of worker income who produce intangible goods is set at 40% for organizational occupations (twice the share used in (Görzig et al., 2010)), 70% for RD occupations, and 50% for ICT occupations. The factor multiplier from the intermediate and capital costs is set to represent the entire EU27 area and is a weighted average of the factor multipliers for Germany (40% weight), the United Kingdom (30% weight), Finland (15% weight), the Czech Republic, and Slovenia (both countries have weights of 7.5%). The factor multipliers employed account for the use of capital, and intermediate inputs are 1.76 for organizational wage expenses, 1.55 for R&D wage expenses, and 1.48 for ICT wage expenses. Labor costs are annual earnings instead of hourly wages because (1) the earnings include performance-related pay and (2) workers in managerial positions are not paid for overtime hours. As a result, managers’ recorded hours are consistently lower than the actual number of hours worked. Table A.1 summarizes the combined multiplier $A^C$ (the product of the share of effort devoted to IC production and the factor multiplier) and the depreciation rates that we employed.

Table A.1. Combined multipliers for OC, RD and ICT in the expenditure-based approach and their depreciation

<table>
<thead>
<tr>
<th></th>
<th>OC</th>
<th>R&amp;D</th>
<th>ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment shares</td>
<td>20%</td>
<td>70%</td>
<td>50%</td>
</tr>
<tr>
<td>Combined multiplier $A^C$</td>
<td>70%</td>
<td>110%</td>
<td>70%</td>
</tr>
</tbody>
</table>

12 The input-output tables are from the EU KLEMS database, and the countries are covered with LEED data from INNODRIVE, which is the product of the 6th framework research project financed by the European Commission to analyze productivity in the European Union at the industry level.
Organizational and ICT investments represent 70% of the labor costs in the occupations that we consider (in ICT, the figure is an approximation of the combined multiplier of 0.74). In RD activities, the total wage costs are close approximations of the total investment, and they have a combined multiplier of 110%.