POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland

Carter Bloch[a,*], Carita Eklund[a] and Hannu Piekkola[b]

[a]Danish Centre for Studies in Research and Research Policy (CFA), Department of Political Science, Aarhus University, Aarhus, Denmark
[b]Department of Economics, University of Vaasa, Vaasa, Finland.

[*]Corresponding author, email: carter.bloch@ps.au.dk

January 7, 2021

Abstract

This paper examines how intangible assets contribute to firm-level productivity in the small open economies of Denmark and Finland from 2000 to 2013. 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 where intangible capital deepening decreased in 2008-2013 in many European countries. This decrease in innovative input in many countries with Finland as an example has been drastic also in the face of their increasing effect on total factor productivity. The productivity analysis is conducted in two stages. First, we derive total factor productivity (TFP), and second, we estimate the effects of intangible assets on total factor productivity. Our approach for measuring intangible assets is based on innovation work evaluated from occupational classifications in a linked employer–employee dataset. We construct measures for three types of intangibles: broad R&D assets (R&D), organizational assets (OC) and information and communication technology assets (ICT). In both countries the TFP effects of broad R&D increases slightly in the period after the crisis. For Finland, we also find that the TFP effects of OC increase after the crisis, while Denmark experienced after financial crises considerable increase in OC assets in intangible intensive industries such as information, education and health industries where productivity is lower.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

1. Introduction

Manufacturing and service sectors in advanced economies have been under increasing pressure in the last decade. The pressures of global competition have been growing over a longer period but have clearly become more acute since the financial crisis in 2008 and 2009. The financial crises led to a decrease in innovation capacity as intangible investments slumped (Piekkola, 2020; Roth, 2020). This raises a question: can innovation capabilities help with recovery from or adjustment to changing conditions? This question has become even more relevant in light of the economic crisis that has been precipitated by Corona virus and global efforts to contain its spread. Companies are faced with the challenge of first coping with the crisis, wider adoption of ICT and then, as societies slowly return to normalcy, with the challenge of adapting and rebuilding under likely very different conditions than prior to the crisis.

A number of studies have focused on ways forward for firms in advanced economies such as Denmark and Finland to tackle the challenges of global competition, with a particular focus on manufacturing. Manyika et al. (2012) argue that a new era is emerging for global manufacturing, and that manufacturing is expected to play an important role 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). Furthermore, while declines in employment have drawn greater attention to manufacturing, these are equally relevant to service sectors.

In advanced economies, these challenges place new demands on manufacturing and service firms to be competitive. Firms need to be agile, able to operate on a worldwide scale, and be able to adjust quickly in response to changing conditions and take advantage of them (Wiengarten, 2016). This includes both product and process innovation. Within the latter, particular focus has been placed on the implementation of ICT-based technologies such as digitalization or automation. Flexibility also involves structural capital such as the organizational ability to enter new markets and the ability to adjust operations to meet changing demand conditions.

Intangible assets are non-physical assets that are expected to create value now and in the future. Hence, they embody the structural capital and ICT competences that firms possess. The link between intangibles and productivity is not fully understood, where returns to intangibles can potentially depend on many firm-specific and environmental factors. For example, how do innovative competences contribute to firm productivity (Higón, Gómez, & Vargas, 2017)? What is the role of broader, organizational competences

(Ritala, Heiman, & Hurmelinna-Laukkanen, 2016)? Moreover, to what extent is the implementation of new information technologies driving performance for successful firms? An important additional factor is the role of intangibles in facilitating adjustment to major shocks such as financial crises or the current Corona crisis (Cucculelli & Bettinelli, 2015).

This paper studies the role of intangible assets for productivity in Denmark and Finland. In particular, the analysis will examine the role of intangible assets since the slump in innovative investment in Finland and Denmark after the financial crisis in 2008 but also facilitating the potential recovery given their important role for total factor productivity (TFP). Denmark and Finland are both small open economies with populations of approximately 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. As the market size is small for both countries, many companies pursue opportunities outside of the home market to gain access to a large enough pool of customers. Both countries suffered large declines in GDP because 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.

We calculate intangible assets at the firm level by relying on employee occupational data and salary data that is linked with firm-level balance sheet data. Drawing on methods developed in the Innodrive project (Görzig, Piekkola, & Riley, 2010; Piekkola, 2016), and the GLOBALINTO project (www.GLOBALINTO.eu), we identify intangible-producing employees by their occupations and assume that a certain share of their work effort is used to invest in new knowledge and capabilities. R&D covers technical and R&D activities (such as science, engineering and health innovation development). OC relates to managerial and marketing capabilities and branding. ICT covers database and software development and the maintenance of ICT networks because they require long-term planning.

Our analysis covers the period from 2000 to 2013. We employ a productivity analysis (Olley & Pakes, 1996), similar to that in (Higón et al., 2017), that utilizes a two-stage estimation method, where total factor productivity (TFP) is estimated in the first stage, while the second stage analyses the relation between TFP and intangible assets.

The next section reviews recent studies to measure IA 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 constructing firm-level measures of IA. 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

Much work on the measurement of investments in intangible assets is fairly recent, particularly at the firm level. However, early work by (Kendrick, 1994) on intangible investment in the United States during the 20th century shows a pronounced increase in the ratio of intangible to tangible investment, reflecting the important rise in resources devoted to education, training and especially R&D.

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[1]. Corrado, Hulten, & Sichel (2005) identify three main categories of intangible assets: economic competencies, innovative property and computerized information. Economic competencies include spending on strategic planning proxied by management expenditures, worker training, redesigning or reconfiguring existing products in existing markets, investment to retain or gain market share and branding such as investing in brand names. Innovative property refers to 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 includes computer software and databases. de Rassenfosse (2017), among others, broadens branding activities to cover design that creates design rights.

