Carita Eklund

Innovation Capabilities, Design and Cutting Edge

Innovative Growth in the 21st Century

ACTA WASAENSIA 426

Vaasan yliopisto
UNIVERSITY OF VAASA

ACADEMIC DISSERTATION

To be presented, with the permission of the Board of the School of Accounting and Finance of the University of Vaasa, for public examination in Auditorium Kurtén (C203) on the 30th of August, 2019, at noon.

Reviewers

Professor Tuomas Takalo
Hanken School of Economics
Department of Economics
PL 479
FI-00101 Helsinki
Finland

Associate professor Ebbe Krogh Graversen
Aarhus University
Department of Political Science, Danish Centre for Studies in Research and Research Policy School
Bartholins Allé 7
DK-8000 Aarhus C
Denmark

Julkaisija	Julkaisupäivämäärä
Vaasan yliopisto	Elokuu 2019
Tekijä(t) Carita Eklund	**Julkaisun tyyppi** Esseeväitöskirja
ORCID tunniste orcid.org/0000-0002-4217-0927	**Julkaisusarjan nimi, osan numero** Acta Wasaensia, 426
Yhteystiedot Vaasan yliopisto Rahoituksen ja laskentatoimen yksikkö Taloustiede PL 700 FI-65101 VAASA	**ISBN** 978-952-476-872-6 (painettu) 978-952-476-873-3 (verkkoaineisto) URN:ISBN:978-952-476-873-3 **ISSN** 0355-2667 (Acta Wasaensia 426, painettu) 2323-9123 (Acta Wasaensia 426, verkkoaineisto) **Sivumäärä** 124 — **Kieli** englanti

Julkaisun nimike

Innovaatiokyvykkyys, Muotoilu ja Suunnannäyttäjät - Innovatiivinen kasvu 2100-vuosisadalla

Tiivistelmä

Tässä väitöskirjassa tarkastellaan aineettoman pääoman ja muotoilu-osaamisen vaikutusta niin innovaatioihin kuin yrityksien tuottavuuteen ja yrityksen nopeaan kasvuun. Ensimmäinen essee tarkastelee kuinka muotoilu-osaaminen eri vaiheissa innovaatioprosessia vaikuttaa uusien tuotteiden kehittämiseen. Kirjallidessa on teoreettista keskustelua muotoilun ja muotoilu-osaamisen vaikutuksesta innovaatioihin mutta empiiristä tutkimusta on toistaiseksi vähän. Essee luo uuden konseptin, design-skaalan, jonka avulla designin suhdetta innovaatioihin tarkastellaan CIS-kyselyaineiston avulla.

Toisessa esseessä yhdistetään kyselyaineisto rekisteridataan, josta aineeton pääoma lasketaan. Tutkimuksessa testataan, selittääkö aineeton pääoma tulevia tuote- ja prosessi-innovaatioita. Essee toisin sanoen pyrkii validoimaan aineettoman pääoman käyttöä innovaatiokyvykkyysmittarina. Tuloksien perusteella aineeton pääoma on toimiva innovaatiokyvykkyysmittari.

Kolmannessa esseessä aineetonta pääomaa käytetään Suomen ja Tanskan tuottavuuserojen selittäjänä. Finanssikriisin aikana tanskalaiset yritykset lisäsivät organisaatiopääomaa, kun taas suomalaiset yritykset vähensivät sitä. Toisaalta suomalaisien yrityksien tuottavuus hyötyi tanskalaisia enemmän tuotekehityspääomasta. Tanskalaisten yrityksien suhteellinen etu on organisaatiopääomassa.

Neljännessä esseessä selvitetään, auttaako aineeton pääoma yrityksen korkeaa kasvua. Tulokset riippuvat jonkin verran suhdanteesta, esimerkiksi hidastuneessa syklissa muotoilijoiden osuus ei tue nopeaa kasvua, toisin kuin noususuhdanteissa. Toisaalta, organisaatiopääoma tukee tuloksien mukaan nopeaa kasvua kaikissa suhdanteissa.

Asiasanat

Innovaatiot, aineeton pääoma, design, muotoilu

Publisher	Date of publication	
Vaasan yliopisto	August 2019	
Author(s) Carita Eklund	**Type of publication** Doctoral thesis by publication	
ORCID identifier orcid.org/0000-0002-4217-0927	**Name and number of series** Acta Wasaensia, 426	
Contact information University of Vaasa School of Accounting and Finance Economics P.O. Box 700 FI-65101 Vaasa Finland	**ISBN** 978-952-476-872-6 (print) 978-952-476-873-3 (online) URN :ISBN :978-952-476-873-3 **ISSN** 0355-2667 (Acta Wasaensia 426, print) 2323-9123 (Acta Wasaensia 426, online)	
	Number of pages 124	**Language** English

Title of publication

Innovation Capabilities, Design and Cutting Edge: Innovative Growth in the 21st Century

Abstract

This dissertation examines the capability of intangible assets and design competences to predict innovations. The first essay examines how design competences at different innovation stages support new product development. Literature has discussed this theoretically but empirical research is limited. The essay performs a qualitative study to illustrate how design can be used in innovation and develops a novel concept, design scale, and uses it in analyzing innovativeness with the Danish Community Innovation Survey (CIS).

The second essay links CIS to register data, from where intangible assets are calculated. The essay tests if intangible assets can predict product and process innovations in order to contribute to the validation of intangible assets literature. The essay finds support for using intangibles as innovation capability measure.

The third essay explains Finnish and Danish productivity during and after the financial crisis with intangible assets. During the financial crises, the Danish firms had an increase in organizational capital assets, while the opposite was true in Finland. Yet, research and development assets have larger impact on Finnish firms' productivity than on the Danish firms' productivity, which have comparative advantage in organizational capital assets.

The fourth essay examines if intangible assets, i.e., innovation capabilities, and employees with design education can predict firm's high growth. High growth is important to policy makers as these exceptionally fast growing firms typically create a large share of new jobs. To measure high growth, the essay uses Birch index and finds that the results depend on the business cycle; an example is the share of designers with negative or insignificant coefficient during recession but a positive and significant coefficient in all other periods. Yet, organizational capital assets have significant and positive coefficient in all periods.

Keywords

Innovation, intangible assets, design

ACKNOWLEDGEMENT

Although a PhD is granted to one person at a time, the production of a PhD is a group effort. I want to thank all my colleagues in the Economics and Business Law Department at the University of Vaasa and in CFA at Aarhus University. Each of you affected the book at hand. I want to thank Jaana Rahko for being my role model & almost a secret supervisor and Saara Vaahtoniemi & Lauri Parikka for walking this walk with me. From Aarhus, I want to thank Qi, Maria, Pernille, Ea, Andreas and Dorthe, who were there during my most productive time. I am also grateful for the friendships formed during the core courses at the Finnish Doctoral Program in Economics, FDPE. The pressures were the highest during the first two years. Julia and Sara, thank you for being there.

For guidance, I own much to Niels Mejlgaard and my stunning supervisors Hannu Piekkola and Panu Kalmi. For mentorship, my sincere thanks go to Vesa Annola, Mika Kärkkäinen, Pekka Vainio and Juuso Vataja. I want to extend my gratitude to my mentor and almost fourth supervisor Petri Kuosmanen, who provided constructive comments on the final version of my dissertation. It has also been delightful to learn about university teaching from him. Without the supervision of Carter Bloch, this dissertation would have taken a substantially longer time. He helped me to see the larger context of intangible assets, which was crucial to my motivation. Our collaboration helped me find my own perspective on innovation economics and to even develop my own concept, design scale. Furthermore, I want to express my gratitude to the two pre-examiners Ebbe Krogh Graversen and Tuomas Takalo for the constructive comments on the manuscript of this dissertation.

Additionally, there are several foundations that have made this book possible by letting me concentrate on the topics that interest me the most and by enabling my 1.5-year research stay at CFA. These are the Foundation for Economic Education, OP Research Foundation, Finnish Cultural Foundation, South Ostrobothnia Regional fund: Viljo Syrenius' Foundation and Niilo Helander Foundation.

Finally, but importantly, I want to thank my support groups outside academia. I am forever thankful for the international choir Pro Pace in Aarhus and for Vaasan Uimaseura, the swimming society in Vaasa, for helping me take time off from work-related thoughts. Furthermore, I am thankful to my spouse Jan Gustafsson, my departed dad, and my half-brothers, who are each a role model to me in their own way (especially Rolf and Kaj). My mom, Merja Eklund, deserves a bigger thank you than this text can deliver. My mom is a single parent who, in practice, has been a superhero. She took care that I always had multiple cool hobbies and

found support for my strong dyslexia. For me, school has been getting easier ever since I learned to read. Thus, I want to encourage others with dyslexia to pursue higher education. There are many of us, I know, but very few of us know that dyslexia is actually a double-edged sword, with the other edge pointing outside: dyslexia can be a strength. Because of dyslexia, I learned to make sense of things through visualization (this may also explain my interest in design). My biggest weakness is and has been English. None of my other languages (all six of them) nor math has ever been a problem. Nevertheless, here it is – an academic book written in English. As I was able to achieve this, so are you, my dyslexic friends, able to do anything.

Contents

Figures

Tables

Essays

This dissertation consists of an introductory chapter and the following four essays:

1. Bloch, Eklund, Kjeldager Ryan (2019) Design Strategies for Innovation – An analysis of the multifaceted concept of design

2. Eklund (2019) Innovations from Capabilities

3. Bloch, Eklund, Huovari (2019) Innovative Competences and Firm-Level Productivity in Denmark and Finland

4. Eklund (2019) Why Do Some SME's Become High-Growth Firms? The Role of Employee Competences

1 INTRODUCTION

The phenomenon of economic growth is being pursued by virtually all modern societies. The expectation of economic growth motivates people to invest in companies. Investment, in turn, helps businesses to develop innovations such as new products or new processes, two forms of innovation that then create economic growth.

However, experts routinely debate whether innovativeness reduces employment in the short run: process innovation allows the same amount of production with less labor. However, the situation will vary depending on whether the innovation is more of a product or a process innovation. In the case of new-to-the-market product innovations, the economy and employment may both grow. The focus of this dissertation is on the innovation competences that are linked to both product and process innovation output types.

I investigate whether an innovation-competent firm can become a high-growth firm (HGF), i.e., one of the fastest growing firms in the economy during a three-year period (Hölzl, 2013). These firms have been shown to create the most new jobs without replacing existing jobs in the economy (Coad & Hölzl, 2012). A high degree of employment is an important goal for general welfare—especially for the funding of a Nordic welfare state. If innovativeness supports high growth, then it can create new jobs. This dissertation concentrates mainly on innovativeness in Denmark but also discusses similar issues in Finland.

The starting point for this study is the premise that a breakthrough in innovation requires diverse competences because the simplest inventions have likely already been invented. Currently, novelties require an increasingly diverse set of specialists. These include but are not limited to technological knowledge, formal research and development (R&D) and information communication technology (ICT) specialists but also include organizational knowledge, marketing, management and design specialists. The recognition of the role of design in innovation is the main contribution of this dissertation.

Traditionally, design means to shape the end-product, a process that I call shaping later in this study. In Finnish, the word originates with the verb "muotoilla," which is related to the noun for shape, "muoto." In arts, design can be described as follows: "The content of design is no longer sought in the artifact itself. It becomes a receiver's thought, which is constructed through the receiver's contact with the design" (Kazmierczak, 2003, p. 48). In the past, designers were asked to put "a beautiful wrapping around the idea" (Brown, 2008, p. 2); today, they are encouraged to “create ideas that better meet consumers’ needs and desires” (Brown, 2008, p. 2). Hence, designers are receiving increased attention and gaining importance in many firms. In modern companies today, designers may even initiate the innovation process, and design may be utilized in strategic planning and management processes (Na, Choi, & Harrison, 2017). The concept of design thinking is currently a trending practice in management. To conceptualize all the diverse aspects of design, I present a new concept, design scale, which based on the Danish Community Innovation Survey, helps to link design competences to innovation. To the best of my knowledge, this is the first concept to link design activities to data and following the design spectrum from Na et al. (2017), the second concept to consider the use of design in innovation.

