GLOBALINTO

Deliverable 5.4

Spillovers, intangibles and productivity

Due date of deliverable: January 31, 2021

Submission January 31, 2021

Actual submission date: September 30, 2022

Globalinto Identifier:	WP5 Academic article on the role of intangible investments in technological, ICT, organizational and other capabilities in explaining the role of supply and demand side factors in the productivity puzzle
Author(s) and company:	Carter Bloch (AU), Josefine Bjørnholm (AU), Carita Eklund (AU), Kristof van Criekingen (AU)
Work package/task:	WP5
Document status:	draft / final
Confidentiality:	confidential / restricted / public

This project has received funding from the European Union's Horizon 2020 The mechanisms to promote smart, sustainable and inclusive growth under grant agreement No 822259.

TABLE OF CONTENTS

1. About GLOBALINTO

Close to ten years after the start of the financial crisis, productivity growth rates are still very low in European Union (EU) and OECD countries (Van Ark and Jäger 2017). Low growth stems partly from the financial crisis, but also appears to be part of a longer-term slowdown in productivity growth since the 1970's. This has prompted strong attention to possible reasons for the slowdown and potential policy responses also in relation to intangible capital.

While a number of possible explanations have been put forward, we lack convincing evidence of the main reasons behind the slowdown. Both research and policy are hampered by a lack of data and evidence. The GLOBALINTO project seeks to fill this gap.

The focus of GLOBALINTO, both in measurement and analysis, is on the role of intangibles; how they can be measured in a sustainable manner, their accumulation and diffusion, and their use in generating innovation and productivity growth. These processes are central in understanding the underlying factors behind the role of globalization, demographic change, the public sector and growth in SMEs.

GLOBALINTO will:

- Review existing literature, methodologies and data for measuring intangible assets.
- Conduct conceptual work on intangible assets and their relation to innovation and productivity, mapping key factors such as globalization and the role of value chains, how the demand side effects innovation and productivity, IT and digitization, and the role of public sector intangibles.
- Develop new measures of intangibles and advanced methods to link data and construct them.
- Utilize this new data to analyze the various potential explanations of the productivity puzzle, at both micro and macro levels.
- Conduct analyses of existing economic policies and their role in promoting intangibles investment, innovation and productivity growth

The project runs from February 2019 to January 2022.

2. Introduction

Since the 1970's, European Union (EU) and OECD countries have struggled with low productivity growth rates. While periods of low growth can be connected to the financial crisis in 2008-2009 and even more dramatically the current COVID-19 crisis, it also appears to be part of a longer-term slowdown in productivity growth. In addition, the productivity gap between the EU and the USA, measured by output either per worker or hour, remains significant. This is also the case with the productivity gaps between EU economies. As a result, the productivity puzzle has become a key issue discussed in the literature and primarily also among policymakers at different levels.

A pressing question is thus how to boost productivity growth. Productivity is affected by a complex set of both demand- and supply-side factors. Among the demand-side factors are macroeconomic characteristics, technological and the business environment in general, the international links of the economy, financial markets, macroeconomic, industrial and social policies (Redek et al. 2019). Supply-side factors include labor and human capital, allocation of resources, new technologies and intangible capital.

These various factors have motivated many possible explanations for the productivity slowdown. One explanation is that the opportunities for innovation and productivity growth have declined. In other words, the potential gains from innovation are now smaller and require stronger capabilities and greater effort to realize them (Cowen 2011). This explanation motivates a number of additional issues in order to better understand – and promote – innovation and its returns.

Among these are measuring intangibles investments in broad terms and their impact on innovation and productivity. And there are several dimensions that influence the economic impact of technological change and innovation, such as the rate of innovation, diffusion and novelty. Also, gains from innovation which depend on competences to exploit them, absorb them, may differ across the value chain. Global factors are very important here, as are demographics and ICT.

Work by the OECD argues that innovation at the frontier has not diminished, but the gap between the most advanced firms and all others has greatly expanded in the 2000's, suggesting that productivity slowdowns may reflect *slowed* diffusion of new technology and innovations (Andrews, Criscuolo, and Gal 2015). This builds on the main, supply-side explanation, arguing that the rate of technological change is not weakened, but diffusion (and thus exploitation) is lagging. This points back to global knowledge flows and competences, where firms from emerging countries may now be more capable of exploiting new technologies (at different stages of value chain) than earlier.

Others argue that opportunities have not diminished, and that in particular information and communication technology (ICT) continue to offer great potential for innovation and productivity growth (Brynjolfsson and McAfee 2014). However, as technologies and their applications become more complex, demands increase for organizational and other capabilities needed to develop and apply new ICT-based applications. This concerns the important role of ICT but also the ability to exploit advances in ICT. Other explanations point to slowdowns in corporate investment ("secular stagnation") and the role of policy and other demand-related factors as barriers to productivity growth (Eichengreen 2015; Gordon 2015).

As argued in Redek et al. (2019), these many supply and demand-side factors can also be viewed in terms of those factors that are internal to the firm and those that stem from external determinants. Such a perspective is particularly useful when examining productivity at the level of individual firms.