In the last 15-20 years, an increasing literature has examined the contribution of intangibles. Niebel, O'Mahony, & Saam (2017) 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 assets than those used in this paper. The output elasticity of intangibles was found to be between 0.10 and 0.20, which may be related to narrower data availability and knowledge spillovers than when using macro levels where the elasticity has been around 0.25 or above (see e.g. Corrado, Haskel, Jona-Lasinio, & Iommi, 2013; Roth & Thum, 2013). Corrado et al. (2013), Marrano, Haskel, & Wallis (2009) and van Ark, Hao, Corrado, & Hulten (2009) highlight the important knowledge spillovers between R&D, organizational and ICT capital. Also, research originating in the EU-funded Innodrive and COINVEST projects found that intangible capital has made considerable contributions to increases in labor productivity in 1995-2005, which was later confirmed by Piekkola (2018) and Corrado, Haskel, Jona-lasinio, & Iommi (2014). However, for analyses using firm-level data, output elasticities are typically lower around 0.10.

[1] See, in particular, the work undertaken on intangibles measurement at both the macro and micro level in the EU FP7 project, Innodrive (www.Innodrive.org) and the Horizon 2020 project, GLOBALINTO (www.GLOBALINTO.eu).

Among firm level analyses, extensive work has been done on the relation between R&D and productivity (for a review, see Hall, Mairesse, & Mohnen (2010)) and innovation and productivity, while there is less experience with broader measures of intangibles.

There has also been a relatively long tradition to measure intangible capital using balance sheet information on intangible assets that have been capitalized. Marrocu, Paci, & Pontis (2012) conduct such a firm level productivity analysis of intangibles for six European countries: France, Italy, Netherlands, Spain, Sweden and the United Kingdom. They find elasticities in the range of 0.04-0.06. Bontempi & Mairesse (2015) also rely on balance sheet data of Italian firms, but go 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).

Crass & Peters (2014) 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 is measured by training and the share of highly skilled labor, while branding capital is measured by marketing expenditures and stocks of trademarks. In addition, dummy variables concerning organizational innovations function as proxies of organizational capital.

The approach here follows the relatively new tradition of measuring intangible assets from innovative work. In GLOBALINTO with a comparable occupational classification, Piekkola (2020) considers organizational capital and technology, such as R&D and proprietary software systems, to be parts of the structural capital that are highly complementary to each other . Eklund (2020) shows the importance of organizational capital for high-growth SMEs, in addition to R&D. The 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, and through purchase of intangibles from suppliers. Measures of investments in intangibles are constructed from the annual labor costs 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.

Intangible assets (IA) are classified into three categories[3]:

[2] ISCO-08, http://www.ilo.org/public/english/bureau/stat/isco/isco08/
[3] Another approach used by Ilmakunnas and Piekkola (2014) measures intangibles investments with employees of Finnish firms, where work shares proxy intangible capital for three categories: organizational, RD and ICT.

- Organizational assets (OC)
- Broad Research and Development assets (RD)
- Information and communication assets (ICT)

Organizational assets are 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 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.

The investment calculations consist of IA-type labor costs, a multiplier accounting for the investment share of work (as not all work activities contribute to knowledge creation) and a factor multiplier that approximates the purchase of intangible (expensed as intermediate inputs) and tangible capital for each type of intangible asset. Estimates of the multipliers used in this analysis are based on Görzig et al. (2010) and Piekkola (2016). 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 (which given current restrictive accounting practices comprise only a small share of intangibles investments from an economic perspective), allowing us to construct 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 linked employer-employee data (LEED) 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 of 2000-2013. The datasets include all firms[4] having an average of at least ten employees over the period. The samples cover all manufacturing industries and a broad range of market services[5]. 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), tangible capital (total fixed assets) and fixed capital investments. Data for

[4] The resulting final sample used includes all firms in 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).
[5] In terms of NACE Rev. 2 2-digit code, the sample includes manufacturing (10 to 33), excludes other production (35-39), construction 41 and includes all services 45 to 74 with the exception of financial services (64-66).

employees include labor cost from annual wage income for each employment, type of occupation, and the level and field of education.

As noted above, intangible assets are approximated from the amount of intangibles producing employees to which we use a so called factor multiplier to account for acquisitions of related intermediate goods and intangible capital, ranging from 1.48 for ICT to 1.76 for OC (Görzig et al., 2010). Based on occupational classifications, we identify employees (in managerial and technical positions) that are viewed as contributing to the generation of organization, broad R&D (RD) and ICT based capabilities. IA-related employees are classified according to the following occupational coding (based mainly on two or three digit codes) based on ISCO2008:

- Organizational work: Managing Directors and Chief Executives 112 ; Administrative and Commercial Managers 12; Managing, mining, construction and distribution managers 131, 132, 134; Business and Administration Professionals 24; Legal, Social, Cultural and Related Associate Professionals 341; Business and Administration Associate Professionals 331-333 (342, 343)
- RD work: Technical and mathematical work professionals, R&D managers 1223; Science and Engineering Professionals 21 (excluding telecommunication engineering 2153); Health professionals 221, 222, 226; Science and Engineering Associate Professionals 311, 314 (311, 321)
- ICT work: ICT managers 133; Telecommunication engineering 2153; Information and Communications Technology Professionals 25; Information and Communications Technicians 35

Managerial and technical staff are assumed to contribute partly to daily operations and partly to the accumulation of intangible capital. The working shares spent on producing intangibles are assumed to be 20% for OC workers, 70% for RD workers and 50% for ICT following the work within the Innodrive project (Görzig et al., 2010)