Although innovation surveys are an excellent source of knowledge about innovation activities in firms, one problem with using surveys as a source of information is the limited number of observations they afford. In collecting information on firms, the Community Innovation Survey is collected by a random sampling that weights large companies. Hence, this dissertation includes a discussion of how the register data, such as the linked employer–employee data set, can partly replace innovation surveys. With register data, we avoid the problem of selection bias because the register includes all firms and employees in the focal country. This study utilizes three different types of intangible assets that support both product and process innovations. These intangibles are also used in the prediction of whether a firm will become an HGF and can help us to compare the innovativeness of Danish and Finnish companies. Additionally, I will investigate whether innovativeness has supported Denmark’s and Finland’s recovery from the financial crisis of 2008. By 2018, the Finnish economy had not recovered in terms of the level of the country’s GDP compared to that in the prefinancial crisis period. It is interesting to compare the Finnish and Danish economies to determine which factors are behind the different performance of the two since 2008. One possible source of the stronger GDP growth in Denmark is its continuing investment in knowledge capital.

1.1 Objective of the dissertation

The dissertation consists of four essays discussing the gains from knowledge in firms. The main aim of this dissertation is to highlight the importance of different innovation competences in firms. To achieve this, the dissertation primarily discusses two measures of innovation capability: design competences, which are not yet included in the intangible assets concept in the current literature, and intangible assets, such as capitalized IT work and management effort. Design competences traditionally relate to marketing innovation, for example, a new shape for a product or a similar shape for all products within the firm (branding). However, currently, design is increasingly being seen as an integral part of management: design thinking is a fashionable approach to managing modern firms (Brown, 2008). If the firm is already applying design competences in the early stage of the innovation process, then the design supports the creation of a new product, i.e., product innovation. To approach this, we use a new concept, namely, a design scale that accounts for different application timing for design in the innovation process. Indeed, the first essay considers different design orientations considering design scale. Additionally, it tests how design scale affects product innovation and the novelty of the innovation, i.e., whether the innovation is only a new product to the firm, to the market, or even to the world. The first essay also considers the sales of these new products; its main objective is to highlight the potential gains from design in innovation.

The second essay discusses differences between two popular strategies for measuring innovativeness in firms: the examination of the firms' innovation inputs and outputs through the Community Innovation Survey and the analysis based on register data of the firms' intangible assets (Görzig, Piekkola, & Riley, 2010). The objective of this essay is to study the similarities and differences between these measurement practices. For example, it is possible to obtain the intangible assets for all firms with more than ten employees by using the Nordic Register-based data. Alternatively, the survey gives us more detailed information on the firm's innovation activities than can be obtained through the intangible assets approach. The main aim of the essay is to clarify whether intangible assets are usable in broader contexts than those in which they are currently utilized in innovation economics. Moreover, the second essay enlarges the concept of intangible assets to a broader audience.

The third essay builds on the intangible asset measure and evaluates the importance of innovation competences in Denmark and Finland. The essay focuses on how these competences can help the firm cope with challenges during and after turbulent economic conditions such as the financial crisis of 2008. In a broader context, the objective of the third essay is to show how different innovation competences can aid value creation under challenging economic circumstances.

The fourth essay discusses how innovation competences may support an enterprise as it becomes an HGF. This is an essential issue for the generation of new jobs and, in general, for creating economic growth. The essay studies how innovation competences are associated with the emergence of HGFs. I will explore this by examining the firms' share of highly educated employees and intangible assets compared to that of the firms' competitors. The essay contemplates how under different economic circumstances, different innovation competences, such as design and engineering, may have different impacts on high growth in firms.

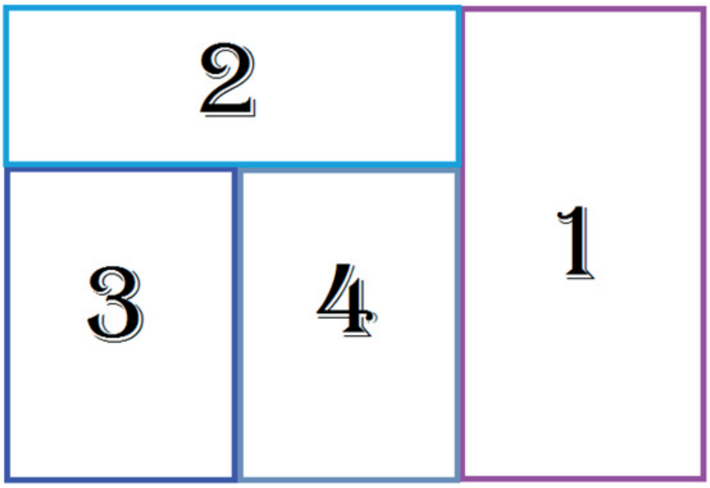

Figure 1. The interconnections of essays 1-4.

Figure 1 describes the interconnections of the four essays. While focusing on design competences, the first essay uses an innovation survey to define innovativeness and innovation capabilities. The second essay discusses and measures differences in innovation surveys and register-based intangible asset approaches. Building on intangible asset data, the other two essays test how innovation capability supports productivity (3) and high firm growth (4). Inspired by Bloom and Van Reenen (2010), who show how important factor management can be for productivity, each of the essays recognizes the importance of management.

1.2 Methods and Sources

One of the most essential methodological choices in this dissertation is how to evaluate innovativeness and innovation capability. A typical and simplified way to measure the firms' innovativeness is to use a dichotomous measure of whether the firm has at least one new product or process. Accordingly, a product innovation has typically been categorized in the previous literature into three novelty levels: new to the firm, new to the markets, and new to the world. Another simple measure of innovativeness is a binary variable identifying when the firm has a process innovation. Community innovation surveys measure and report these. Using the Danish Community Innovation Survey, in the first essay, we access detailed knowledge on innovation efforts and managerial practices in firms. This especially benefits the research on design competences. To gain a deeper understanding of this specific issue on a practical level, the first essay utilizes a clean technology manufacturing case study based on semistructured interviews.

Alternatively, intangible assets can be used to measure innovation capability. Intangible assets can be used to measure the innovation competence in the firm. Simply put, the intangible asset approach to innovation measurement uses the education level achieved and occupation of the employee to evaluate his or her knowledge, capabilities and potential to use these skills in the job; see, e.g., the EU 7th framework project INNODRIVE or COINVEST at the macro level. The approach from INNODRIVE presumes that a portion of working time is used to develop something new: in other words, there is a share of work time that is an investment in future innovations. Additionally, similar to capital formation, the formation of intangible assets requires a certain share of tangible capital and intermediate inputs. Consequently, each intangible capital type has its own yearly depreciation rate. Intangibles have three components approximating different innovation competences: research and development (RD) assets (approximating broader innovativeness than the traditional R&D), organizational assets (approximating organizational and marketing capital), and ICT assets. The second article discusses this in detail: this explains the position of the second essay in the middle of figure 2. Figure 2 presents the innovativeness measures used in the essays along with the focus of the essays. The focus can be categorized by the degree to which it is business or innovation related.

While the first essay mainly focuses on how to innovate more with design, it also discusses the relation between design competences and the share of sales from new products. The third essay uses intangibles to explain productivity, which can be conceptualized as the ability to do things smarter—this is a form of process innovation. Finally, the fourth essay uses intangibles to predict high growth; hence, the approach of the fourth essay is highly business related.

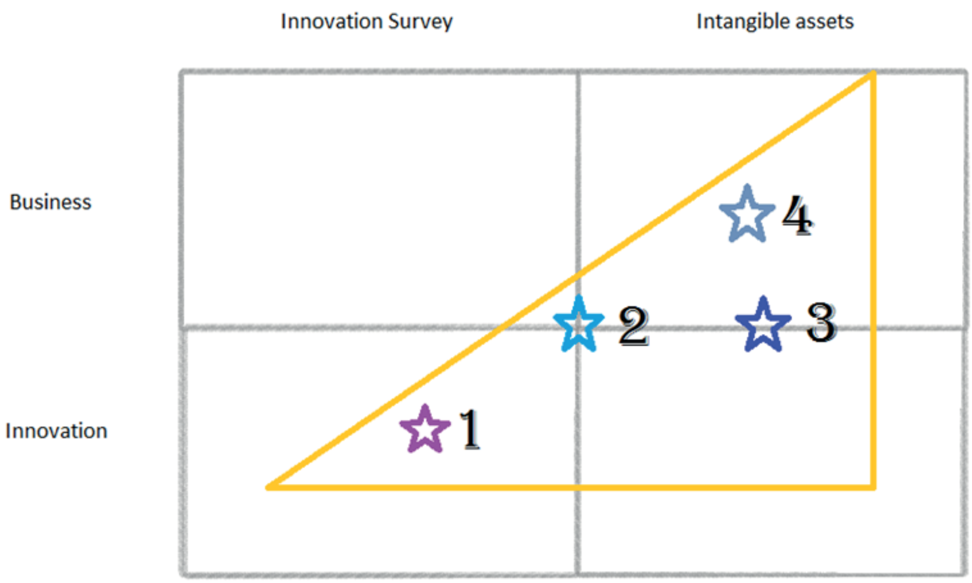

Figure 2. Innovation competence measures and their objects (stars are the essays).

The data in this dissertation are obtained from the Statistics of Denmark and the Statistics of Finland. All the essays of this dissertation use data from Denmark. The third essay uses Finnish data in addition to the Danish data. The first two essays use the Community Innovation Survey and register-based data, and the other two use register data. The main estimation methods include probability estimation and panel data analyses.

1.3 Structure of the dissertation

This dissertation is organized as follows. Section 2 summarizes the essays of this dissertation and places their conclusions in a broader context. Section 3 presents the first essay, which explains innovativeness by using a measure of design competences in firms. The quantitative results are illustrated through semistructured interviews conducted to determine what functions or facilities innovative firms find important in their innovation process. The second essay in section 4 shows how the attention-gaining concept of intangible capital can support the generation of innovations. The third essay in section 5 uses large micro datasets to demonstrate the gains from intangibles in Denmark and Finland and the development of intangibles during and after the financial crisis. Finally, the fourth essay in section 6 discusses the links between innovativeness and HGF.

2 SUMMARY OF THE ESSAYS

This section summarizes the four essays of this doctoral dissertation. Overall, this dissertation finds strong support for using intangible assets as an innovativeness measure and calls attention to design competences as a special type of effort to support innovativeness. The following subchapters summarize the main outcomes and findings of the essays.

2.1 Essay 1: Design strategies for innovation – An analysis of the multifaceted concept of design

The first essay examines the different design competences involved at different innovation stages in firms. Overall, design competences are increasingly valued in the business context (D'Ippolito, 2014). Traditionally, design has been narrowly seen as the shaping of the final product; however, comprehensive design thinking is gaining attention from management. Accordingly, managers are increasingly using the problem-solving tools of user-oriented designers to gain a competitive edge for the firm.

Na et al. (2017) formulate the design spectrum concept to describe the use of design in innovation. Continuing in their footsteps, this essay presents a new concept, a design scale, which helps us to analyze design in innovation with the Community Innovation Survey (CIS). The empirical testing has been possible only now, as the Danish CIS involves two waves with more detailed design questions than previously asked. Hence, empirically testing the design scale concept, the essay widens the results from Roper, Micheli, Love, and Vahter (2016). Moreover, semi-structured interviews illustrate how Danish firms use design competences. The essay finds that the use of design does support product and process innovations. However, new product sales benefit mostly from integrated design, i.e., the middle of the design scale.

2.2 Essay 2: Innovations from capabilities

The second essay discusses an innovation measurement approach based on intangible assets, as developed in Görzig et al. (2010). Understanding this approach is important for determining whether intangibles can explain and predict new product launches and the development of new processes. According to the results of the second essay, each category of intangible assets explains these innovations. In a wider context, this means that by using register-based data, we can approximate the innovativeness of more firms in the economy than just the thousands that respond to the CIS.

Both research and development (RD) assets and ICT assets support all levels of novelty in product innovation. Organizational assets most often support market novelty and firm novelty. Furthermore, firms with RD or ICT assets are more likely to generate process innovation, marketing innovation and organizational change than are firms without these assets, while organizational assets, in turn, support marketing innovations. This essay proposes that intangibles serve as a valid innovation capability measure.