The focus of this paper is on the role of intangibles for productivity, both from an internal and external perspective to firms. Firms' performance is dependent on their technological and organizational knowhow, on their ability to manage relations with others and on their ability to access, apply and build on external knowledge (Cohen and Levinthal 1990). The idea that knowledge generated by a firm's research efforts can spillover to other firms and produce effects on their production processes was proposed by Arrow (1971) in his work on the impacts of learning embodied in new capital equipment. Since then, there have been significant theoretical discussions on the extent to which a firm can take advantage of flows of external knowledge, particularly looking at the impacts of such spillovers on firms' productivity growth (see e.g. Jaffe 1986, Griliches 1992).

Firms may obtain new knowledge through a variety of channels, such as openly available information sources, external knowledge embedded in capital or software, through collaboration, or through the employment of new personnel. Human resources also play a central role in firms' ability to access new knowledge (Cohen and Levinthal 1990; Moretti 2004). Furthermore, the type of the knowledge may play a role in how beneficial it is to other firms or in the ease of access. For example, the diffusion of organizational knowledge may be quite different from technological knowledge.

The diffusion of new knowledge can contribute to other firms' innovation, boosting their productivity and reducing gaps between frontier and less-productive firms (Andrews, Criscuolo, and Gal 2016). However, recent work instead finds a growing divergence of productivity levels among firms, as opposed to convergence (Andrews, Criscuolo, and Gal 2016). This suggests that diffusion and the role of spillovers may be dependent on other factors.

The objective of this paper is to examine how spillovers and diffusion processes affect firm productivity growth. In doing so, we analyze these channels from three different perspectives. First, we examine the role of technological progress and diffusion processes in bridging or widening productivity gaps between firms at the technological frontier and less-productive firms.

Second, we examine the impact of employee mobility on firm productivity and whether high levels of employee turnover are positively associated with productivity. We differentiate between intangibles-based employees and other employees, with the expectation that intangibles-based employees may bring innovative knowhow to the new firm (and potentially take knowhow with them when they leave). We also differentiate between employees that come from similar firms (within same NACE2 industry) and employees that come from other industries, based on the idea that employees from similar firms may possess knowhow that is more closely related to firms' own knowhow, while the capabilities of employees from other industries may be more different.

Third, we examine the relation between firm productivity growth and growth in industry knowledge pools generated through domestic and international intangibles investments, and the role of firms' own innovation capabilities, measured in terms of their intangible assets.

The analysis is conducted on linked employer-employee data for Danish companies in the period 2000-2016. It draws both on firm level and industry level measures of intangible assets developed and compiled as part of the GLOBALINTO project.

We find that on average the productivity gap among Danish firms has diminished over the period examined in this study, however this overall trend is the product of a number of factors. First, catching up appears to be happen further away from the productivity frontier, potentially indicating that firms with lower productivity can gain more from the diffusion of new knowledge. Second, when we examine catch up over selected sub-periods, we find these effects to be lowest in the years after the financial crisis, suggesting that there has been divergence in productivity. We find evidence of positive effects on productivity through inflows due to hiring of new knowledge intensive employees, however we do not find and difference in effects among the mobility of staff between firms within the same industry compared to mobility from outside of the industry. Effects are strongest among R&D based staff compared to organizational or ICT based staff. Results concerning industry inflows of intangibles are mixed, making it difficult to draw any conclusions concerning the roles of these inflows both as knowledge spillovers and as indicators of strengthened industry competition. Most clear is the positive effect of organizational spillovers on firm productivity.

3. Measuring intangible assets

The approach used in this analysis is based on the assumption 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, and through the purchase of intangibles from suppliers. The 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.

Intangible assets (IA) are classified into three categories. 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.

Intangible assets are approximated from the number 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 1.53 for R&D and 1.57 for OC to 1.70 for ICT. Based on occupational classifications, we identify employees (in managerial and technical positions) that are viewed as contributing to the generation of organization (OC), broad R&D and ICT based capabilities. 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 45% for organizational workers, 90% for RD workers and 60% for ICT.

The measures of industry-level intangibles spillovers are taken from the new GLOBALINTO Input-Output Intangibles database that covers EU-28 countries over the years 2000-2014 (Tsakanikas et al. 2020; Tsakanikas et al. 2020 (1)). The aim of this novel dataset is to track, year by year, the inward and outward flows of intangible intermediate inputs from/to the home economy to/from abroad alongside other relative data (i.e., exports of intermediates, productivity estimates etc.). From a conceptual point of view, the approach seeks to track the contribution of intangible inputs along the Global Value Chain (GVC). This approach can be distinguished from the stream of literature originating from (Nakamura 2001) and Corrado, Hulten, and Sichel (2005) that focuses on country's (or economic sectors within countries) investments in intangible assets. The GVC perspective focuses on the generation of added value from intangible intermediate inputs into the final production.

4. Empirical strategy

The focus of this paper is on the relation between knowledge flows and productivity, where we focus on flows through employee mobility and through industry level purchases of intangibles. As mentioned above, the topic of spillovers has received much attention, both empirically and theoretically through the New Growth literature. Recent work has shifted focus from R&D to a broader range of intangible assets.

Moretti (2004) examines the effects of increases in overall pools of human capital and how this influence between industry spillover across different spillover channels, such as input-output flows, technological specialization, and patent citations. He finds that spillovers are largest between industries that are similar to one another. O'Mahony and Vecchi (2009) find that, after accounting for capital deepening, that productivity is higher among R&D and skill intensive industries, suggesting that spillover effects may be a source of this productivity differential. Corrado et al. (2017) also find evidence of positive externalities of intangible capital deepening on total factor productivity, tfp, growth. Drawing on this work, our first research question is:

How do industry intangibles inflows affect total factor productivity growth?