The appendix shows the details surrounding the construction of expenditure-based measures of intangible assets at the firm level. Real intangibles investments N_{it}^{IA} of type IA=OC, RD, ICT are calculated as follows:

$$P_{j,t}^{N} N_{i,t}^{IA} \equiv A^{IA} W_{i,t}^{IA}, \tag{1}$$

In equation 1, W_{it}^{IA} represents labor costs of intangible worker in firm i at time t. We multiply the labor costs by the combined multiplier A^{IA} that is reported in table A.1 in the appendix. P_{jt}^{N} is the industry (j) deflator proxied by the IA-producing business services deflator at a two-digit NACE level when assessable[6]. The intangible assets R_{it}^{IA} follow the standard accumulation of capital stock, where the depreciation rate is 20% (25%[7]) of the previous organizational asset in manufacturing (services). The depreciation rate of RD is 15% for the previous stock value, and 33% similarly for ICT. Using the measure of intangible investment from equation 1, the stock of capital R_{it}^{IA} for IA of type OC, RD, ICT is as follows:

$$R_{it}^{IA} = N_{it}^{IA} + (1-\delta_{ia})R_{it-1}^{IA},\ with\ R_{i,t=0}^{IA} = \overline{N}_{i,t=0}^{IA} / (\delta_{ia} + g) \quad (2)$$

The initial IA investment $\overline{N}_{it=0}^{IA}$ is defined as the average growth-adjusted investment over a three-year period of the industry in the first year of the data coverage. $R_{i,t=0}{}^{IA}$ is calculated from intangible investments using the geometric sum formula, with the depreciation rate of δ_{IA} and the growth rate of the intellectual asset g. The growth rate g is set at 2% for all IA, which follows the sample average growth rate of real wage costs for IA-related activities. Nominal variables are deflated using industry-level producer price indexes for firm financial variables. As noted above, the measures of intangible investments are deflated using the producer price index for the business service industry, as it was viewed that price developments in this industry better reflected developments in intangibles costs than price levels in firms' own respective industries. Much of these assets, such as purchased organizational, R&D and ICT assets, are unaccounted for in national accounts.

Table 1 shows the shares of firms with each type of intangible capital over the period. Denmark and Finland seem to have different developments in the composition of intangible assets. In our sample, a higher share of Danish firms have organizational capital (OC), research and development (RD) and information communication technology (ICT) in 2013 than in 1999. The opposite is true for Finland, where shares have declined for all intangibles types. At the start of the sample, all intangible types are more typical in Finland than in Denmark. However, the share of firms with R&D is fairly similar in the two countries after 2010. OC experiences similar developments though Denmark has a higher share with OC from 2009 onwards.

[6] We deflated values from Danish service industries with an aggregated producer price index for the entire service sector, as we did not find deflators for individual service industries for the sample from 1999 to 2013.
[7] One finding of Awano, Franklin, Haskel, & Kastrinaki (2010) is that the benefit of intangibles last longer in manufacturing than in service industries.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

Table 1. Share of firms with intangible investments.

	Denmark			Finland		
year	Firms with OC	Firms with RD	Firms with ICT	Firms with OC	Firms with RD	Firms with ICT
1999	73 %	55 %	18 %	91%	84%	55%
2000	75 %	57 %	22 %	91%	84%	54%
2001	77 %	59 %	24 %	90%	84%	52%
2002	78 %	62 %	25 %	90%	83%	52%
2003	79 %	64 %	26 %	90%	83%	52%
2004	79 %	66 %	27 %	90%	82%	52%
2005	80 %	67 %	29 %	89%	81%	51%
2006	80 %	67 %	30 %	89%	81%	51%
2007	80 %	68 %	31 %	88%	79%	49%
2008	80 %	68 %	31 %	87%	77%	48%
2009	80 %	69 %	32 %	86%	75%	46%
2010	82 %	70 %	33 %	85%	73%	45%
2011	82 %	70 %	34 %	83%	70%	42%
2012	83 %	71 %	35 %	82%	68%	40%
2013	85 %	73 %	37 %	79%	65%	38%

Table 2 shows size and growth rates in intangible assets for the samples in Finland and Denmark, where the growth rates have been going in opposite directions after the start of the financial crisis. Average firm size of Finnish firms is somewhat larger and a larger share of firms has RD and ICT assets than for Denmark. In contrast, Denmark has more OC. Denmark has larger growth rates in OC after 2003. Finland has larger rates of growth in R&D before 2008, but a decrease of 2.5% after 2008, while there is a small increase of 0.5 % in Denmark. Similar patterns are found in Finland for OC and ICT: Organizational assets have a 3.5% decrease while ICT assets have a 5.4% decrease. For Denmark, growth rates are positive both before and after 2008. Furthermore, the growth rates of ICT assets are interesting. From 1999 to 2003, the growth rate was 8.1% in Finland, and 5.0% in Denmark. From 2003 to 2008, ICT assets grew again around 8% in Finland and less, 2.4%, in Denmark. Then, the growth turned negative in Finland, - 5.4%, and stayed positive in Denmark 5.0%.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

Table 2. Summary statistics.

Variable	Finland	Denmark
Employees	125	81
Value-Added	10314.3	5789.0
Growth over period 99-03	1.8%	4.5%
Growth over period 03-08	2.3%	3.6%
Growth over period 08-13	-4.8%	-0.9%
RD	4268.7	2961.9
Growth over period 99-03	4.1%	3.7%
Growth over period 03-08	3.3%	2.5%
Growth over period 08-13	-2.5%	0.5%
OC	1075.3	565.3
Growth over period 99-03	4.2%	3.3%
Growth over period 03-08	1.6%	2.2%
Growth over period 08-13	-3.5%	6.5%
ICT	1196.0	157.2
Growth over period 99-03	8.1%	5.0%
Growth over period 03-08	7.9%	2.4%
Growth over period 08-13	-5.4%	5.0%
Number of observations	63377	91005

Value added and intangible assets in thousand euros.