Register-based data have an advantage because of their broad coverage in Nordic countries. Register data contain information on all firms, a classification of the employees' occupation and the employees' completed university degrees. According to Harris and Moffat (2013, p. 355), knowledge "resides in employees" and moves more easily inside than outside the firm. Based on this, using the employees' capabilities to approximate the innovation capability of the firm is justified. In contrast, register-based data are limited in terms of identifying the attitudes and practices used in the firm. Therefore, CISs are needed to approach questions about the specific efforts invested by employees and management. Moreover, surveys reveal how keen a firm is about approaching new trends in marketing and management.

2.3 Essay 3: Innovative competences and firm-level productivity in Denmark and Finland

The third essay analyses the development of productivity in Denmark and Finland during and after the financial crisis. The essay analyses how the link between intangibles and productivity has evolved between 2000 and 2013 in both countries. Although productivity is a measure of ignorance in the basic model, it is important for firm survival, as highlighted by Syverson (2011, p. 332): "The positive correlation between productivity and survival is one of the most robust findings in the literature."

The differences between Denmark and Finland in their firms' intangibles are interesting. Firms with organizational assets (OA) increased in Denmark from 76 % in 1999 to 90 % in 2013, while in Finland the development was the opposite: in Finland, firms with OA declined from 91 % to 79 %. Research and development assets (RD) and ICT assets show a similar development in reverse directions: firms with RD increased in Denmark by 30 % and decreased in Finland by 20 %. The difference in ICT assets between Denmark and Finland was only 1 % in 2013.

Accordingly, the gains in productivity differ as well. Finland has achieved more productivity gains from RD than has Denmark, which in turn has a comparative advantage over Finland in OA.

2.4 Essay 4: Why do some SMEs become high-growth firms? The role of employee competences

The fourth essay continues the focus on intangibles and explores how they are related to high growth. HGFs are the engine for new job creation (Hölzl, 2013; Schreyer, 2000) and are thus highly interesting for governments and policymakers.

The essay measures HGFs by using a size-neutral Birch index based on the number of employees. High growth can be measured by either an increase in sales or one in employment. The latter is chosen here because employment decisions are future oriented. Additionally, the OECD sales measure acts as a robustness test. The main interest lies in exceptional HGFs, i.e., the top 5 % of the fastest growing firms. In addition, the essay reports the results for the top 10 % fastest growing firms. The essay includes both high-growth groups because the literature does not agree on a threshold for defining fast growth.

The essay finds that all intangible asset types are associated with the probability of a firm becoming an HGF. Additionally, the firms' share of designers supports high growth before and after the financial crisis but not during the crisis. The firms' share of engineers predicts high growth in each period; however, the share of engineers is less significant after the financial crisis. Similarly, if we expand our attention from the top 5 % HGFs to the top 10 % HGFs, then diversity in the area of education also has prediction power. The fourth essay concludes that innovation capabilities can well predict the emergence of an HGF.

3 CONCLUSIONS AND POLICY IMPLICATIONS

This dissertation combines research and discussions on intangible assets, innovativeness and the broad gains derived from making things smarter by applying design competences.

In innovation, the importance of design has been undervalued for a long time, although design competences support product innovation and innovation performance. Design is an important strategic choice for a variety of firms and represents an investment in increasing innovativeness. This dissertation illustrates this role in the context of Denmark, and the relationship between design and innovation is likely to be similar in other developed countries. Therefore, this dissertation shows that design should be an integral part of the concept of intangible assets and suggests developing a new intangible assets type, “design assets,” to better measure the knowledge capital in the firms. The knowledge capital measure is a key concept supporting future research because knowledge capital is the engine of growth in modern economies.

One of the most crucial questions in the innovation literature is how to measure innovativeness and the innovation capability in firms. This dissertation contributes to the literature by showing that new types of intangible assets are needed in addition to conventional R&D spending to predict innovation. Hence, measuring innovation competences based on a broad definition of intangible assets is likely to be a concept with potential benefits for all developed countries. Furthermore, this dissertation uses intangibles to evaluate innovativeness in Denmark and Finland, which have similar register databases, and studies the development of productivity in both countries during the financial crisis. While fewer Finnish firms have invested in intangible assets, the opposite is true in Denmark. Therefore, either the financial crisis had different effects on these two countries, or the response was different in these countries. It is clear that for both countries, after the financial crisis started, ICT assets offered gains through higher productivity enhancement. However, given the similarities in production, Finnish firms should benefit from investing more in managerial abilities. Denmark has the clear potential to combine its strength in organizational capabilities with R&D activity but meanwhile is to some degree a follower to Finland in regard to RD and ICT investment. The recovery from the financial crisis in Denmark was much faster than it was in Finland; this may be linked to Denmark’s continued investment in intangible assets.

Moreover, the dissertation finds that innovativeness increases the likelihood of a firm becoming an HGF. These firms are of great importance to economic growth, as HGFs have been shown to create the most new jobs in an economy (Hölzl, 2013). Thus, contradicting a general understanding, innovativeness does not necessarily destroy jobs. In contrast, innovativeness creates growth and new jobs in innovative firms. In other words, intangible assets as well as highly educated employees, designers and engineers create economic growth. Innovative HGFs are an integral part of creative destruction, but these firms also create genuinely new jobs.

Given the well-grounded findings of this dissertation, the importance of design in business can be clearly recognized. Hence, design education should be an integral part of all business and technical education.

References

Bloom, N. & Van Reenen, J (2010) Why Do Management Practices Differ across Firms and Countries?. Journal of Economic Perspectives, 24(1), 203-224

Brown, T. (2008). Design Thinking. Harvard Business Review, 6.

Coad, A., & Hölzl, W. (2012). Firm growth: empirical analysis. Handbook on the economics and theory of the firm.

D'Ippolito, B. (2014). The importance of design for firms' competitiveness: a review of the literature. Technovation, forhcoming.

Görzig, B., Piekkola, H., & Riley, R. (2010). Production of intangible investment and growth: Methodology in INNODRIVE. INNODRIVE WP1.

Harris, R., & Moffat, J. (2013). Intangible assets, absorbing knowledge and its impact on firm performance: theory, measurement and policy implications. Contemporary social science, 8(3), 346-361. doi:10.1080/21582041.2012.751498

Hölzl, W. (2013). Persistence, survival, and growth: a closer look at 20 years of fast-growing firms in Austria. Industrial and corporate change, 23(1), 199-231.

Kazmierczak, E. (2003). Design as meaning making: from making things to the design of thinking. Design issues, 19(2), 45-59.

Na, J. H., Choi, Y., & Harrison, D. (2017). The design innovation spectrum: An overview of design influences on innovation for manufacturing companies. International Journal of Design, 11(2).

Roper, S., Micheli, P., Love, J. H., & Vahter, P. (2016). The roles and effectiveness of design in new product development: A study of Irish manufacturers. Research Policy, 45(1), 319-329.

Schreyer, P. (2000). High-Growth Firms and Employment (Vol. 3). Paris: OECD Publishing.

Syverson, C. (2011). What determines productivity? Journal of economic literature, 49(2), 326-365.

Essays

This dissertation consists of an introductory chapter and the following four essays:

1. Bloch, Eklund, Kjeldager Ryan (2019) Design Strategies for Innovation – An analysis of the multifaceted concept of design

2. Eklund (2019) Innovations from Capabilities

3. Bloch, Eklund, Huovari (2019) Innovative Competences and Firm-Level Productivity in Denmark and Finland

4. Eklund (2019) Why Do Some SME's Become High-Growth Firms? The Role of Employee Competences

Design Strategies for Innovation – An analysis of the multifaceted concept of design

Carita Eklund*, University of Vaasa, Aarhus University, CFA,

Carter Bloch, Aarhus University, CFA,

Thomas Kjeldager Ryan, Aarhus University, CFA,

*Corresponding author

Abstract

Design is considered fundamental to business performance. While there has been an increasing theoretical focus on the complex and multifaceted nature of design, empirical knowledge is limited on how different usages and the integration of design activities relate to innovative propensity and performance. This article provides detailed analyses of how different design activities support innovativeness. First, through a qualitative study of firm innovation strategies, we illustrate different approaches to incorporating design. Second, we analyze the role of different design types on the propensity for innovation for Danish firms. The quantitative analysis uses the Danish Community Innovation Survey for 2010 and 2012, which has unique data on design activities. Thereafter, we estimate the relation between design and innovation performance, measured by the share of sales from product innovations. We find a positive relation from end-product shaping and the inclusion of designers in multidisciplinary teams with the propensity to innovate. Moreover, we find that integrating design in management practices, innovation practices and branding increase both the likelihood of innovation and innovation performance.

Keywords: innovation, innovation performance, design, design thinking, CIS

Introduction

Design has long been considered fundamental to business performance (D'Ippolito, 2014; Sanderson & Uzumeri, 1995). Although traditionally, the focus has been placed on the role of design in the shaping of end-products, design is now increasingly seen as a creative process influencing innovation processes and innovation success. Design can be understood as a spectrum ranging from shaping (activities to create a user-friendly product) to design strategy (management of the design process) and to design thinking (a management approach applying design to management) (Na, Choi, & Harrison, 2017). Hence, the relation between design and innovation may be complex and multifaceted (Santamaría, Nieto, & Barge-Gil, 2009), encompassing many ways in which design can influence innovation.

Previous empirical work finds that design supports innovation[1]. Czarnitzki and Thorwarth (2012) find that in-house designers support both imitation and market novelty . However, their results show external designers supporting only new-to-the-firm products. Marsili and Salter (2006) show that firms with more design spending are more innovative[2]. Both articles stress design activities as one of many innovation capabilities. Filippetti (2011, p. 19) finds that design complements R&D, is more effective in dynamic firms with complex innovation strategies and relates to better economic performance[3]. The existing quantitative analyses of how design affects innovation are often unable to distinguish between different types of design activities. Most studies have either limited their focus to end-product design (Czarnitzki & Thorwarth, 2012) or use a single broad conceptualization of design that encompasses all aspects (Filippetti, 2011). An exception is Roper, Micheli, Love, and Vahter (2016), who use the designers' roles in the innovation process to explain innovative sales and the novelty of the developed product.

Following Roper et al. (2016), we examine whether different types of design activities support innovation in firms. Utilizing unique data on design activities from the Danish Community Innovation Survey (CIS) for 2010 and 2012, we develop a categorization of different design activities and analyze how design relates to the propensity for innovation and innovation performance. For product innovation, we examine three levels of innovative novelty: new to the firm, new to the market or new to the world. By examining whether the effects of design and shaping are different for the introduction of new-to-the-firm (approximating incremental) or new-to-the-world (approximating radical) products, we also test the reasoning of Norman and Verganti (2014), who expected low (high) radical (incremental) innovation gains from design.

[1] Czarnitzki and Thorwarth (2012): the fifth Belgian Community Innovation Survey
[2] Marsili and Salter (2006): the second Dutch Community Innovation Survey.
[3] Filippetti (2011): Innobarometer Survey 2009.

Through semistructured interviews, we illustrate the broad role of design in management. We aim to discover how innovative companies seek to create a competitive edge through close customer interaction in different stages of design activities, through the design of custom solutions and through design thinking. These cases help inform the design of our quantitative analysis and support the construction of indicators.

A key feature of this study is the ability to examine the different roles of design in innovation and innovation performance. The case studies illustrate the role of design in innovation activities within the area of clean technology. We contribute to the question of how design thinking contributes to the firms' value creation process, as presented by D'Ippolito (2014, p. 723).

Literature review

Design has many definitions in the literature (Creusen & Schoormans, 2005; Galindo-Rueda & Millot, 2015; Mortati, 2015; Na et al., 2017; Norman & Verganti, 2014; Walsh, 1996). Many view design as appearance-focused activities, which we name 'shaping' [4]. Shaping relates to consideration of the products' visual look, materials, and expenses and typically occurs at the end of the innovation process. Thus, shaping has a limited effect on functionality, but it plays a key role in traditional design and marketing research because it affects buying decisions and user experience. Shaping is an aesthetics communicator (Creusen & Schoormans, 2005, p. 63): it makes sense of things and creates artifacts. A subsection of this role is industrial design, in which, as opposite to the traditional timing of shaping activities, the shaping is conducted before production. The research on shaping focuses on people's preferences, for example, preferences for product appearance (Creusen & Schoormans, 2005, p. 68), and on how the aesthetics affect the user (Berkowitz, 1987). Hence, shaping can be seen as a form of communication (Kazmierczak, 2003). A product's appearance is meant to communicate its usability and the consumer's feelings while using the product (Creusen & Schoormans, 2005). This perspective also explains why OECD and Eurostat (2005) previously categorized design as marketing innovation. However, recently, the design concept has been expanded. For instance, Kazmierczak (2003) describes design as content or meaning generation. Kazmierczak (2003) calls for a paradigm change in the research on product design. Design links comprehension to form but can also structure conversations. "The content of design is no longer sought in the artifact itself" (Kazmierczak, 2003, p. 48): now, user experience dominates.