We examine both the effects of industry inflows of organizational, R&D and ICT capital, and how these effects are mediated by firms' own investments in intangible capital.

Tambe et al. (2014) examine the role of mobility among information technology (IT) workers as a mechanism by which IT-related innovations diffuse throughout the economy. They find that firms' productivity benefits from the IT investments of other firms from which they hire IT labor. Almeida and Kogut (1999) also find some evidence of spillovers through employee mobility, that the inter-firm mobility of engineers influences the local transfer of knowledge among IT firms.

Laursen et al. (2020) find that the hiring of high-skilled migrant workers has a positive impact of firm innovative performance, suggesting that diverse hiring has added benefits. They also find that benefits are highest for firms with high integration capacity and are hence most able to capitalize on complementarities. Boschmaet al. (2008) find that the impact of mobility inflows is strongest among employees with the types of skills that are already in place at the new firm, hence that similarity augments the impact of mobility inflows. Based on this, we investigate:

How does inter-firm mobility affect total factor productivity growth?

We will both examine the impact of mobility inflows overall, and inflows from different types of intangibles occupations. And, to examine the role of similarity, we compare inflows from employees moving from within and outside of the new firm's industry.

Andrews, et al. (2015) find that despite slowdowns in aggregate productivity, productivity growth at the global frontier, defined as the most productive firms in each NACE 2-digit industry across 23 OECD countries, has experienced steady growth, resulting in a growing productivity gap with other firms. This raises questions on how diffusion processes for new knowledge function and what factors may complicate this process. Andrews et al. (2016) find though that productivity divergence is still present after accounting for capital deepening, and that divergence is not solely driven by productivity growth at the frontier. Building on this work, our third research question is:

> *Is there convergence or divergence in total factor productivity growth rates across firms?*

We will both examine trends in productivity gaps among Danish firms and the relation between gaps and growth of the productivity frontier, and firms' tfp growth. We will also examine whether the size of the productivity gap has an influence on the diffusion processes that we examine here, both due to employee mobility and industry spillovers.

The framework of most previous studies is the production function approach using a Cobb-Douglas production function. We follow this path and estimate the production function utilizing a two-stage approach following Higón et al. (2017), O'Mahony and Vecchi (2009), Crass and Peters (2015). First, we estimate a production function in growth rates consisting of tangible capital and labor and save the residual as our measure of total factor productivity growth (dtfp). Then, we explain total factor productivity growth with intangible assets and the measures of employee mobility, industry spillovers and productivity gaps.

The productivity function is estimated in differences:

$$\Delta q_{it} = \Delta a + \alpha \Delta l_{it} + \beta \Delta k_{it} + \Delta \eta_{it} \qquad (1)$$

Firms choose their capital and labor accounting for following periods where they use their knowledge of forthcoming shocks. We follow the Olley & Pakes (1996) method, henceforth OP, and assume that firm specific shocks are a strictly increasing function of investments (Van Beveren 2010; Yasar, Raciborski, and Poi 2008). The OP method is chosen over Levinsohn & Petrin (2003), which is a method using intermediate inputs as a proxy variable. First, we lack data on intermediate inputs for the first years of the sample and, second, investments have more non-zero values than intermediate inputs in our sample.

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.

The second stage of the model is estimated using random effects. The basic model is the following:

$$\Delta tfp_{it} = \beta_0 + \beta_1 \Delta rnd_{it} + \beta_2 \Delta oc_{it} + \beta_3 \Delta ict_{it} + X_{it} + \varepsilon_{it} \qquad (2)$$

Where tfp growth is a function of growth in the three types of intangible assets, organizational, broad R&D and ICT. We expand this model to include measures of intangibles employee mobility, industry-level intangibles spillovers, and the productivity gap.

5. Data and measurement

This study utilizes register data for Danish firms in the period of 1999-2016. The datasets include all firms having an average of at least ten employees over the period. The samples cover all manufacturing industries and a broad range of market services. 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 employees include labor cost from annual wage income for each employment and type of occupation. The total number of observations in the resulting sample is in all 215,579. Note that both taking logarithms and use of lagged observations result in a lower number of observations in the regressions. In addition, industry spillover variables are only available for the period 2000-2014. Hence, the number of observations in individual regressions can vary slightly due to these factors.

Both value added and number of employees are corrected based on intangibles measurement. To avoid double-counting, labor that is used in intangibles generation is subtracted from number employees. Value added is corrected to account for the intangible capitalization, resulting in the conversion of expenses to investments.

Intangible investments are measured as described above. Asset accumulation follows the standard accumulation of capital stock, where the depreciation rate is 20% (25%) 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. Initial intangible assets are estimated using a standard perpetual inventory model with the above depreciation rates and an assumed growth rate of 2%. Deflators for R&D were based on price indices for intellectual property within each NACE 2-digit industry, while deflators for organizational and ICT capital were based on producer price indices for management services and ICT services, respectively. For all other variables, industry level producer price indices were used as deflators.