The following table shows average annual GDP growth rates in intangible intensive industries and other industries over 2007-2013.

Table 3. Annual GDP growth rates by intangible intensive and other industries 2008-2013

	Denmark	Finland
GDP of which	0.0	-0.9
Agriculture	-0.3	1.1
Manufacturing	0.7	-4.8
Pharmaceutical	12.6	8.4
Electronics	-0.5	-8.0
Paper and Pulp	-5.1	-0.3
Trade	-0.5	0.3
Information	5.9	3.5
KIS	0.7	-0.1

Electronics cover manufacture of computer, electronic and optical products (C26) and electrical equipment (C27), KIS industries are professional, scientific and technical services (M).

We can see that after financial crises in Denmark intangible intensive industries (marked in bold) have been growing strongly. The divergent development of intangibles since the financial crisis is hence due to rapid increase in intangible intensive manufacturing in Denmark. During the period Finland was hit by downsizing of operations of Nokia (electronics industry) with a decrease in employment from 25,000 to 6,000 by 2013 and annual decrease GDP in the electronic industries by 8%. The following section presents the methods that we employ in explaining the effects of intangibles. Section 4 first explains our estimation of the production function. Then we discuss total factor productivity estimation and limitations.

4. Analysis method

The framework of most previous studies is the production function approach using a Cobb & Douglas (1928) production function[8]. We follow this path and estimate the production function utilizing a two-stage approach following Higón et al. (2017). First, we estimate a production function consisting of tangible capital and labor, and save the residual as our measure of total factor productivity (TFP). Then, we explain total factor productivity with intangible assets. The empirical strategy primarily draws on Bontempi & Mairesse (2015), Higón et al. (2017), and Crass & Peters (2014). Higón et al. (2017) use the Levinsohn-Petrin method to estimate the first stage and OLS to estimate the regression for TFP. We use here the similar Olley-Pakes method for the first stage, but estimate the second stage using fixed effects (within). This better measures the productivity evolvement over time, while between effects are more sensitive to economic cycles. Our method is described in greater detail below.

4.1 Production Function Estimation

Firms choose their capital and labor accounting for following periods where they use their knowledge of forthcoming shocks v_{it} that are a part of the error term η_{it} 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. As we measure output as value added, intermediate inputs are not used in the production function. The underlying assumption is that intermediates do not make notably more value to the final product than their own price.

$$q_{it} = a + \alpha l_{it} + \beta k_{it} + \eta_{it} \tag{3}$$

We follow Olley & 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 the Levinsohn & Petrin (2003), henceforth LP, which is a method using intermediate inputs as a proxy

[8] An exception here is Bontempi and Mairesse (2015) who use a constant elasticity of substitution function.

variable. First, we lack data on intermediate inputs for the first years of the sample and, second, investments had more non-zero values than intermediate inputs in our sample. More importantly, some of the intermediate inputs would be used in intangible investment, thus causing multicollinearity problems.

In OP, the investment rate inv_t in period t is a function of period t - 1 state variable capital k, and unobserved technical efficiency parameter s_t (proxied by ϕ_t): $s_t = f(k_{t-1}, \phi_t)$. Inverting this relationship yields the unobserved technical efficiency parameter s_t as a function of the lagged state variables $\phi_t = f(k_{t-1}, inv_t)$. The unobserved technical efficiency parameter is approximated by polynomials of the proxy and state variable k and their interaction terms. In the first step, y is regressed on ϕ_t as well as on k, freely adjusting employment l and the controls. This gives the production function parameter other than the state variables (here k) to evaluate TFP

The unobserved technical efficiency parameter is obtained from the first step as $\hat{s}_t = \hat{\phi}_t - c_K k_{t-1}$ where $\hat{\phi}_t$ is the predicted y minus the contribution of l and controls. Assuming a Markov process, we express the unobserved technical efficiency parameter as a polynomial of the lagged shock. The final step uses moment conditions to estimate the coefficients of the production function parameters of state variables (here k) in which the regressors of $\hat{\phi}_t$ are the k, the polynomial of the lagged shock $\hat{s}_{t-1}$, and the polynomial of the predicted probability of exit and its interactions with the shock. In addition, before the final step of the proxy variable estimation, we control for the selectivity caused by the exit of firms.[9] For example, low-productivity firms are more likely to exit through failure so that remaining firms would disproportionately consist of high-productivity firms. From all the production function parameters, we get an approximation for TFP.

4.2 From Intangible Assets to Productivity

We explain TFP from the first estimation with beginning of year values[10] of intangibles in order to avoid endogeneity problems, as in (Hall & Mairesse, 1995). This simultaneity problem results from the possibility that the period's productivity and investment choices are influenced by the same factors. Lagging the assets makes the problem of endogeneity less severe but may not fully eliminate it. The regression is presented in equation (4) where TFP denotes total factor productivity, rd_{it} lagged logarithm of R&D, and oc_{it} and ict_{it} similarly for OC and ICT. X_{it} includes controls, year and, as in Higón et al. (2017), firm size dummies. Year

[9] The firm's exit decision can be a function of unobservable productivity shocks in an unbalanced panel like ours.

[10] The beginning of year assets are the same as the assets at the end of the previous period. This means that depreciation and investments of year t has not happened but depreciation and investments of time t-1 have.

dummies control for macroeconomic changes from the error term whereas the size dummies control partly for the communication environment and other size related advantages. R&D, ICT and OC are constructed from linked employer-employee data as described both above.