[4] The term follows from the Finnish word for shape, "muoto."

Firms implement design at different stages of production. Na et al. (2017) develop the Design Innovation Spectrum concept, dividing design into the design of a product or service, the management of design (Battistella, Biotto, & De Toni, 2012; Chiva & Alegre, 2009) and design as a management strategy, i.e., design thinking. Design thinking is a managerial philosophy that uses the designers' problem-solving methods in business decisions. Designers are now asked to "create ideas that better meet consumers' needs and desires" whereas before, their mandate was to "put a beautiful wrapping around the idea" (Brown, 2008, p. 2). Brown (2008, p. 4) describes the design process as a nonlinear process of inspiration, ideation and implementation. Inspiration contains the search for opportunity or for a problem. Ideation includes idea generation, development and testing. Commonly, a project loops between these two stages for a period as solutions generate more problems or opportunities. Finally, implementation introduces the product to the markets.

The relation between innovativeness and design competences has gained attention (Roy & Riedel, 1997; Utterback et al., 2006). Previous research has focused on shaping's relation to innovation (Marsili & Salter, 2006) and the effect of broadly defined design (Czarnitzki & Thorwarth, 2012; Filippetti, 2011). To the best of our knowledge, Roper et al. (2016) is the only study that empirically tests how design activities affect innovation. They approach the relation between design and innovation by considering the three roles of designers: a functional specialist role, a bridging role and a continuous involvement role in innovation production (Roper et al., 2016, pp. 321,323,325). In the role of a functional specialist, the designer is involved in one stage of innovation production. In the bridging role, the designer is part of diverse teams. In a continuous involvement role, the designer is involved in the process from the start to the commercialization of the innovation (Roper et al., 2016, p. 321).

The design literature has discussed how design can support innovativeness. An interesting conceptual research stream discusses how a user focus, an important part of design, affects the newness and significance of development. Norman and Verganti (2014, p. 85) attribute the biggest technology changes to technology-push innovations in which technology changes radically. They elaborate as follows: "Radical innovation brings new domains and new paradigms, and it creates a potential for major changes" (Norman & Verganti, 2014, p. 84). Radical innovations search for the 'highest hill,' the global maximum, of product quality. However, Norman and Verganti (2014) explain that incremental innovations, such as new design, use radical innovations and profit from them. Incremental innovations aim to develop products within the firm's current product space and processes. Thus, they identify the top of the hill or the local maximum.

Nevertheless, the most successful innovations employ both innovation types: Nintendo Wii exemplifies the fusion of radical design and technology innovations.

Czarnitzki and Thorwarth (2012) tested how internal and external designers contribute to the innovativeness of the firm. They find contradictory evidence as to whether design activities only lead to imitation. They highlight that many factors contribute to successful innovation performance and that "design expenditures by themselves cannot be the exclusive reason for a firm's innovation success"(Czarnitzki & Thorwarth, 2012, p. 889). They note that expenditures can act as a catalyst for successful differentiation in the market. This observation is in line with Gemsera and Leenders (2001), who find that shaping is a strategic choice that depends on the industry's design maturity. Czarnitzki and Thorwarth (2012), however, show different gains from internal and external designers. Internal design activities can support both new-to-the-market and new-to-the-firm products, while external design only supports firm novelty. The underlying mechanism comprises the dynamics among designers and between designers and other employees. The risk of an internal designer is that he/she will experience boredom, while that of an external designer is that he/she leaks information. By contrast, external designers bring fresh ideas, while internal designers are accessible and know the firm's story. Czarnitzki and Thorwarth (2012) elaborate that external designers might likely be used in the last stages of product development, while internal designers can participate throughout the process.

Czarnitzki and Thorwarth (2012) note that no single measure can describe the complex process of innovation. Østergaard, Timmermans, and Kristinsson (2011) show that having highly educated employees and value-change's collaboration supports innovativeness. They report that higher education, diversity policy, organizational change and collaboration have marginal effects of 0.1 on value change (Østergaard et al., 2011). Marsili and Salter (2006), using the Dutch CIS, also examine the effect of shaping on innovation and focus on turnover from innovation. For new-to-the-firm and new-to-the-market products, they find a positive effect from design on turnover but a nonsignificant effect on the turnover of improved products [5].

The above analyses, based on CIS data, operate with a narrow design concept that only includes shaping. In contrast, the analysis in Filippetti (2011), which utilizes 2009 Innobarometer data for all EU countries, works with a broader definition of design. In the 2009 Innobarometer survey, design includes graphic, packaging, process, product, service and industrial design activities. Filippetti (2011) finds

[5] Our data include improved products as a part of new-to-the-firm products.

that design is often not an alternative to a technology-based approach to innovation but typically a complement. While this definition of design is broader, the survey does not allow any distinction between the different types of design activities involved in innovation. Roper et al. (2016) find that all tested roles of designers contribute positively to the share of sales from new products when the firm engages in R&D. Roper et al. (2016, p. 326) report that designers playing a bridging role in the innovation process increase the novelty of the developed product.

Roper et al. (2016) use the data on Irish manufacturing plants during 1991–2008 to find how design affects innovation production and performance. Importantly, design benefits plants performing R&D in-house, and these positive results also drive the results for the whole sample. Following Roper et al. (2016), we distinguish between different types of design activities and analyze their relation to innovation and innovation performance. The categories of design activities that we use are based on a unique design module that was included in the Danish CIS for 2010 and 2012. Section 5 describes this in detail.

To better understand the diverse aspects of design, we adapt a concept developed by Na et al. (2017): a design spectrum. As conceptualized by Na et al. (2017), we divide design activities into three parts according to the function of design. Na et al. (2017) designate these three stages as follows: designing, design strategy and corporate-level design thinking. From the user and production perspectives, they broadly define designing as the professional designers' activity that creates an artifact (Na et al., 2017, p. 15). This definition includes the correct and efficient use of materials and the consideration of aesthetics and functionality. When designing starts to affect the strategic level, then we are talking about a design strategy, which is associated "with the management of design in a firm" (Na et al., 2017, p. 15). When firm-level management uses the designers' problem-solving tools (design principles), the design activity is called corporate-level design thinking.

Creating a suitable concept, the design scale, which differs slightly from the design spectrum, we modify the design spectrum to better suit the data with the guidelines of the Oslo Manual (OECD & Eurostat, 2005),. The first activity of the design scale is shaping, i.e., the formulation of a product with small functional changes, an activity thus described in a survey item. The second activity is integrated design that includes shaping. The third part of the design scale consists of management practices that implement the designers' problem-solving tools. We call this central design because management can use design skills without fully implementing design thinking. We test these, as done in Roper et al. (2016).

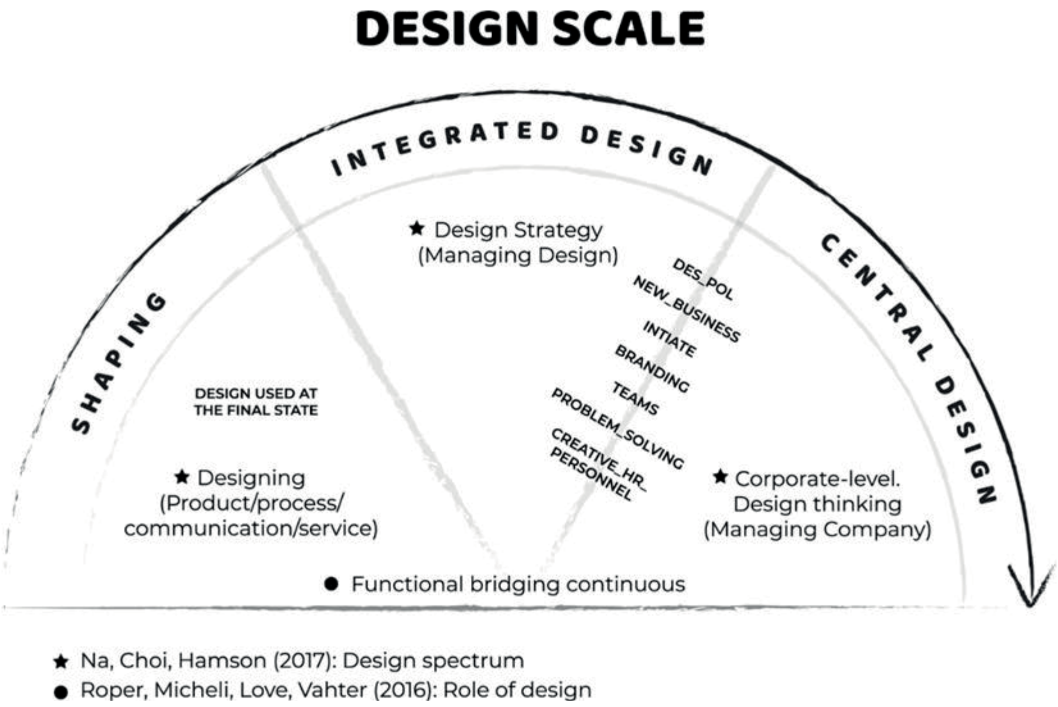

Figure 1.1. Design Scale.

Consistent with the Oslo Manual (OECD & Eurostat, 2005, p. 36), we define innovation as a new or significantly improved product, process, organizational or marketing method. Product innovations have three novelty levels: firm (imitation), market and world novelty. This article focuses on product innovation but provides some evidence for process innovations and innovation in a broader sense.

Case studies of the role of desing in innovation strategies

For a more nuanced view of the firms' innovation strategies, we conducted case studies with innovative Danish manufacturing companies within the field of clean technology. The purpose of these studies is to provide illustrations of how these firms incorporate design into innovation strategies and business models in practice and to identify what competences firms need to succeed in implementing these changes. In each case, we examined the companies' development in recent years and then conducted semistructured interviews with the key managers involved in innovation or development activities. These cases cannot be considered representative of the broader population of Danish companies. Instead, this qualitative study provides empirical knowledge of how design can be included in business practices.

Interviews were conducted with key personnel in management, R&D or innovation activities. The semi structured interviews revolved around central topics, such as the firm's value proposition, its business and innovation models, a typical innovation process, the role of design, networking, collaboration and users in innovation, and the needed competences in innovation processes. To focus the interview on concrete cases, we allowed the interviewee to decide where to begin by giving examples of projects, products or strategies. Thus, the time used on particular themes differed in each interview, reflecting that the importance of aspects fluctuated. The interviews lasted approximately one hour. The coding was performed in the NVivo program. Initially, we identified empirical themes that revolved around a specific theme, and these were subsequently horizontally aggregated into broader themes. The reported analysis describes these and their relation to each other.

The interviews covered five Danish companies. C1 produces industrial purpose refrigeration and freezing products. The products have changed from standardized to customer-specific solutions. C2 develops and produces electronic climate control solutions and applications for industrial refrigeration, ventilation systems and heat pumps. C3 manufactures product services for measuring energy and water consumption. The company sells products and delivers turnkey solutions. Thus, customers can buy tailor-made products for which they either control the system or they pay C3 to control the system. C4 develops, produces, sells and installs solar panel systems. The company's main product segment is systems integrated in large buildings and domestic houses. C5 belongs to a large international concern within the mechanical and electronic components industry; we focus on a specific division that specializes in electronic solutions for a range of industries. The majority of their business is in custom solutions, entailing ongoing relationships with customers and often collaborating with them during product development.

The interviews uncovered that the case companies to some degree experienced the same general pressures that ignited strategic and operational changes. Some interviewees expressed these pressures as a feeling of being on a burning platform, which in part represents increased competitive pressures, especially from large companies based in low-wage countries. These large foreign companies are able to deliver quality and differentiation at a lower price due to large production capacity and low wages. This development was perceived as rapid rather than incremental. The interviewees described many attempts to solve the recent challenges by following the various strategies discussed below.