Productivity gaps are measured as the difference between the firm's tfp and the frontier, which we define as tfp for the 95th percentile for their NACE 2-digit industry. For firms either at or higher than this frontier, the productivity gap is set equal to zero. We include both the gap in t-1 and the change in the gap from t-2 to t-1.

As noted above, industry spillovers are measured using the GLOBALINTO Input-Output database. Spillovers are measured as the inflows of both domestic and international management, R&D and ICT services to the industry. In order to examine the role of absorptive capacity and the firms' in house knowhow in mediating the effect of intangible spillovers, we interact each of the types of intangibles spillovers with the firms' own intangibles assets.

We measure in and outflows of intangibles due to inter-firm mobility using employee data. Inflows from period t-1 to t are based on intangibles employees that have started in the firm in time t, while outflows are based on intangibles employees that exit the firm in time t. In both cases, the flow of intangibles that employees bring in or leave with are measured as the value of intangibles created by these employees in time t-1. We measure intangibles mobility inflows in three ways: the inflows overall for each firm, inflows from within and outside the firm's NACE 2-digit industry, and inflows from each of the three intangibles types.

Table 5.1 shows the shares of employees within each intangibles type, both by year and by broad industry groups. The following industry groupings are used here:

- Manufacturing sector is defined by Technology levels and split into four groups: HighTech, Medium-HighTech, Medium-LowTech, and LowTech classes
- Service sector split by intangible services (which include ICT services (NACE 62-63), Management services (NACE 70), R&D and Technical services (NACE 71-72)), other Knowledge Intensive Services (KIS, which includes all other knowledge intensive services), and Less Knowledge Intensive Services, LKIS

For all three intangibles types, intangibles shares have been increasing over time, with ICT shares almost doubling over the period. The highest share is within broad R&D capital. Shares of R&D workers are highest within high tech manufacturing, while intangibles services industries have high shares of both R&D workers and ICT workers.

Table 5.1: Share of employment within each intangibles type

Year	OC emp. share	R&D emp. share	ICT emp. share	**Industry groups**	OC emp. share	R&D emp. share	ICT emp. share
2000	0.046	0.087	0.033	**High tech**	0.063	0.326	0.036
2001	0.045	0.090	0.033	**Med.-high tech**	0.050	0.159	0.019
2002	0.044	0.092	0.032	**Med.-low tech**	0.042	0.068	0.007
2003	0.044	0.087	0.029	**Low tech**	0.043	0.046	0.012
2004	0.046	0.088	0.034	**Other KIS**	0.047	0.103	0.072
2005	0.052	0.096	0.038	**Intangibles services**	0.096	0.237	0.192
2006	0.050	0.094	0.036	**LKIS**	0.046	0.043	0.017
2007	0.051	0.092	0.036				
2008	0.050	0.094	0.035				
2009	0.062	0.107	0.045				
2010	0.063	0.120	0.056				
2011	0.056	0.116	0.057				
2012	0.058	0.115	0.058				
2013	0.061	0.121	0.059				
2014	0.059	0.117	0.058				
2015	0.059	0.118	0.058				
2016	0.065	0.127	0.060				

Table 5.2 shows intangible assets per employee (in 1000 euros), where these amounts follow to a large degree the pattern for shares of intangibles workers above. We can see that average mobility inflows and outflows per employee are around the same size, with each amounting to around 2-4 % of total intangible assets.

For all three types, average intangibles assets are fairly stable over the course of time, increasing moderately alongside the growing size of firms in the sample. Broad R&D assets are the largest, in part reflecting the broad measurement of technical and innovation personnel, and in part the quite narrow specification of organizational asset creation to those occupations that assessed to make the largest contribution in terms of their work share. Intangibles inflows through worker mobility vary over the course of the period, though are strongest in the first years.

Table 5.2: Intangible assets per employee, mean values

Year	Employees excl. intangibles	Value added	OC. assets share	R&D asset share	ICT asset share	Inflow costs	Outflow costs
2000	87	101.51	9.87	69.45	13.34	3.45	2.96
2001	93	97.99	9.95	72.04	13.39	2.87	2.42
2002	92	99.19	10.06	73.99	12.59	2.06	2.18
2003	90	104.99	10.30	73.23	12.38	1.68	1.97
2004	90	109.30	10.55	72.82	12.43	1.55	2.14
2005	89	104.80	10.27	71.77	12.37	1.89	2.47
2006	92	97.44	9.74	67.19	11.17	1.86	2.50
2007	95	95.99	9.08	60.52	10.23	2.10	2.19
2008	97	93.81	8.71	58.60	9.38	1.97	1.68
2009	88	101.02	9.96	64.91	10.55	1.63	2.18
2010	84	115.78	10.41	67.63	11.26	1.99	2.42
2011	87	109.43	10.15	66.49	11.25	1.83	2.23
2012	89	110.18	10.45	65.93	11.23	1.72	2.23
2013	88	113.09	10.72	65.82	11.13	1.80	2.25
2014	94	112.60	10.57	63.51	10.83	1.80	2.31
2015	98	114.50	10.57	63.60	10.92	1.78	2.07
2016	100	114.08	10.70	63.85	11.00	1.98	

Table note: Average number employees after accounting for employment used in intangibles production. All other variables in 1000 euros.