Second, we model a structural break for the financial crisis in 2008. The underlying assumption is that the crisis introduced a change in the business environment notably because of new tight situation in access to finance and changes in demand. The structural break helps to test whether the financial crisis affects the productivity gains from intangible assets and these can explain why Denmark has recovered better from the crisis than Finland. Equation (4) is:

$$tfp_{it} = \beta_0 + \beta_1 brd_{it} + \beta_2 oc_{it} + \beta_3 ict_{it} + X_{it} + \varepsilon_{it} \quad (4)$$

where variables in small letters imply logarithmic form[11].

Inclusion of firms without intangibles investments can introduce a downward bias on coefficient estimates. As shown in table 1, a high share of firms have OC while smaller shares also have other types of intangible assets, particularly for ICT assets. We have chosen to use a broad sample that includes all firms with OC in at least one year (but not necessarily RD or ICT). Dummies are included for missing RD or ICT capital. An alternative method would explicitly estimate the decision by firms to invest in intangibles as inputs for innovations, however this would reduce the sample size considerably. For comparison, we have estimated the model for other samples, such as firms with both OC and RD in at least one year, or firms with all three types of intangible capital. This leads to slight changes in coefficient estimates, though patterns before and after the crisis remain the same. Going from small to large sample, coefficients increase slightly for RD and decrease slightly for OC and ICT. Results for smaller samples are not shown here but are available on request from the authors.

Note that we do not include intangible assets in the estimation of TFP because we treat intangible assets as one of the determinants of TFP dynamics in our regression equation. An alternative approach would be to include intangible assets directly into the OP model, though the relationship between intangible assets and TFP would then be decided in the estimation of output, which differs from the empirical strategy used in this analysis. However, for comparison, we also estimate the entire model in one stage, also including intangibles in the OP model. We are not aware of any studies where intangibles would be included both in OP and TFP estimations. The following section presents the results.

[11] Results are essentially unchanged if the break is set at 2008 instead of 2009.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

5. Results

This section presents the results of the analysis. First, we discuss production function estimates of both countries. We report the OP production model, though we have also tested the LP model and found that it gives similar results. Second, we present the results of the TFP estimation where productivity is explained by intangible assets. Finally, as a robustness check we also include the intangible assets in the OP model. The comparison of these two approaches is particularly instructive given the size and duration of the productivity shock that we are seeking to measure.

5.1 Production Functions

Table 4 presents the Olley and Pakes production function estimation for Denmark and Finland. We are aware that using the number of employees might be problematic though the number of hours worked might be even more highly correlated with our intangible assets estimation[12]. We correct double counting of labor by subtracting the employees who are involved in producing intangibles. Cuneo & Mairesse (1983), Hall & Mairesse (1995) and Schankerman (1981)) show that without this correction the elasticity of R&D is downward biased. Table 3 reports the production function coefficients for all firms that have OC in at least one year during the estimation period and for the smaller sample of firms with all three types of intangibles.

The capital in Finland is evaluated from buildings and machinery and equipment, whereas in Denmark is the fixed assets reported in balance sheets. Thereby in Table 3 also the output elasticity is larger for Denmark than for Finland as fixed assets cover a larger variety of capital. The coefficient of the log of employees is instead larger in Finland than in Denmark. For both countries, the sum of coefficient estimates for labor and capital are less than one. Hence, the results indicate decreasing returns to scale for both countries, or, alternatively, that the production function is lacking factor inputs, namely intangible assets. From this first stage we save the residuals as a measure of (the log of) total factor productivity (TFP). In TFP we have examined the effects of extreme values by removing the 99th and 1st distribution from the model. This does not alter the basic findings, but lowers the standard deviation of the coefficients.

[12] We have examined use of the ACF correction (suggested by Ackerberg, Caves, & Frazer (2015)) to improve production function estimates of Olley and Pakes (1996) and Levinsohn and Petrin (2003), which might suffer from functional dependence problem for both countries but as it was unfeasible with industry dummies and did mostly affect dummy coefficients, we decided not to use the correction.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

Table 4. Olley-Pakes Production function estimates from value added.

	Denmark	Finland
Tangible capital	0.163***	0.029***
	(0.000)	(0.000)
Employees	0.748***	0.871***
	(0.010)	(0.006)
Industry dummies	yes	yes
N	91005	63377

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Tangible capital, employees and value added in logs. Standard errors in parentheses, employees exclude IA-type workers to minimize correlation. (*) only firms with all three IA types.

5.2 The impact of intangibles on TFP

Based on the approximation of TFP above, we obtain the following results for Denmark and Finland (table 5). The model is estimated using fixed effects estimation. R&D elasticities for TFP are similar for the two countries, at 0.039 in Finland and 0.043 in Denmark, and with elasticities also increasing in both countries after the crisis. These estimates for R&D assets exceed those for R&D in[13], but are generally in line with those found for R&D in Crass and Peters (2014). On the other hand, our TFP effects do not appear to be sensitive to very divergent developments of high tech industries such as large growth of pharmaceuticals in Denmark and major drawbacks of Nokia in electronics in Finland. This is first explained by relatively few firms in high tech industries (all firms are given equal weight in our analysis). Second, the development of technology has been smoother within firms compared to developments across firms (between effects).

In contrast, results differ across countries for the other intangibles measures. In Finland, elasticities for OC are increasing after the crisis, from 0.015 before the crisis to 0.02 after. The OC elasticity for Denmark is lower than in Finland and declines and becomes insignificant. These differences in the recovery period can be related to growth trends during 2008-2013 in organizational assets, with negative growth among Finnish firms, potentially as part of consolidation, compared to large increases in Denmark. Furthermore, we can see from table 3 that the growth in OC assets in Denmark is in industries that are on average less productive such as information, education and health.