Targeting niche markets

One response to the increased price competition was to focus on segmentation; some of the companies changed from competing in many market segments to competing in only a few and attempted to tailor their products to a segment or to single customers. The interviewees expressed that the focus on a few segments allows specialization that serves as a shield from direct competition with large broad-based companies.

This niche market strategy thus involves both closer interactions with users and a greater focus on design at the end stage of product development. For example, C1 moved from a broad focus on consumer appliances to a narrow focus within three industrial segments. According to the interviewee, due to their small scale, these segments are not relevant to larger competitors, but for C1, the size and specialization suffice. C2, which has two large clients and many smaller clients, focuses on delivering solutions tailored to specific targeted segments and to the single customer.

"We want to be the specialists, we do not want to be the mass-producing company, we want to deliver solutions and understand what the customer's needs are, that is what is our core, and then we have to be able to translate the knowledge we have—the hard-core competences with hardware, software and mechanics—and make a product from it."

C3 has a still different strategy because they focus on several markets and segments, attempting to create products that can fit into any system. However, most of the company's competitors deliver entire systems. C4 concentrates on custom-built xxx solutions; however, it still sells standard products to the market in broad terms. Thus, the company has not focused on a particular segment. C5 has adopted a focus segmentation strategy because its customers value a very high level of sophistication.

Intelligent solutions

These companies have to some extent focused on providing 'solutions' rather than stand-alone products. The terms intelligent products and solutions were often used to explain the companies' value propositions. The solutions focus requires the strong incorporation of design elements at different stages in the innovation processes.

For adopting this strategy, the primary reason mentioned by the interviewees was their inability to compete in an undifferentiated and price-focused commodity-like market.

"*So, we make customer-specific solutions; we do not want to make standard products, shelf products, because it quite quickly becomes a commodity, if it is not already."*

"So, in my world, there is innovation, ... solutions we can invoice, but they must address customer's real needs, and it may well be the customer is not fully aware of what the real needs are, but then we will see if we can figure out together how we can do this even better and how we can jump in and say 'hey, listen to these possibilities that we can bring to the table', and then we have come full circle."

Close customer relationships and customer involvement in all aspects of the value chain

Close customer relationships can be seen as a prerequisite of the abovementioned strategies or as a strategy on its own. The case companies focus on integrating the customer into the entire value chain and including customers early on in the product development process. The advantage of this strategy is an ability to create products tailored to the customer and to thereby offer a solution that is superior to off-the-shelf solutions. The relationship creates codependence and long-term revenue. This approach thus goes beyond the integration of design and uses design thinking in the overall innovation strategy.

"I think actually we're going to see more that it will be more like partnerships than customer-supplier relationships because then it becomes much 'so what do you say on specifications?', and not so much on the understanding that we can understand the customer's situation. ...So, we can make just as much technology, but if we do not fit into any business models, then it is not that interesting."

The interviewees often mentioned speed, flexibility and adaptation and that these areas were a primary focus. The interviewees expressed a desire to be flexible in terms of both upstream and downstream activities. They expressed this often in conjunction with customer involvement. They emphasized needing to include customers early in the process. The interviewees also mentioned just-in-time considerations, such as being able to deliver solutions very quickly to anywhere in the world.

"This idea with Blue Ocean ... that's where we want to be, we need to understand our customers' needs, have the level of innovation, speed, flexibility, and

flexibility throughout. Whether we are doing product development or making production plans, we just need to be changing in a changing world and with (focus) on quality, environment and design.”

The described competences and activities exemplify the role of design in broader innovative strategies or business models that the case companies have developed and applied in recent years. In particular, from our interviews, three strategies emerge that are either employed individually or in combination.

The first is the niche markets strategy, where design is focused on shaping products. While design is oriented towards products, it is important to note that design is involved in the strategic choice of product portfolio, as companies gear their operations towards tailored products for a narrow market. Products made by order often involve incremental improvements in shaping or functionality.

The second is the solutions in product development strategy. Close, long-term relations are established with customers from idea to R&D to product/solution. Companies work with customers to determine their needs and thereafter target their innovation and R&D to provide solutions to those needs. Essentially, the development and manufacture of physical goods becomes a service solution that the company offers its customers. Design requires close coordination between marketing, innovation and production activities, all of which need to be flexible and agile in adjusting and producing new products with short lead times.

The third strategy is the systems solutions strategy, where many services (maintenance, monitoring, and data management) are combined with new products. This is a very widespread trend, where manufacturing firms increasingly rely on service provision to create value for their manufacturing goods. However, design-thinking strategies that involve the inclusion of R&D and product development with these other services increase the complexity of solutions and the demands on the company in terms of know-how, flexibility and coordination.

Hypothesis development

These examples of the activities of innovative Danish firms highlight the pressures of global markets. Global developments have caused these companies to focus on the choice of business area, the support services accompanying the product, and closer consumer relations. Some have redesigned their operations to be more flexible and to offer made-to-order products. These actions are examples of using design in process innovations. The firms recognized the importance of shaping, which was defined to include the consideration of materials, costs, and product quality. The product's shape communicates its functionality and value.

Based on the literature review and these illustrated cases, we formulated the following hypotheses regarding the relation between design and innovation.

Hypothesis 1A. Design has a positive relation to product innovation.

Some firms apply design early in the innovation process, indicating that design could support product innovations. Thus, we hypothesize that design can support product innovativeness. Furthermore, designers can suggest changes other than product improvement. They may support consumer value creation through a different production process. As Na et al. (2017) and the interviewees discuss, global changes require flexibility. Indeed, many managers had realized the need for process innovation—a change in production processes and organization. For example, process innovations can be delivered straight from the factory: this is one way to provide quick service and to save storage costs.

Hypothesis 1B. Design has a positive relation to all innovation types.

Although the interviewees demonstrated a positive view of design, design can relate negatively to innovation novelty. Norman and Verganti (2014) discuss how human-centric design is unlikely to support radical innovations but will support incremental innovations. The authors explain design as the identification of market potential and usability research that they see as only likely to lead to small developments in technology, i.e., only incremental innovations, (Norman & Verganti, 2014, pp. 82, 84, 93). They define radical innovation as "a change of frame"(Norman & Verganti, 2014, p. 82), while incremental innovations are smaller developments in product quality. However, radical innovations are rare; Norman and Verganti (2014, p. 83) suppose that radical innovations might occur only once every 5-10 years. They do not recall any radical innovation (technological breakthroughs) resulting from design (Norman & Verganti, 2014, pp. 79,83). As we approach the relation between design and innovation from an empirical perspective, we measure innovativeness by analyzing process innovation and the level of novelty in the product innovation.

Providing us with three novelty levels, the Danish CIS asks whether the company has introduced a new product and if it is new to the firm, the market or the world. Based on Norman and Verganti (2014), we expect the following.

Hypothesis 2. Design better supports the introduction of new-to-the-firm products than it does that of new-to-the-market products or new-to-the-world products.

As the qualitative study illustrates, the interviewees expect gains in competitiveness from their strategy changes. They think that their recent changes have been successful and that more gains are ahead after more changes. We hypothesize that new products developed with design competences will replace a large share of sales. Thus, we expect the following.

Hypothesis 3. Design supports innovation performance, i.e., the share of sales from new products.

Moreover, design is a broad concept applicable to different development stages. Design can be shaping, managing design or a company-wide management practice, design thinking. Design thinking affects activities in the whole firm, whereas shaping is focused on marketing and communication. Shaping can be a result of a firm's strategy. Thus, design thinking can support shaping, whereas shaping is unlikely to change firm management.

The interviewees describe similar characteristics of design thinking: being flexible and "changing in a changing world." Moreover, the innovative Danish firms realize that simply identifying the current needs of the customer does not suffice: "It may well be the customer is not fully aware of what the real needs are."

Hypothesis 4. A wider spectrum of design applications, including design thinking, is more likely to generate innovations and improve innovation performance.

Hypothesis 4 means that applying design before the last stages of product development can support innovativeness and new products' turnover. At best, this would result in new products attracting new customers. Here, our quantitative data are limited. Thus, the introduction of the new product either creates a demand that replaces the demand for the old products or generates a new demand. The separation is left for future research.

Like Roper et al. (2016, pp. 320-321), we hypothesize that design contributes to the probability of product innovation. They also hypothesize that the designers in bridging roles support more innovativeness than the designers employed as functional specialists. We test whether designers involved in multidisciplinary teams support innovation, as hypothesis 4 means that the more extensive and deep the use of design is, the greater the number of innovations generated.

Furthermore, Roper et al. (2016) hypothesize that the involvement of designers throughout the whole process of new product development brings greater benefits than does using designers only in bridging roles. This overlaps with our hypothesis four. We do not expect different effects from the different utilization of design work.

Data and methods

The quantitative analysis uses firm-level data from two waves of the Danish CIS for 2010 and 2012. Each wave covers innovations and innovation activities for a three-year period, 2008-2010 and 2010-2012. These waves of the Danish CIS include an additional module covering design activities. These data offer a unique opportunity to model different design approaches and examine their relationship with innovation. The dataset comprises a representative sample of Danish firms within manufacturing and offering a broad range of services. We combine the waves to form a pooled sample with 7774 observations and merge it with the linked employer–employee data (IDA) used as the control variables.

The standard CIS collects data on marketing innovations involving changes in aesthetic design (i.e., shaping) but not on design in general or other forms of design activities such as design thinking or the use of design as a problem-solving approach. The module on design and innovation in the Danish CIS for 2010 and 2012 consisted of two questions. The first asks how much focus the firm has on design in operations, and the second covers specific design-based approaches. The latter question covers activities such as the following: using design in product development problem-solving tools; the inclusion of designers in cross-functional teams or throughout development processes; design-based branding strategies that establish a common link between products, services and concepts; the use of design thinking for product development strategies; and involving designers in the development of new business areas.

Table 1 describes the design variables used in the regressions, while table 2 includes descriptions for all other variables. These six design measures serve to capture many aspects found in the case studies. A niche market focus exemplifies a reliance on the shaping of end-products while also involving a design policy to broaden the connection between product, brand and market. A solution orientation uses some user-oriented design approaches for problem solving in the innovation process. Finally, a broader systems solutions approach can be seen as utilizing design thinking to organize the overall innovation process.

Table 1.1. Description of design questions and variables from the Danish CIS for 2010 and 2012.

Which statement best reflects your company's work with design?	
	The company does not work with design in a systematic way
SHAPING	Design is used only at the final stage when something new is developed
INTEGRATED	Design is an integrated—but not determining—element in the company's development work
CENTRAL	Design is a central, determining element in the company's development work
	Not relevant / Don't know
(If integrated or central) How does your company work with design?	
PROBSOL	Design is used to solve problems related to the development of new concepts, products or services
TEAMS	Designers are involved in multidisciplinary teams for the development of new concepts, products or services
INITIATE	Designers are involved from the beginning with the development of new concepts, products or services
BRANDING	The company has a design policy that ensures a visible connection between products, services, concepts, brands, graphic design and sales venues
DES_POLICY	The company has a design policy for the development of new concepts, products or services
NEW_BUSINESS	Designers are involved in the defining of new business areas

Source: Danish R&D and innovation questionnaire 2012, Statistics Denmark

The analysis uses several measures of innovation and innovation performance as dependent variables. The CIS contains data on the introduction of four types of innovations—product, process, marketing and organizational innovations—over a three-year period. For product innovations, firms report their novelty level: new to the firm, new to the market or new to the world. Innovative performance is measured as the share of innovation sales in the last year of the survey period. We separately explain sales from different novelty levels and examine the role of innovation collaboration with customers and collaboration with public research.

While design often focuses on product development, broader forms of design strategies and design thinking seek to incorporate creative approaches within other business functions. For this, we include a measure of the extent to which human resources uses creative competences.