Average tfp in the beginning and end of the period is essentially the same, while the average productivity gap and tfp95 have increased slightly over the time period. These trends point in the same direction as results in Andrews, Criscuolo, and Gal (2016), though increases in the productivity frontier would appear to be more gradual for the Danish sample here. We examine this trend further in the regression analysis below.

Table 5.3: Total factor productivity and the productivity gap

Year	tfp		tfp95	Productivity gap	
	Mean	Std.err.	Mean	Mean	Std.err.
2000	-0.041	0.554	0.642	0.683	0.401
2001	-0.046	0.536	0.662	0.709	0.411
2002	-0.042	0.505	0.651	0.693	0.407
2003	-0.012	0.519	0.657	0.669	0.403
2004	0.006	0.520	0.697	0.691	0.433
2005	-0.038	0.510	0.661	0.699	0.414
2006	-0.089	0.500	0.605	0.694	0.443
2007	-0.139	0.526	0.568	0.708	0.460
2008	-0.145	0.508	0.614	0.758	0.506
2009	-0.084	0.492	0.638	0.722	0.455
2010	-0.029	0.474	0.685	0.713	0.423
2011	-0.037	0.480	0.691	0.728	0.460
2012	-0.057	0.463	0.664	0.722	0.455
2013	-0.055	0.448	0.625	0.681	0.434
2014	-0.038	0.437	0.662	0.701	0.424
2015	-0.040	0.434	0.663	0.703	0.462
2016	-0.048	0.447	0.659	0.707	0.439

Note: tfp estimated using OP estimation method. Tfp95 is tfp at 95th percentile of tfp for each NACE2 industry.

6. Analysis

We examine first the relation between the tfp growth and the productivity gap. We first estimate the basic model with intangibles assets and thereafter include the measures of the productivity gap, differentiating both over time and distance from the productivity frontier.

Table 6.1: TFP estimation, productivity gap

	(1)	(2)	(3)	(4)	(5)
*dln(*OC assets*)*	0.019***	0.022***	0.022***	0.022***	0.022***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
*dln(*R&D assets*)*	0.014***	0.014***	0.014***	0.014***	0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
*dln(*ICT assets*)*	0.005**	0.009***	0.009***	0.009***	0.009***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Productivity gap_{t-1}		0.220***	-0.120***	0.234***	-0.118***
		(0.003)	(0.011)	(0.009)	(0.014)
*d(*Productivity gap_{t-1}*)*		0.027***	0.029***	0.026***	0.028***
		(0.003)	(0.003)	(0.003)	(0.003)
Productivity gap_{t-1} 25			0.384***		0.378***
			(0.01)		(0.01)
Productivity gap_{t-1} 50			0.227***		0.222***
			(0.01)		(0.01)
Productivity gap_{t-1} 75			0.161***		0.158***
			(0.01)		(0.01)
Productivity gap $_{t-1}$ (2003-2007)				0.005	0.018
				(0.01)	(0.01)
Productivity gap $_{t-1}$ (2008-2010)				0.029**	0.047***
				(0.01)	(0.01)
Productivity gap $_{t-1}$ (2011-2016)				-0.066***	-0.037***
				(0.01)	(0.01)
Constant	-0.013*	-0.119***	-0.081***	-0.095***	-0.062***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Number of obs.	126,398	111,869	111,869	111,869	111,869
R-squared within	0.01	0.099	0.131	0.101	0.132
R-squared between	0.007	0.016	0.024	0.018	0.026
R-squared overall	0.01	0.063	0.083	0.065	0.084
$sigma_e$	0.401	0.373	0.366	0.373	0.366
$sigma_u$	0.157	0.141	0.144	0.137	0.14
rho	0.132	0.125	0.134	0.118	0.128

Table note: Productivity gap 25/50/75 is productivity gap for firms with tfp in lowest/second/third quartile within their industry.
Estimates are obtained by a random effects model. Standard errors are reported in the parenthesis.
Significance level are indicated by ***p<0.01, **p<0.05, *p<0.1.

All three types of intangibles assets are positive and significant, indicating that total factor productivity growth rates are positively related to increases in intangibles investment. The elasticities range from 0.019 for organizational capital growth to 0.014 for broad R&D capital and 0.005 for ICT capital.

Both the productivity gap in t-1 and the change in the productivity gap are positive and significant. The coefficient on the lag of the productivity gap is 0.220, and 0.027 for the change in the productivity gap. Hence, with a constant productivity frontier, less productive firms would catch up. However, the question is whether, or at what rate, firms can catch up with growth in the productivity frontier. This was essentially the finding of Andrews et al. (2016); that productivity growth among firms at the frontier was stronger than other firms, leading to divergence in productivity gaps.

Our efforts to examine how productivity gaps have developed over time are complicated by the financial crisis in 2008-09, where there were dramatic falls in productivity. To examine this further, we have broken the time period into four parts. The first three years, 2000-2002 (which function as a reference period), 2003-2007, 2008-2010, and 2011-2016. The results show that that the period of greatest convergence was during the crisis period, likely due as much to falls in the productivity at the frontier as to increased catch up growth by less productive firms. Coefficients after the crisis are significantly lower than those prior to the crisis, suggesting a slowdown in convergence.