ICT asset elasticity is positive in Denmark, and increases from 0.015 before to 0.019 after the crisis. In contrast, in Finland the ICT elasticity is negative in the period up to and after the crisis. Finland experienced an IT bubble in the 2000s where companies appear to have over invested in ICT, making ICT company prices

[13] Higón et al. (2017, p. 874) reports significant coefficients from 0.002 to 0.006 to R&D stock.

skyrocket. For example, the stock price of Nokia in the electronics industry fell from 60€ in 2000 to 12€ in 2004, and similar drops took place also in ICT industries (NACE J62 and J63)[14]. The negative output elasticity prior to the crisis could reflect over investment in ICT. Though, it is important to keep in mind that our measure of ICT only includes own-account investments, whereas purchases of ICT may be quite large for many firms.

Table 5. The impact of intangibles on TFP, before and after crisis, fixed effects

Dependent variable: TFP

	Finland		Denmark	
R&D	0.039***		0.043***	
	(0.004)		(0.002)	
R&D before 2008		0.036***		0.039***
		(0.004)		(0.002)
R&D after 2008		0.039***		0.043***
		(0.004)		(0.002)
OC	0.015***		0.005***	
	(0.004)		(0.000)	
OC before 2008		0.015***		0.007***
		(0.004)		(0.000)
OC after 2008		0.020***		0.001
		(0.004)		(0.001)
ICT	-0.014***		0.017***	
	(0.003)		(0.002)	
ICT before 2008		-0.018***		0.014***
		(0.003)		(0.002)
ICT after 2008		-0.016***		0.019***
		(0.003)		(0.002)
R&D dummy	0.399***	0.392***	0.544***	0.490***
	(0.048)	(0.048)	-0.021	-0.021
ICT dummy	-0.161***	-0.190***	0.167***	0.162***
	(0.036)	(0.037)	-0.021	-0.021
Constant	10.595***	10.669***	10.309***	10.367***
	(0.063)	(0.063)	-0.029	-0.029
year dummies	yes	yes	yes	yes
N	63377	63377	91005	91005
r2_w	0.042	0.044	0.069	0.074
r2_b	0.163	0.161	0.168	0.169
r2_o	0.134	0.131	0.145	0.146
sigma_e	0.279	0.279	0.279	0.279
sigma_u	0.395	0.396	0.413	0.413

[14] http://www.ts.fi/uutiset/talous/1073977134/Itkupla+oli+porssitaivaan+musta+aukko

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses. Intangible assets in logs, beginning of period values.

5.3 Robustness check

Our two stage approach first measures TFP as a residual for the first stage OP estimation and thereafter the effect of intangible assets on TFP. In doing so, we model intangible assets as a determinant of TFP. An alternative approach would be to include intangible assets directly into the OP model. The OP model controls for productivity shocks and can be argued to leave more identifying variance in freely adjusting and state variables than in fixed effect estimates. The OP approach may thus potentially be better able to control for the negative shocks due to the financial crisis. A potential drawback is that the correlation between inputs that can affect coefficient estimates.

As robustness check we have thus estimated the OP model including intangible assets, and where intangible assets were used as state variables.

Table 6. Olley-Pakes production function estimates from value added with intangible assets as state variables.

	Finland			Denmark		
Tangible assets	0.029***	0.028***	0.028***	0.163***	0.139***	0.138***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Employees	0.871***	0.642***	0.650***	0.748***	0.603***	0.608***
	(0.007)	(0.009)	(0.009)	(0.010)	(0.006)	(0.006)
R&D		0.025***			0.034***	
		(0.000)			(0.000)	
R&D before 2008			0.022***			0.032***
			(0.000)			(0.000)
R&D after 2008			0.026***			0.038***
			(0.000)			(0.000)
OC		0.052***			0.029***	
		(0.000)			(0.000)	
OC before 2008			0.057***			0.029***
			(0.000)			(0.000)
OC after 2008			0.048***			0.025***
			(0.000)			(0.000)
ICT		0.019***			0.029***	
		(0.000)			(0.000)	
ICT before 2008			0.017***			0.027***
			(0.000)			(0.000)
ICT after 2008			0.021***			0.031***
			(0.000)			(0.000)

N	63377	63377	63377	91005	91005	91005

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses. All variables in logs.

For Finland, the OP model output coefficient estimates for OC and ICT are much l higher compared to the TFP coefficients, while at the same time the output elasticity for labor is lower. In contrast, elasticities are lower for RD. As discussed above, the output elasticity coefficients now also account for the capital deepening effects so that it is indeed expected that the output elasticity of labor should fall when controlling for intangible inputs. Note also that the OP output elasticities for ICT are positive, and increasing over time from 0.17 before crisis to 0.21 after. Table 3 shows also that information industry was the high-growth sector during financial crises

Results for Denmark are somewhat more similar across the two models than for Finland. Coefficient estimates for RD in Denmark are very similar for the two models. And the elasticities for OC and ICT are higher in the OP model and quite constant over the two periods.

6. Conclusion

This paper has examined the role of intangible assets for firm-level productivity for Finland and Denmark. While there is now a fairly extensive amount of evidence supporting 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 the lack of data availability, particularly the lack of data that captures broader measures of intangibles. This paper contributes to this emerging strand of work. An important contribution of this work is the construction of intangible asset measures based on linked employer–employee data and the use of these measures in firm-level productivity analyses. The advantages of this approach are that the data allow a broad-based measurement of IA, capturing a separate effect from different knowledge capabilities. The analysis also allows for the extensive coverage of firms across industries. Our estimation covers the period from 2000 to 2013. Based on occupational data, intangible assets are classified into three categories: organizational capital (OC), broad research and development (RD) and information communication technology (ICT) assets.