Table 1.2. Variable descriptions

ANY INNO	= 1 for a product, process, organizational OR marketing innovation (at least one type) and 0 otherwise
ALL INNO	= 1 for all four types of innovation and 0 otherwise
FIRM NOVELTY	= 1 for a new-to-the-firm product innovation and 0 otherwise
MARKET NOVELTY	= 1 for a new-to-the-market product innovation and 0 otherwise
WORLD NOVELTY	= 1 for a new-to-the-world product innovation and 0 otherwise
FIRM NOVELTY SALES	= the share of total sales from product innovations
WORLD NOVELTY SALES	= the share of total sales from new-to-the-market or new-to-the-world product innovation
WORLD NOVELTY SALES	= the share of total sales from new-to-the-world product innovation
CREATIVE	= 1 if creative competences and input are used in the development of HR, organization and management and 0 otherwise
CUS	= 1 for active collaboration with customers and 0 otherwise
CUN	= 1 for active collaboration with public research organization and 0 otherwise
SMALL, MEDIUM, LARGE	Size dummies for small (<= 20 emp.), medium (20-250 emp.) or large (> 250 emp.) firms
SH_HI_EMP	Share of employees with a master's degree or higher

Our data differ slightly from the data of Roper et al. (2016), who use plant-level data to explain, first, how novel the product is [6] and, second, the share of sales from each new product. The data are collected by post, and the response rate is boosted by follow-up telephone calls. The data include survey waves 1991–1993, 2000–2002, and 2006–2008. They approach design usage with three dummy variables summarizing different design roles – the functional specialism role, the bridging role, and the continuous engagement role – in the new product's development (Roper et al., 2016, pp. 322-323). A plant has a functional specialism design role if the designers are in at least one of the following roles but not in any other: the identification of new products and the development of a prototype or shaping (called the "final product design" by Roper et al. (2016, p. 322)). According to these authors, these roles comprise the design-related stages of product development. However, if the plant has a designer in at least one of the roles for the design stage but also in any other part of new product development, Roper et al. (2016) say that the plant has designers in bridging roles. Finally, designers engage continuously in the process if they are involved in all levels of the process.

Whereas the design variables in Roper et al. (2016) represent the designers' participation in different innovation stages, our measurement also includes questions about strategy-level recognition. The strength in the approach in Roper et al. (2016) is that they avoid the problem of silent design (Gorb & Dumas, 1987),

[6] The product can be new to the plant or new to the markets.

where design can be performed by someone other than a designer. The data we use from the CIS are also based on some questions that share this strength: the data are captured by the TEAMS, INITIATE, and NEW_BUSINESS variables. To answer these questions in the survey, the firm must use an integrated or central design. This is where we complement the empirical strategy of Roper et al. (2016): SHAPING includes both the external and internal use of designers, as we do not rely on the employment of internal designers for the analysis. However, our data structure assumes that the company uses designers in product development only if design work has an INTEGRATED or CENTRAL standing in innovation and if management knows where the designers are involved. The variable TEAMS captures the effect of designers as a part of multidisciplinary teams during product development. This is our measure closest to that of the bridging role in Roper et al. (2016). The variable INITIATE captures the designers' involvement from the start of the development process. This role is again close to the bridging role of design but also somewhat relates to the continuous engagement role; unfortunately, we lack precise data on whether the designer is involved in every stage. However, we know from the construction of the CIS that the firm has at least an integrated role in design. Finally, NEW_BUSINESS is a dummy variable that in firms in which design work is at least integrated, captures whether the firm uses designers to define new business areas. However, NEW_BUSINESS is quite infrequent: only 4 % of observations have it, while 10 % use designers at the initiation phase of innovation.

Table 3 describes the data. Over the two observation years, we have 7774 observations from the years 2010 and 2012. Some firms answered both surveys. In the data, 27 % of firms have a new-to-the-firm product (FIRM NOVELTY), 18 % have a new-to-the-market product (MARKET NOVELTY), and 8 % reported a new-to-the-world product (WORLD NOVELTY), where a world novelty is also a market and a firm novelty. The average share of sales from new products range from 37 % (firm) to 19 % (market) to 7 % (world novelties). In terms of broader innovation, over half of the firms have either a product innovation or another type of innovation, such as a marketing innovation. Meanwhile, only 10 % have a product innovation and all other types of innovation.

The mean share of highly educated employees is 0.11; therefore, approximately every tenth employee has completed higher education. However, the standard deviation is large. The size of the firm also affects the likelihood of employing a highly educated employee; half of the firms are small or medium sized, and the rest are large firms employing over 250 persons.

Table 1.3. Descriptive statistics.

Variable	N	mean	sd	min	max	sum
FIRM NOVELTY	7774	0.27	0.45	0	1	2131
MARKET NOVELTY	7774	0.18	0.38	0	1	1361
WORLD NOVELTY	7774	0.08	0.28	0	1	658
FIRM NOVELTY SALES	2163	0.37	0.39	0	1	793.64
WORLD NOVELTY SALES	2163	0.19	0.32	0	1	421.27
WORLD NOVELTY SALES	2163	0.07	0.20	0	1	147.19
ANY INNO	7774	0.54	0.50	0	1	4207
ALL INNO	7774	0.10	0.30	0	1	774
SH_HI_EMP	7774	0.11	0.18	0	1	863.52
DES_POLICY	7774	0.07	0.25	0	1	541
NEW_BUSINESS	7774	0.04	0.19	0	1	301
INITIATE	7774	0.10	0.30	0	1	771
BRANDING	7774	0.10	0.29	0	1	741
TEAMS	7774	0.09	0.28	0	1	678
PROBSOL	7774	0.10	0.31	0	1	815
CREATIVE	7774	0.13	0.34	0	1	1041
SHAPING	7774	0.05	0.21	0	1	374
SMALL	7774	0.35	0.48	0	1	2701
MEDIUM	7774	0.10	0.30	0	1	777
LARGE	7774	0.48	0.50	0	1	3746
y2010	7774	0.52	0.50	0	1	4036
UNL	2163	0.19	0.39	0	1	407
UNO	2163	0.42	0.49	0	1	916
CUS	2163	0.33	0.47	0	1	718
CUN	2163	0.27	0.44	0	1	587

Table 3 presents seven different measures of design activity. Four percent of firms use designers when finding new business areas and 5 % reported shaping activities as the highest level of design that they use. Nine percent reported having designers as members of diverse teams, while 7 % report a company-wide design policy. Using designers from the start of the innovation process was as common as doing branding or using the designers' problem-solving methods, at ten percent. Thirteen percent of the firms reported having creative personnel involved in guiding the management of the firm and human resources. These creativity specialists were consultants from outside of the firm. The survey gives respondents some examples of who to include in this group, such as designers and architects. As the management team would be unlikely to take advice from the respondents, the presence of creative specialists is treated as an indicator that outside designers are being used. These questions are asked of firms that report the degree of design integration as integrated (12 %) or central (8 %). The correlations of these variables are low and reported in the appendix.

We test whether these variables explain the propensity to innovate and the share of innovative sales. Equations 1A & 1B present the estimated equation of propensity to innovate, which is also called the innovation production function, and equations 2A & 2B present the estimated equation of innovation performance. The subscript n represents the novelty level when the innovation type is a product. We have three novelty levels: new to the firm (imitation), new to the market (market novelty) and new to the world (world novelty). As control variables (included in vector X), we use the share of highly educated employees, e.g., employees with at least a master's degree, a year dummy for 2010, the share of R&D over sales and industry dummies. Equation 1A explains product innovation, $inno_n$ (where n denotes the novelty levels: new to the firm, market and world), and the level of design and controls. The level of design can be either shaping, integrated or central, as shown in Table 1. If the firm has at least an integrated level of design, then the firm answers questions that are more precise about design usage. We implement these in the following equation 1B. Equation 1B explains product innovation in firms that have at least integrated design with designers at the initiation of the innovation process (INIATIVE), being part of diverse teams (TEAMS), using designer methods as problem-solving tools (PROBSOL), using creative personnel in management (CREATIVE) and if the company performs shaping (SHAPING). Equation 1A and 1B are estimated with probit.

(1A) $P(inno_n) = \beta_0 + \beta_1 SHAPING + \beta_2 INTEGRATED + \beta_3 CENTRAL + \boldsymbol{X}$

(1B) $P(inno_n) = \beta_0 + \beta_1 SHAPING + \beta_2 INITIATE + \beta_3 BRANDING + \beta_4 TEAMS + \beta_5 PROBSOL + \beta_6 CREATIVE + \boldsymbol{X}$

In the model of innovation performance, equations 2A and 2B, are much like equations 1A and 1B, but the dependent variables are the shares of sales from product innovation. Following Roper et al. (2016), the estimations are performed with a Tobit model (Tobin, 1958) and include additional variables for innovation collaboration with customers (CUS) and universities (CUN). Companies that have no new products are excluded here because they lack product innovativeness.

(2A) $innosales_n = \beta_0 + \beta_1 SHAPING + \beta_2 INTEGRATED + \beta_3 CENTRAL + \beta_4 CUS + \beta_5 CUN + \boldsymbol{X}$

(2B) $innosales_n = \beta_0 + \beta_1 SHAPING + \beta_2 INITIATE + \beta_3 BRANDING + \beta_4 TEAMS + \beta_5 PROBSOL + \beta_6 CREATIVE + \beta_7 CUS + \beta_8 CUN + \boldsymbol{X}$

Results

The results are divided into two sections. First, by using a probit estimation, we examine the relation between design activities and the propensity to innovate. Second, we analyze how the same factors relate to innovation performance as measured by the share of sales from product innovations. We report the marginal effects.

Tables 4 and 5 present five regressions explaining the propensity to innovate with design measures. First, we use firm (imitation), market and world novelty as innovativeness measures in columns (1)-(3). Columns (4) and (5) broaden this by including organizational, process and marketing innovations. Column (4) defines an innovative firm as a firm having at least one of the four types of innovations: product, organizational, process or marketing innovations. Furthermore, regression (5) defines an innovative firm as having all four types. An individual innovation may span more than one type; for example, a product innovation may require the introduction of a significant change in processes and in the organization.

The control variables used include year dummies for the business cycle, industry and size (employment) dummies, and R&D expenses per sales (RD_SALES), which is limited to a range between 0 and 1. Following Roper et al. (2016, pp. 325-326), we know that plants without R&D (1) do not gain from design in innovation sales and (2) with a 10 % significance level, relate positively to innovativeness from only functional design roles. Furthermore, we add a knowledge measure, the share of highly educated employees, while Roper et al. (2016) used employees with a degree. Roper et al. (2016) also cover manufacturing, while our data are representative of the private sector.

Following Galindo-Rueda and Millot (2015, p. 30), to explain innovativeness, we first use the degree of design integration, i.e., shaping ("design used as the last finish"), integrated design ("design an integrated though not determining element") and central design ("design is a central and determining element"). Thus, table 4 presents how design integration affects innovativeness, and table 5 presents how specific design tasks affect innovativeness. Both report the marginal effects.

Table 1.4. Innovation explained by the degree of design integration.

Probit VARIABLES	(1') FIRM NOVELTY	(2') MARKET NOVELTY	(3') WORLD NOVELTY	(4') ANY INNO	(5') ALL INNO
SHAPING	0.236***	0.122***	0.0352**	0.280***	0.117***
	(0)	(2.06e-06)	(0.0141)	(0)	(2.96e-07)
INTEGRATED	0.286***	0.201***	0.0781***	0.298***	0.146***
	(0)	(0)	(0)	(0)	(0)
CENTRAL	0.269***	0.180***	0.0759***	0.312***	0.148***
	(0)	(0)	(4.54e-08)	(0)	(0)
SH_HI_EMP	0.196***	0.159***	0.0972***	0.186***	0.0782***
	(1.45e-07)	(1.10e-08)	(0)	(9.26e-05)	(1.82e-05)
RD_SALES	0.322***	0.239***	0.0920***	0.388***	0.0851***
	(0)	(0)	(0)	(1.87e-09)	(2.47e-06)
SMALL	-0.0650***	-0.0345***	-0.0124**	-0.163***	-0.0323***
	(2.72e-08)	(0.000145)	(0.0111)	(0)	(9.17e-08)
LARGE	0.153***	0.107***	0.0391***	0.153***	0.0755***
	(0)	(5.90e-09)	(0.000307)	(0)	(3.02e-08)
y2010	0.00113	0.0105	0.00269	0.0456***	0.00684
	(0.915)	(0.197)	(0.540)	(0.000287)	(0.210)
Observations	7,183	7,183	7,183	7,183	7,183
Industry dummies	yes	yes	yes	yes	yes

Marginal effects and p-values are in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

All three levels of design integration (shaping, integrated, and central) relate positively to all innovation types. Shaping has positive and significant marginal effects in all product innovation regressions (1')-(3') and (1)-(3) supports hypothesis 1A (design has a positive relation to product innovation) [7]. Additionally, shaping has a positive and statistically significant marginal effect on the probability of having any type or all types of innovations. This result is consistent with hypothesis 1B: design relates positively to all innovation types. The results are also consistent with Galindo-Rueda and Millot (2015, p. 30), who in product innovations, report the highest gains from integrated design and the second highest from central design. Integrated and central designs strongly support process innovations. These results are comparable to our results in columns (1') and (2').