We have also examined whether results differ among firms according to their distance from productivity frontiers. We compare the effects of the productivity gaps for firms in each quartile according distance to the productivity frontier within their industry. A clear pattern emerges where the largest coefficient is for firms in the lowest quartile (productivity gap 25), i.e., with the largest productivity gap, where coefficients decline as tfp increases and are in fact negative for the highest quartile.

In table 6.2 below, we investigate mobility by looking at the effects of employee intangibles inflows. As noted above, these mobility inflows are modeled in three ways: overall, within and between industry, and by intangibles type.

Overall inflows and outflows of intangibles due to employee mobility have the expected signs. The elasticity of mobility inflows is slightly smaller than changes to existing intangibles capital stocks. When the mobility measures are included, the elasticities for all three intangible assets decline, and ICT assets in fact become insignificant.

The results show no difference in the elasticities of mobility inflows within and outside of firms' industries. Both are positive and significant with a coefficient of around 0.005. Hence, this simple breakdown of intangibles inflows according to industry origin does not indicate differences in contribution to tfp growth. In contrast, the results show some differences in terms of types of intangibles mobility inflows. R&D mobility inflows appear to be most important, with positive and significant coefficients that are larger than the two other types, which are less strongly significant.

The last three regressions in table 6.2 include the measure for the productivity gap and its growth rate. Accounting for distance to the productivity frontier leads to a few changes in the coefficients for the other variables. First, the change in ICT assets is larger and now strongly significant, while the change in organizational capital is also larger. The coefficient for R&D mobility inflows is larger (from 0.006 to 0.009) while organizational mobility inflows become insignificant.

Table 6.2: TPF estimation, mobility

	(1)	(2)	(3)	(4)	(5)	(6)
*dln(*OC assets*)*	0.016***	0.016***	0.016***	0.019***	0.019***	0.020***
	(0.001)	(0.001)	(0.001)	(0.001)	-0.001)	(0.001)
*dln(*R&D assets*)*	0.011***	0.011***	0.011***	0.011***	0.011***	0.011***
	(0.001)	(0.001)	(0.001)	(0.001)	-0.001)	(0.001)
*dln(*ICT assets*)*	0.002	0.002	0.002	0.006**	0.006**	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
*ln(*inflow costs*)*	0.007***			0.009***		
	(0.001)			(0.001)		
ln(outflow costs$_{t-1}$*)*	-0.008***	-0.008***	-0.008***	-0.007***	-0.007***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
*ln(*inflow cost w/i*)*		0.005***			0.006***	
		(0.001)			(0.001)	
*ln(*inflow cost b/i*)*		0.005***			0.007***	
		(0.001)			(0.001)	
*ln(*inflow cost ICT*)*			0.003**			0.002*
			(0.001)			(0.001)
*ln(*inflow cost R&D*)*			0.006***			0.009***
			(0.001)			(0.001)
*ln(*inflow cost OC*)*			0.002*			0.002
			(0.001)			(0.001)
Productivity gap$_{t-1}$				0.221***	0.221***	0.221***
				(0.003)	(0.003)	(0.003)
*d(P*roductivity gap$_{t-1}$*)*				0.026***	0.027***	0.027***
				(0.003)	(0.003)	(0.003)
Constant	-0.012*	-0.011*	-0.01	-0.125***	-0.124***	-0.122***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Number of obs.	126,398	126,398	126,398	111,869	111,869	111,869
R-squared within	0.011	0.011	0.011	0.101	0.101	0.101
R-squared between	0.009	0.009	0.009	0.017	0.017	0.017
R-squared overall	0.011	0.011	0.011	0.064	0.064	0.064
sigma$_e$	0.401	0.401	0.401	0.373	0.373	0.373
sigma$_u$	0.156	0.156	0.156	0.141	0.141	0.141
rho	0.132	0.132	0.132	0.125	0.125	0.125

Table note: Estimates are obtained by a random effects model. Standard errors are reported in the parenthesis. Significance level are indicated by ***p<0.01, **p<0.05, *p<0.1.

In the final table, we analyze the industry spillover pools. Due to high correlation between domestic and international industry inflows, the two measures are combined to a total measure of intangibles inflows to each industry. Industry inflows are first included on their own and then interacted with firms' own intangible assets.

Table 6.3: TPF estimation, industry inflows

	(1)	(2)	(3)	(4)
d*ln(*OC assets*)*	0.019***	0.016***	0.022***	0.018***
	(0.001)	(0.001)	(0.001)	(0.002)
d*ln(*R&D assets*)*	0.014***	0.007***	0.014***	0.007***
	(0.001)	(0.001)	(0.001)	(0.002)
d*ln(*ICT assets*)*	0.004**	0.002	0.009***	0.007**
	(0.002)	(0.002)	(0.002)	(0.002)
*dln(*OC industry inflow$_{t-1}$)	0.015***	0.018***	0.008	0.015*
	(0.003)	(0.003)	(0.005)	(0.007)
*dln(*ICT industry inflow$_{t-1}$)	-0.008*	-0.011**	-0.005	-0.026**
	(0.004)	(0.004)	(0.005)	(0.008)
dln(R&D industry inflow$_{t-1}$)	-0.011***	-0.017***	-0.005	-0.007
	(0.002)	(0.003)	(0.003)	(0.004)
d*ln(*OC assets) x d*ln(*OC industry inflow$_{t-1}$)		0.018***		0.012***
		(0.003)		(0.004)
d*ln(ICT* assets) x d*ln(ICT* industry inflow$_{t-1}$)		-0.002		-0.012***
		(0.003)		(0.004)
d*ln(R&D* assets) x d*ln(R&D* industry inflow$_{t-1}$)		0.002		0.002
		(0.003)		(0.003)
Productivity gap$_{t-1}$			0.220***	0.233***
			(0.003)	(0.003)
*d(P*roductivity gap$_{t-1}$*)*			0.027***	0.031***
			(0.003)	(0.003)
Constant	0.022**	0.009	-0.102***	-0.090***
	(0.007)	(0.005)	(0.011)	(0.005)
Number of obs.	126398	108897	111869	95350
R-squared within	0.01	0.009	0.01	0,083
R-squared between	0.007	0.008	0.016	0.026
R-squared overall	0.01	0.009	0.063	0.076
sigma$_e$	0.278	0.265	0.259	0.244
sigma$_u$	0.109	0.090	0.098	0.086
rho	0.092	0.071	0.087	0.076