Our main results are as follows. First, the productivity elasticities of RD found for Denmark and Finland for the period as a whole are 0.0.39 and 0.043, respectively. These results are thus quite comparable to those found in other recent analyses using different measurement approaches (such as Bontempi & Mairesse (2015), Crass & Peters (2014) and Marrocu et al. (2012)). The coefficients of R&D are closest to Crass & Peters

(2014), who report a highly significant coefficient of 0.031. This similarity is interesting given that our measure of R&D is broader than measures based on formally defined R&D expenditures and perhaps 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, approximately two-thirds to three-quarters of all firms (with 10 or more employees) have R&D, while the share of firms with R&D or innovation activities is typically much lower. This comparability in elasticity estimates despite these measurement differences suggests that the broader 'non-R&D' activities in related tasks are equally important to building technical knowhow that contributes positively to firm performance.

An important contribution of this analysis is to examine how the crisis has affected the relation between intangible assets and productivity, essentially comparing a period of strong growth prior to the crisis to a period with an initial, large fall in productivity followed by a gradual period of rebuilding. We find differences in elasticities before and after the crisis, and also a number of differences in the patterns for Finland and Denmark. While the economies of Finland and Denmark share a number of similarities, their trajectories of growth and intangibles investments up to and after the crisis have been quite different, and can be related to the results of our econometric analysis.

As indicated in table 2, growth in intangible assets was much larger in Finland than in Denmark in the period leading up to the crisis. Following the financial crisis, the growth path of IAs in Finland has been highly negative. Following the financial crisis, all types of IAs dropped dramatically in Finland, which is connected to the fact that GDP dropped 8 % in 2009 and only began to approach the pre-financial crisis period level only in 2018.

For Finland, we find that the R&D elasticity increases from 0.036 to 0.039 after the crisis. While investments in R&D may have helped in the recovery, Finnish firms still had to contend with a more severe economic downturn than for example in Denmark. In contrast to R&D, ICT elasticity for Finland was negative both before and after the crisis, which can potentially reflect over investment in ICT prior to the crisis (where table 2 shows high growth rates pre-crisis). Increases in elasticities both for R&D and OC, can in part reflect consolidation on the part of Finnish business, as large declines in intangible investments following the crisis.

Lome, Heggeseth, & Moen (2016) find that in Norway, R&D-intensive firms performed significantly better during the financial crisis and we find the same pattern to be true for Danish firms. Both R&D and ICT elasticities for Denmark increase after the crisis. Growth in intangibles investment was more modest in Denmark prior to the crisis, which may have put Danish firms in a better position to gain from increased investment following the crisis. The opposite appears to be the case for OC. OC elasticity for Denmark falls from 0.007 to an insignificant 0.001 following the crisis, and this decrease corresponds with a strong increase in overall OC investments after the crisis. This could indicate an overinvestment in OC following the crisis.

We believe that this analysis confirms the value and feasibility of using occupational data to measure intangible assets at the firm level. Future work can both engage in further examination of the measurement methods, and in uncovering the role of intangibles for productivity. While we have utilized the same approach in both countries, further analysis would be useful to assess whether there are differences in data quality or perhaps in reporting practices for occupational classifications. This would allow us to better discern the extent to which cross-country differences reflect actual firm differences (for example, that Danish firms have greater focus on managerial, organization and nontechnical aspects of innovation than Finnish firms do) as opposed to differences in the data.

Improved measurement of intangibles is also important to support policymaking. While much work has been done on the development of policy measures to support R&D and innovation, the potential role of policy in supporting intangibles investment is much less studied. Intangibles include R&D but are much broader, raising the question of how and to what extent policy can support the development of firms' broader dynamic capabilities. The results here indicate the importance of broader forms of intangibles investments for productivity, including their role in recovery from the financial crisis. This would suggest an important role for policy in promoting continued intangibles investment during difficult economic downturns.

References

Ackerberg, D. A., Caves, K., & Frazer, G. (2015). Identification Properties of Recent Production Function Estimators. *Econometrica*, 2411–2451.

Awano, G., Franklin, M., Haskel, J., & Kastrinaki, Z. (2010). Measuring investment in intangible assets in the UK: Results from a new survey. *Economic and Labour Market Review*. https://doi.org/10.1057/elmr.2010.98

Bontempi, M. E., & Mairesse, J. (2015). Intangible capital and productivity at the firm level: a panel data assessment. *Economics of Innovation and New Technology*. https://doi.org/10.1080/10438599.2014.897859

Cobb, C. W., & Douglas, P. H. (1928). A Theory of Production. *The American Economic Review*, *18*(1), 139–165.

Corrado, C., Haskel, J., Jona-lasinio, C., & Iommi, M. (2014). Intangibles and industry productivity growth : Evidence from the EU. *IARIW 33rd General Conference*.

Corrado, C., Haskel, J., Jona-Lasinio, C., & Iommi, M. (2013). Innovation and intangible investment in europe, japan, and the united States. *Oxford Review of Economic Policy*. https://doi.org/10.1093/oxrep/grt017

Corrado, C., Hulten, C., & Sichel, D. (2005). Measuring capital and technology - An expanded framework. In

Measuring capital in the new economy (pp. 11–46). University of Chicago Press.

Crass, D., & Peters, B. (2014). Intangible Assets and Firm-Level Productivity. *ZEW Discussion Paper*, *14*(120).