[7] Shaping and branding could be driving innovation by having established a pioneer image for the firm. However, an innovative firm can also have good capabilities in these areas.

Although the coefficients of each design level diminish with product newness, they remain positive. Thus, this result supports hypothesis 2. However, supporting hypothesis 4, our data suggest that the more central the design is, the more likely the innovations. Moreover, integrated and central designs have higher marginal effects than shaping. Furthermore, for firm novelty, central design has an approximately 14 % larger coefficient than shaping, while for world novelty, the difference between shaping and central design is approximately 46 %. However, integrated design has slightly larger coefficients than central design has. Table 5 reports the full version, in which integrated and central design are disaggregated into specific types of design activities.

Using designers at the start of the innovation process (INITIATE) and a design policy (DES_POLICY) relate positively to firm novelty and any innovation type. Meanwhile, branding (branding) and having designers in multidisciplinary teams (TEAMS) relate statistically significantly and positively to all innovation measures. Interestingly, using design to find new business areas (NEW_BUSINESS) does not have a statistically significant influence on innovativeness but does have a statistically negative relation to new-to-the-firm products. Additionally, using creative personnel in management (CREATIVE) and design to solve problems (PROBSOL) both have statistically significant relationships with all other innovativeness measures considered except new-to-the-world product innovation, i.e., regression (3). Finally, the larger the firm is, the more it innovates.

While there are no gains to the propensity to innovate from designers defining new business areas, the opposite seems to be true for branding and shaping. While both have positive coefficients and are mostly statistically significant (but only by 10 % in their relationship with world novelty), the coefficient size decreases with the novelty level. Similar patterns are noticeable for the variable denoting teams and which captures the presence of designers in diverse teams. TEAMS is our closest measure of the designer's bridging role asserted in Roper et al. (2016), who report a positive relation with product innovations through an ordered probit estimation. The teams' variable relates with world novelty by 0.03 and with imitation by 0.01. Based on Norman and Verganti (2014), we expected a negative relation between design and innovativeness, and these results support hypothesis 2: design seems to have a decreasing relationship with the novelty of the innovation. However, even the coefficients of R&D per sales decrease with the novelty of the innovation.

As shown by Østergaard et al. (2011), diversity in education supports innovation. Having designers in the firm might also support the use of design thinking to improve prototyping, as design thinking requires a notably different approach than the one included in the traditional training for engineers. Thus, the positive and significant results for the presence of designers on teams and for using the designers' problem-solving techniques indicate benefits from design thinking, thereby supporting hypothesis 4.

Table 1.5. Innovation and design tasks, full version.

Probit VARIABLES	(1) FIRM NOVELTY	(2) MARKET NOVELTY	(3) WORLD NOVELTY	(4) ANY INNO	(5) INNO_ANY
SHAPING	0.198***	0.0898***	0.0246*	0.249***	0.0790***
	(0)	(0.000160)	(0.0546)	(0)	(3.86e-05)
DES_POLICY[1]	0.0886***	0.0147	-0.000181	0.113***	0.00964
	(0.00487)	(0.468)	(0.985)	(0.00402)	(0.438)
NEW_BUSINESS[1]	-0.0533**	-0.0160	0.0163	0.0289	-0.00377
	(0.0426)	(0.410)	(0.204)	(0.595)	(0.744)
INITIATE[1]	0.0630**	0.0229	0.0156	0.0863**	0.00355
	(0.0194)	(0.234)	(0.158)	(0.0110)	(0.754)
BRANDING	0.0562**	0.0465**	0.0201*	0.133***	0.0340**
	(0.0289)	(0.0204)	(0.0669)	(1.54e-05)	(0.0131)
TEAMS[1]	0.103***	0.0839***	0.0309**	0.0522	0.0333**
	(0.000357)	(0.000342)	(0.0163)	(0.155)	(0.0204)
PROBSOL[1]	0.120***	0.0638***	0.00738	0.192***	0.0559***
	(1.84e-06)	(0.000875)	(0.401)	(0)	(0.000137)
CREATICE[1]	0.112***	0.0838***	0.0120	0.263***	0.0855***
	(1.62e-09)	(3.06e-08)	(0.101)	(0)	(0)
SH_HI_EMP	0.163***	0.136***	0.0924***	0.145***	0.0605***
	(1.84e-05)	(1.46e-06)	(3.48e-10)	(0.00271)	(0.00122)
RD_SALES	0.327***	0.241***	0.0916***	0.394***	0.0867***
	(0)	(0)	(6.94e-11)	(1.45e-09)	(1.54e-06)
SMALL	-0.0578***	-0.0288***	-0.0111**	-0.151***	-0.0279***
	(1.16e-06)	(0.00185)	(0.0273)	(0)	(5.36e-06)
LARGE	0.143***	0.0965***	0.0357***	0.140***	0.0638***
	(5.04e-11)	(9.71e-08)	(0.000806)	(0)	(8.60e-07)
y2010	-0.00311	0.00774	0.00261	0.0341***	0.00400
	(0.771)	(0.349)	(0.560)	(0.00725)	(0.466)
Observations	7,183	7,183	7,183	7,183	7,183
Industry dummies	yes	yes	yes	yes	yes

Marginal effects and p-values are in parentheses.
[1] asked of only firms that report the degree of design integration as integrated or central.
*** p<0.01, ** p<0.05, * p<0.1.

The relationship of shaping with innovativeness is more significant and that of diverse teams is less significant than in Roper et al. (2016). They find no significance for the functional specialism of design, which is similar to shaping. However, their findings mean that the level of design does not relate to whether the new product is more novel in plants. Similarly, the smaller the coefficients for shaping are, the higher the novelty level, supporting hypothesis 2. However, by using an ordered probit model, Roper et al. (2016) report a positive and significant relation between novelty and designers with bridging roles. In addition, the continuous involvement of designers is significant at a 10 % significance level. Our closest measures are the integrated and central design positions, which relate positively and significantly to innovation probability.

Moreover, firms that use creative personnel in management seem to be quite innovative. These creativity specialists can come from consulting firms, which would explain their non-significance for world novelty but their positive and significant relationship with different levels of imitation. Czarnitzki and Thorwarth (2012) explain a similar situation with the use of external and internal designers. External designers offer fresh ideas to the company, while bringing a thread of involuntary knowledge spillover to rivals. Although this separation of designers is fruitful, our data are limited. However, the data cover the role and tasks of design in the innovation process. Another example is the PROBSOL variable, which has coefficients similar to those of creative personnel. These findings support hypothesis 4.

While innovation is by itself important, innovation is also a textbook example of how to create a competitive edge. The innovation share of sales is a business measure of innovation performance. Table 6 presents the estimation of equation 2, explaining innovation performance with three product novelty levels: the firm, the markets, and the world. The estimations include collaboration with universities and customers in the innovation process. As only firms with innovations answer these survey questions, the questions are excluded in previous tables. Following Roper et al. (2016), we only include in Tables 6 and 7 the firms that have innovations and use the Tobit model.

Table 1.6. Share of sales from innovations, design and user needs.

Tobit model	(6)	(7)	(8)
VARIABLES	FIRM NOVELTY SALES	MARKET NOVELTY SALES	WORLD NOVELTY SALES
SHAPING	-1.281	0.757	-3.756
	(0.782)	(0.882)	(0.535)
DES_POLICY	-4.811	-11.85**	-6.580
	(0.302)	(0.0202)	(0.251)
NEW_BUSINESS	10.37*	8.608	8.666
	(0.0603)	(0.151)	(0.200)
INITIATE	-7.913*	-10.82**	0.198
	(0.0826)	(0.0306)	(0.972)
BRANDING	6.979	11.12**	11.16**
	(0.101)	(0.0156)	(0.0328)
TEAMS	7.960*	12.07**	7.257
	(0.0756)	(0.0138)	(0.196)
PROBSOL	6.347	3.824	-2.733
	(0.106)	(0.373)	(0.581)
CREATIVE	-2.260	0.811	-1.900
	(0.480)	(0.816)	(0.646)
SH_HI_EMP	-10.69	15.44	36.33***
	(0.227)	(0.109)	(0.000735)
RD_SALES	57.92***	61.94***	59.21***
	(0)	(0)	(1.85e-10)
CUS	-4.105	-3.140	-2.863
	(0.190)	(0.361)	(0.475)
CUN	5.586	10.96***	14.96***
	(0.117)	(0.00463)	(0.000717)
SMALL	4.414	4.761	1.493
	(0.141)	(0.150)	(0.697)
LARGE	-1.329	-1.276	-4.720
	(0.724)	(0.755)	(0.340)
y2010	-6.986***	-1.815	1.723
	(0.00408)	(0.496)	(0.581)
Constant	39.25***	-1.985	-87.98***
	(3.92e-06)	(0.832)	(5.72e-10)
Observations	1,966	1,966	1,966
Industry dummies	yes	yes	yes

Robust p-values are in parentheses; *** p<0.01, ** p<0.05, and * p<0.1.

Design seems to relate less to innovation performance than to the propensity to innovate. Table 7 demonstrates that mostly integrated design supports innovation performance. Table 6 reports no positive and statistical significance for the PROBSOL, SHAPING or CREATIVE personnel variables. Even INITIATE has a negative and significant relation with imitation (at 10 % significance) and market novelty. This means that at least in our sample, the share of sales from innovations is not related to whether the designer is involved from the start of the innovation process or to the use of design problem-solving tools. Additionally, a company-wide design policy (DES_POLICY) has a negative and significant relation with market novelty sales. While traditional design, shaping, does not drive gains in the sales of the innovation, branding seems to support the share of sales for market and world novelty. However, having designers in different teams might support sales from innovation. As shown in column (7), the TEAMS variable is positive and significant for market novelty sales and weakly significant for firm novelty sales.

Thus, we cannot accept hypothesis 3: only some design characteristics support innovation performance. Utilizing the concept of design scale, we can discuss a J-shape relationship, with shaping being non-significant (no effect); integrated design being potentially creativity limiting, thus relating negatively to innovation sales. Branding and diverse teams relate positively to innovation performance. This is partially consistent with hypothesis 4.

However, the importance of technical knowledge is clearly the driving factor in innovation sales. The R&D per sales is significant for innovation performance, and the share of highly educated employees is significant for sales from world novelties. The share of highly educated employees is important in creating innovations and in selling products with world novelty. However, the collaboration with universities supports sales for products with both world and market novelty. While collaboration with universities is one of the few important factors for the sales of products with world novelty, the collaboration with customers in innovation seems not to relate to innovative sales.

For a better overall picture for hypotheses 3 and 4, table 7 analyzes three design positions formed by the integration of design in the product development process. As in Galindo-Rueda and Millot (2015, p. 31), integrated design is found to be the most beneficial. As design thinking is embodied in integrated and central design roles, this result favors hypothesis 4.

Table 1.7. Innovation performance explained by design position.