When the industry spillover pools are included without interaction terms, coefficients are significant for all three types, positive for organizational assets and negative for R&D and ICT. When the interactions with firms' own intangible assets are included, organizational (OC) spillovers are both positive on their own and positive when interacted with own organizational assets, suggesting that the more internal organizational knowhow firms have, the better they are able to gain from external organizational knowledge.

When the productivity gap is included in the model, results for industry inflows change. Effects for organizational assets do not appear to be strongly affected, but results become insignificant for R&D assets. This could potentially reflect that the productivity gap captures effect through the diffusion of R&D spillovers. In contrast, both the spillover pool and its interaction are negative for ICT. Hence, the more in-house ICT capability the firm has, the more negative effect of industry inflows. This last result is puzzling.

7. Conclusion

This paper examines how spillovers and diffusion processes affect firm productivity growth using linked employer-employee data for Danish companies in the period 1999-2016. We analyze these channels from three different perspectives. First, we examine the role of technological progress and diffusion processes in bridging or widening productivity gaps between firms at the technological frontier and less-productive firms. Second, we examine the impact of the mobility of intangibles-based employees on firm productivity, where we also differentiate between employees that come from similar firms (within same NACE2 industry) and employees that come from other industries. Third, we examine the relation between firm productivity growth and growth in industry knowledge pools generated through domestic and international intangibles investments, and the role of firms' own innovation capabilities, measured in terms of their intangible assets.

First, and in line with many other studies, we find that intangible capital deepening has positive impact on productivity growth. Growth rates of all three types of intangibles assets are positive and significant, indicating that total factor productivity growth rates are positively related to increases in intangibles investment. The elasticities range from 0.019 for organizational capital growth to 0.014 for broad R&D capital and 0.005 for ICT capital.

We find that on average the productivity gap among Danish firms has diminished over the period examined in this study, however this overall trend is the product of a number of factors. First, catch up appears to be increasing in the distance to the productivity frontier, potentially indicating that firms with lower productivity can gain more from diffusion of new knowledge. Second, when we examine catch up over selected sub-periods, we find these effects to be lowest in the years after the financial crisis, suggesting that there has been divergence in productivity.

We find evidence of positive effects on productivity through inflows due to hiring of new knowledge intensive employees, however we do not find any difference in effects among the mobility of staff between firms within the same industry compared to mobility from outside of the industry. Both are positive and significant with a coefficient of around 0.005. Hence, this simple breakdown of intangibles inflows according to industry origin does not indicate differences in contribution to tfp growth. In contrast, the results show some differences in terms of types of intangibles mobility inflows. R&D mobility inflows appear to be most important, with positive and significant coefficients that are larger than the two other types, which are less strongly significant.

Results concerning industry inflows of intangibles are mixed, making it difficult to draw any conclusions concerning the roles of these inflows both as knowledge spillovers and as indicators of strengthened industry competition. Most clear is the positive effect of organizational spillovers on firm productivity.

While this paper has focused on the case of Denmark, both the questions covered here and the analyses would be expected to be relevant for analysis for other EU countries. Understanding the roles of mobility and knowledge flows for firm productivity are clearly important for all EU countries, though there may potentially be differences in the role of these factors. Among the factors that might have influence here are the degree of innovativeness or research intensity, country size and also labor market conditions that can affect mobility patterns. These factors would be interesting to pursue in future research.

8. References

Almeida, Paul, and Bruce Kogut. 1999. "Localization of Knowledge and the Mobility of Engineers in Regional Networks." *Management Science* 45(7): 905–17.

Andrews, Dan, Chiara Criscuolo, and Peter N. Gal. 2015. *Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries*. https://www.oecd-ilibrary.org/content/paper/5jrql2q2jj7b-en (January 16, 2021).

———. 2016. *The Best versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy*. https://www.oecd-ilibrary.org/economics/oecd-productivity-working-papers_24139424 (January 16, 2021).

Van Ark, Bart, and Kirsten Jäger. 2017. *Recent Trends in Europe's Output and Productivity Growth Performance at the Sector Level, 2002-2015*. www.euklems.net (January 21, 2021).

Arrow, K. J. 1971. "The Economic Implications of Learning by Doing." In *Readings in the Theory of Growth*, Palgrave Macmillan UK, 131–49.