Cucculelli, M., & Bettinelli, C. (2015). Business models, intangibles and firm performance: evidence on corporate entrepreneurship from Italian manufacturing SMEs. *Small Business Economics*. https://doi.org/10.1007/s11187-015-9631-7

Cuneo, P., & Mairesse, J. (1983). *Productivity and R&D at the firm level in French manufacturing*. National Bureau of Economic Research Cambridge, Mass., USA.

de Rassenfosse, G. (2017). An assessment of how well we account for intangibles. *Industrial and Corporate Change*. https://doi.org/10.1093/icc/dtw034

Eklund, C. M. (2020). Why do some SME's become high-growth firms? The role of employee competences. *Journal of Intellectual Capital*, *21*(5), 691–707. https://doi.org/10.1108/jic-07-2019-0188

Görzig, B., Piekkola, H., & Riley, R. (2010). Production of Own Account Intangible Investment: Methodology in Innodrive Project. In *Innodrive Working Paper No 1*.

Hall, Bronwyn H, & Mairesse, J. (1995). Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics*, *65*(1), 263–293.

Hall, Bronwyn H, Mairesse, J., & Mohnen, P. (2010). Measuring the Returns to R&D. In B H Hall & N. Rosenberg (Eds.), *Handbook of the Economics of Innovation* (pp. 1034–1076). Amsterdam: Elsevier.

Higón, D. A., Gómez, J., & Vargas, P. (2017). Complementarities in innovation strategy: Do intangibles play a role in enhancing firm performance? *Industrial and Corporate Change*. https://doi.org/10.1093/icc/dtw055

Kendrick, J. W. (1994). Total capital and economic growth. *Atlantic Economic Journal*, *22*(1), 1–18.

Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies*, *70*(2), 317–341.

Lome, O., Heggeseth, A. G., & Moen, Ø. %J T. J. of H. T. M. R. (2016). *The effect of R&D on performance: Do R&D-intensive firms handle a financial crisis better? 27*(1), 65–77.

Manyika, J., Sinclair, J., Dobbs, R., Strube, G., Raddey, L., Mischke, J., … Ramaswamy, S. (2012). *Manufacturing the future: The next era of global growth and innovation*. McKinsey Global Institute.

Marrano, M. G., Haskel, J., & Wallis, G. (2009). What happened to the knowledge economy? ict, intangible investment, and Britain's productivity record revisited. *Review of Income and Wealth*. https://doi.org/10.1111/j.1475-4991.2009.00344.x

Marrocu, E., Paci, R., & Pontis, M. (2012). Intangible capital and firms' productivity. *Industrial and Corporate Change*. https://doi.org/10.1093/icc/dtr042

Niebel, T., O'Mahony, M., & Saam, M. (2017). The Contribution of Intangible Assets to Sectoral Productivity Growth in the EU. *Review of Income and Wealth*. https://doi.org/10.1111/roiw.12248

OECD. (2015). *Frascati Manual 2015*. OECD Publishing.

OECD, & Eurostat. (2005). *Oslo manual: Guidelines for collecting and interpreting innovation data* (3rd ed.). Paris: OECD.

POSTPRINT: Bloch, C., Eklund, C., & Piekkola, H. (2023). Innovative competences, the financial crisis and firm-level productivity in Denmark and Finland. Economics of Innovation and New Technology, 32(2), 198-212. https://doi.org/10.1080/10438599.2021.1895496

Olley, G. S., & Pakes, A. (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica*, *64*(6), 1263–1297. https://doi.org/10.2307/2171831

Piekkola, H. (2020). Intangibles and innovation-labor-biased technical change. *Journal of Intellectual Capital*, *21*(5), 649–669. https://doi.org/10.1108/jic-10-2019-0241

Piekkola, Hannu. (2016). Intangible Investments in Europe. *11th International Conference Challenges of Europe: Growth, Competitiveness and Inequality*, *11*. Hvar, Croatia: Faculty of Economics, University of Split.

Piekkola, Hannu. (2018). Broad-based intangibles as generators of growth in Europe. *Economics of Innovation and New Technology*, *27*(4), 377–400. https://doi.org/10.1080/10438599.2017.1376170

Ritala, P., Heiman, B., & Hurmelinna-Laukkanen, P. (2016). The need for speed—unfamiliar problems, capability rigidity, and ad hoc processes in organizations. *Industrial and Corporate Change*, *25*(5), 757–777.

Roth, F. (2020). Revisiting intangible capital and labour productivity growth, 2000–2015 : Accounting for the crisis and economic recovery in the EU. *Journal of Intellectual Capital*, *21*(5), 671–690. https://doi.org/10.1108/JIC-05-2019-0119

Roth, F., & Thum, A.-E. (2013). Intangible Capital and Labor Productivity Growth: Panel Evidence for the EU from 1998-2005. *Review of Income and Wealth*, *59*(3), 486–508. https://doi.org/10.1111/roiw.12009

Schankerman, M. (1981). The effects of double-counting and expensing on the measured returns to R&D. *The Review of Economics and Statistics*, 454–458.

van Ark, B., Hao, J. X., Corrado, C., & Hulten, C. (2009). Measuring intangible capital and its contribution to economic growth in Europe. *EIB Papers*.

Van Beveren, I. (2010). Total Factor Productivity Estimation: A Practical Review. *Journal of Economic Surveys*.

Wiengarten, F. (2016). Risk, risk management practices, and the success of supply chain integration. *International Journal of Production Economics*, *171*, 361–370. https://doi.org/10.1016/j.ijpe.2015.03.020

Yasar, M., Raciborski, R., & Poi, B. (2008). Production function estimation in Stata using the Olley and Pakes method. *Stata Journal*, *8*(2), 221.