Van Beveren, Ilke. 2010. "Total Factor Productivity Estimation: A Practical Review." *Journal of Economic Surveys*.

Boschma, R., R. Eriksson, and U. Lindgren. 2008. "How Does Labour Mobility Affect the Performance of Plants? The Importance of Relatedness and Geographical Proximity." *Journal of Economic Geography* 9(2): 169–90. https://academic.oup.com/joeg/article-lookup/doi/10.1093/jeg/lbn041 (January 16, 2021).

Brynjolfsson, Erik, and Andrew McAfee. 2014. *The Second Machine Age: Work, Progress, and Prosperity in a Time Of* ... https://books.google.dk/books?hl=en&lr=&id=WiKwAgAAQBAJ&oi=fnd&pg=PA1&dq=brynjolfsson&ots=4_UoTg1veh&sig=PyEM160RgjT6Ieka64cChBZ0pNw&redir_esc=y#v=onepage&q=brynjolfsson&f=false (January 21, 2021).

Cohen, Wesley M., and Daniel A. Levinthal. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35(1): 128. https://www.jstor.org/stable/2393553 (January 21, 2021).

Corrado, Carol, Jonathan Haskel, and Cecilia Jona-Lasinio. 2017. "Knowledge Spillovers, ICT and Productivity Growth." *Oxford Bulletin of Economics and Statistics*.

Corrado, Carol, Charles Hulten, and Daniel Sichel. 2005. "Measuring Capital and Technology - An Expanded Framework." In *Measuring Capital in the New Economy*, University of Chicago Press, 11–46.

Cowen, Tyler. 2011. *Cowen - The Great Stagnation; How America Ate All the Low-Hanging Fruit of Modern History (2011)*. https://books.google.dk/books?hl=en&lr=&id=tHMNnGFVFQYC&oi=fnd&pg=PT7&dq=tyler+cowen+2011&ots=BDN3zs5LMn&sig=0--PVHqu5s6KvUtTuX-nCgqwhaA&redir_esc=y#v=onepage&q=tyler cowen 2011&f=false (January 21, 2021).

Crass, Dirk, and Bettina Peters. 2015. SSRN *Intangible Assets and Firm-Level Productivity*.

Eichengreen, Barry. 2015. "Secular Stagnation: The Long View." In *American Economic Review*, American Economic Association, 66–70.

Gordon, Robert J. 2015. "Secular Stagnation: A Supply Side View." In *American Economic Review*, American Economic Association, 54–59. http://dx.doi.org/10.1257/aer.p20151102 (January 21, 2021).

Griliches, Zvi. 1992. "The Search for R&D Spillovers." *The Scandinavian Journal of Economics* 94: S29.

Higón, Dolores Añón, Jaime Gómez, and Pilar Vargas. 2017. "Complementarities in Innovation Strategy: Do Intangibles Play a Role in Enhancing Firm Performance?" *Industrial and Corporate Change*.

Jaffe, Adam. 1986. "Technological Opportunity and Spillovers of R&D: Evidence from Firms'

Patents, Profits, and Market Value." *American Economic Review* 76(5): 984–1001. https://econpapers.repec.org/RePEc:aea:aecrev:v:76:y:1986:i:5:p:984-1001 (January 21, 2021).
Laursen, Keld, Bart Leten, Ngoc Han Nguyen, and Mark Vancauteren. 2020. "Mounting Corporate Innovation Performance: The Effects of High-Skilled Migrant Hires and Integration Capacity." *Research Policy* 49(9): 104034.
Levinsohn, James, and Amil Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *The Review of Economic Studies* 70(2): 317–41.
Moretti, Enrico. 2004. "Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions." *American Economic Review* 94(3): 656–90.
Nakamura, Leonard. 2001. *What Is the U.S Gross Investment in Intangibles? (At Least) On Trillion Dollars a Year!* Philadelphia.
O'Mahony, Mary, and Michela Vecchi. 2009. "R&D, Knowledge Spillovers and Company Productivity Performance." *Research Policy* 38(1): 35–44.
OECD. 2015. *Frascati Manual 2015*. OECD Publishing. file:///content/book/9789264239012-en.
Olley, G Steven, and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry." *Econometrica* 64(6): 1263–97. http://www.jstor.org/stable/2171831.
Redek, Tjasa et al. 2019. *A SURVEY ON CHALLENGES TO GROWTH: The Productivity Puzzle in the Context of (New) Growth Determinants*.
Tambe, Prasanna, and Lorin M. Hitt. 2014. "Job Hopping, Information Technology Spillovers, and Productivity Growth." *Management Science* 60(2): 338–55. http://pubsonline.informs.orghttp//www.informs.org (January 16, 2021).
Tsakanikas, A. et al. 2020. *The Contribution of Intangible Inputs and Participation in Global Value Chains to Productivity Performance – Evidence from the EU-28, 2000-2014.*
Tsakanikas, Aggelos, Yannis Caloghirou, Petros Dimas, and Dimitrios Stamopoulos. 2020. *Are Innovation and Intangible Assets Drivers for EU's Manufacturing Competitiveness in Global Value Chains?*
Yasar, Mahmut, Rafal Raciborski, and Brian Poi. 2008. "Production Function Estimation in Stata Using the Olley and Pakes Method." *Stata Journal* 8(2): 221.