Tobit model	(6')	(7')	(8')
VARIABLES	FIRM NOVELTY SALES	MARKET NOVELTY SALES	WORLD NOVELTY SALES
SHAPING	-0.766	2.011	-2.981
	(0.870)	(0.696)	(0.628)
INTEGRATED	8.357***	9.741***	10.14***
	(0.00617)	(0.00341)	(0.00854)
CENTRAL	7.958**	4.582	7.549
	(0.0292)	(0.250)	(0.101)
SH_HI_EMP	-9.699	16.24*	37.06***
	(0.273)	(0.0918)	(0.000594)
RD_SALES	59.37***	63.86***	61.58***
	(0)	(0)	(0)
CUS	-4.119	-3.050	-2.672
	(0.188)	(0.375)	(0.505)
CUN	5.897*	11.27***	14.88***
	(0.0982)	(0.00362)	(0.000786)
SMALL	4.606	4.596	1.330
	(0.124)	(0.164)	(0.729)
LARGE	-0.435	0.0561	-3.588
	(0.908)	(0.989)	(0.467)
y2010	-7.569***	-2.573	1.116
	(0.00190)	(0.336)	(0.721)
Constant	40.61***	0.125	-86.38***
	(1.95e-06)	(0.989)	(9.28e-10)
Observations	1,966	1,966	1,966
Industry dummies	yes	yes	yes

The results are partly in line with Marsili and Salter (2006), who use the Dutch CIS to study innovation in manufacturing sectors. They find that firms using design "tend to be more likely to innovate than firms that spend little on design" (Marsili & Salter, 2006, p. 531) and that "the combination of investments in design with R&D – – stimulate innovation" (Marsili & Salter, 2006, p. 531). The results for diversity are also in line with Østergaard et al. (2011) and Filippetti (2011), who suggest that diverse competences support innovation and innovation performance.

Conclusions

Through semi structured interviews and a quantitative analyses of the Danish Community Innovation Survey, this article has examined the use of design, design thinking and the knowledge of user needs and how it relates to innovation and innovation performance. Overall, the firms engaging in design are likely to innovate. The type of design activity influences this relation, although generally, a wide range of design-related activities are associated with innovation, including both novel product innovation and broad-based innovations. However, the results are somewhat different for innovation performance, where only selected types of design activities relate positively to the share of innovative sales.

Firms performing only shaping (traditional design) are more innovative than are firms without any design activities; further, a broader use of design brings more gains than those derived by using shaping only. This is particularly the case for product innovations. Meanwhile, having designers on different teams seems to support innovation at all novelty levels. However, it seems to support only the sales of market novelties. Additionally, the innovation likelihood is increased by branding and management consulting by creative personnel that use the designers' problem-solving methods. Firm management consulting creative personnel seems to relate positively to both new-to-the-firm and new-to-the-market products and to the presence of all or any innovation type except perhaps new-to-the-world products. This finding is in line with Czarnitzki and Thorwarth (2012), who explain the lower use of external designers in the most novel products as the result of a fear of leaks. However, for company innovation sales, they highlight the benefits from an outside view.

For innovation performance, our main finding is the significance of the support provided by integrated design to sales at all novelty levels. The presence of designers in cross-functional teams is positively and significantly related to sales based on firm and market novelty. However, a selection of design activities relates negatively to innovation performance at some novelty levels. Indeed, innovation is a complex nonlinear process that requires multiple competences. Some examples are highly educated employees and the access to external knowledge through collaboration with universities.

Interestingly, more parts of the design scale relate positively to innovativeness than to innovation performance. Future research could include the distance to other design-oriented firms to test how design knowledge could spill over from other firms in the region and test how design maturity affects the gains from different segments of the design scale: shaping, integrated design and central design.

References

Battistella, C., Biotto, G., & De Toni, A. (2012). From design driven innovation to meaning strategy. *50*(4), 718-743.

Berkowitz, M. (1987). Product shape as a design innovation strategy. *Journal of Product Innovation Management, 4*(4), 274-283.

Brown, T. (2008). Design Thinking. *Harvard Business Review, 6*.

Chiva, R., & Alegre, J. (2009). Investment in design and firm performance: The mediating role of design management. *26*(4), 424-440.

Creusen, M., & Schoormans, J. (2005). The different roles of product appearance in consumer choice. *Journal of Product Innovation Management, 22*(1), 63-81.

Czarnitzki, D., & Thorwarth, S. (2012). The Contribution of In-house and External Design Activities to Product Market Performance *Journal of Product Innovation Management, 29*(5), 878-895. doi:10.1111/j.1540-5885.2012.00935.x

D'Ippolito, B. (2014). The importance of design for firms' competitiveness: a review of the literature. *Technovation*, forhcoming.

Filippetti, A. (2011). Innovation modes and design as a source of innovation: a firm-level analysis. *European Journal of Innovation Management, 14*(1), 5-26.

Galindo-Rueda, F., & Millot, V. (2015). Measuring design and its role in innovation.

Gemsera, G., & Leenders, M. (2001). How integrating industrial design in the product development process impacts on company performance. *The Journal of product innovation management, 18*(1). doi:10.1111/1540-5885.1810028

Gorb, P., & Dumas, A. (1987). Silent design. *Design studies, 8*(3), 150-156.

Kazmierczak, E. (2003). Design as meaning making: from making things to the design of thinking. *Design issues, 19*(2), 45-59.

Marsili, O., & Salter, A. (2006). The Dark Matter of Innovation: Design and Innovative Performance in Dutch Manufacturing1. *Technology Analysis and Strategic Management, 18*(5), 515-534.

Mortati, M. (2015). A Framework for Design Innovation: Present and Future Discussions. *Design issues, 31*(4), 4-16.

Na, J. H., Choi, Y., & Harrison, D. (2017). The design innovation spectrum: An overview of design influences on innovation for manufacturing companies. *International Journal of Design, 11*(2).

Norman, D. A., & Verganti, R. (2014). Incremental and radical innovation: Design research vs. technology and meaning change. *Design issues, 30*(1), 78-96.

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

Roper, S., Micheli, P., Love, J. H., & Vahter, P. (2016). The roles and effectiveness of design in new product development: A study of Irish manufacturers. *Research Policy, 45*(1), 319-329.

Roy, R., & Riedel, J. (1997). Design and innovation in successful product competition. *17*(10), 537-594.

Sanderson, S., & Uzumeri, M. J. R. p. (1995). Managing product families: The case of the Sony Walkman. *24*(5), 761-782.

Santamaría, L., Nieto, M. J., & Barge-Gil, A. J. R. P. (2009). Beyond formal R&D: Taking advantage of other sources of innovation in low-and medium-technology industries. *38*(3), 507-517.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica: Journal of the Econometric Society*, 24-36.

Utterback, J., Vedin, B.-A., Alvarez, E., Ekman, S., Walsh Sanderson, S., Tether, B., & Verganti, R. J. D.-i. i. (2006). Design-inspired innovation and the design discourse. 154-186.

Walsh, V. (1996). Design, innovation and the boundaries of the firm. *Research Policy, 25*(4), 509-529.

Østergaard, C., Timmermans, B., & Kristinsson, K. (2011). Does a different view create something new? The effect of employee diversity on innovation. *Research Policy, 40*(3), 500-509.

Appendix

Table A1.1. The correlations of design variables for firms with a central or leading design role

	DES_POLICY	NEW_BUSINESS	INITIATE	BRANDING	TEAMS	PROBSOL	CREATIVE
DES_POLICY	1.00						
NEW_BUSINESS	0.34	1.00					
INITIATE	0.25	0.33	1.00				
BRANDING	0.48	0.21	0.18	1.00			
TEAMS	0.20	0.31	0.46	0.16	1.00		
PROBSOL	0.19	0.26	0.29	0.06	0.30	1.00	
CREATIVE	0.19	0.20	0.13	0.16	0.15	0.08	1.00

Innovations from capabilities[8]

Carita Eklund

CFA, Aarhus University, Bartholins Allé 7, 8000 Aarhus, Denmark

Economics and business law, University of Vaasa, Wolffintie 34, 65200 Vaasa, Finland

Abstract

Innovation has many overlapping definitions and interest groups; innovation economists sometimes use intangible assets as an indicator when valuing firm- or industry-level innovativeness. The contribution of this essay is the linking of innovation capacity to intangibles, bringing the two lines of the literature together and thus checking the validity of intangibles as an innovation capability measure. I demonstrate the link by using register data for Danish firms (IDA) and the Community Innovation Survey (CIS) 2008–2013.

Keywords: intangible asset, innovation capability, innovation indicator, micro level data

[8] This work was supported by the Finnish Cultural Foundation, South Ostrobothnia Regional fund, Niilo Helander Foundation.

Introduction

Intangible assets are used as an alternative innovation indicator and a method for approximating innovation capability. Innovation is a strategy for surviving and overcoming global competition challenges, a strategy that is sometimes called 'innovate your way out.' In contrast to the red ocean view, in which competition is severe and blood turns the ocean red, this perspective is related to the blue ocean view of the markets, in which markets are seen as full of undiscovered possibilities. For small- and high-price-level markets, such as Denmark, doing things smarter is crucial for competitiveness. Based on Danish data, this essay offers a detailed comparison of intangible assets to 'broadly defined' innovation [9] capability. A related paper by Harris and Moffat (2013) discusses the link between intangible assets (IA) and absorptive capacity, i.e., the company's ability to use external knowledge (Cohen & Levinthal, 1990), and this essay elaborates intangibles by considering different perspectives on the capability to innovate. Following the authors of these existing studies, this article adopts the assumption that the knowledge in firms, i.e., the firms' knowledge base, is within and between employees. This knowledge includes a form of social capital: knowing who knows what. Some knowledge is also firm specific and thus does not leave with the employee if s/he changes employers. However, as knowledge often "resides in employees" and knowledge transactions cost less within the firm than they do outside the firm (Harris & Moffat, 2013, p. 355), I argue that an employee-specific perspective on knowledge is a fruitful tool for approaching innovation capability (for more, see Bloch, Eklund, Huovari, & Piekkola, 2019). Thus, I estimate IA by using the employees' education and occupation.

IA have gained a place on the political stage and are increasingly being used in GDP calculations. de Rassenfosse (2017) notes that although intangibles are a feasible sense-making tool, the academic discussion lacks confirmation of how well intangibles measure exactly what they are supposed to measure. He focuses on a macro level intangible measure presented in Corrado, Hulten, and Sichel (2005), while I concentrate on a firm-level measure by Görzig, Piekkola, and Riley (2010) that uses the occupations of employees and their education. These intangibles have not been previously examined. The key goal of this essay is to examine how well intangibles measure what they are supposed to measure, namely, innovation capability. In other words, does the presence of intangibles in one period predict the probability of innovation in the following periods? To test this, I combine register data and the Community Innovation Survey (CIS) data and explain the

---

[9] Innovation not only applies to product development but also can happen in marketing or management.

innovations reported in the CIS by using intangibles calculated from the Danish register data.

The essay is structured as follows. Section 2 explains how innovations and innovation capabilities can be defined and their relation to IA. Section 3 explains our measurement strategy, while section 4 statistically compares intangible measures to the forms of innovativeness measured in the Community Innovation Survey (CIS). Section 5 concludes the paper.

From innovation capabilities to IA and innovation output

As discussed in Prahalad and Hamel (1990), innovation capability can be seen as one core competence representing the most important abilities of the firm. Like other core competences, innovation capability does not diminish when practiced, though “knowledge fades if it is not used” and learning happens collectively in the firm (Prahalad & Hamel, 1990, p. 82). Further, innovation capability is related to dynamic capabilities, as innovation can lead to “new forms of competitive advantage” and as an innovation capability can renew itself (Teece et al., 1997: 515). In what follows, we elaborate on the definitions and on how IA can serve as indicators of innovation capability.

Innovation capability has no single agreed-upon definition. Zawislak, Cherubini Alves, Tello-Gamarra, Barbieux, and Reichert (2012, pp. 14-15) define it as “an overall capability encompassing the ability to absorb, to adapt and to transform a given technology into specific management, operations and transaction routines that can lead one firm to Schumpeterian profits, i.e., innovation.” They construct innovation capabilities from four blocks leading to a successful product launch. First, the firm needs a technological development capability to develop a novel product. Second, the firm needs an operational capability to initiate the novel product’s production. Next, it needs a transaction capability to introduce the products into the markets. Finally, these capabilities need a coordination and management capability to succeed. (Zawislak et al., 2012)

A new type of product requires knowledge from different fields, ranging from technology and design to knowledge of the customers’ behavioral patterns. These aspects can be labeled differently; one such label is the conceptualization of IA[10] . IA can be divided into several subcategories. Corrado, Hulten, and Sichel (2009) describe the categories as innovation, human, branding and organizational competences. The first category consists of R&D, design and license spending and

[10] Another term is intangible capital; for clarity and linkage to the financial literature, this essay uses intangible assets throughout this article.

patents. Human capital consists of training expenditures and the share of high-skill labor. Branding capital is formed by marketing expenditures and trademark stocks. Organizational capital manages the innovation processes. However, these separate types of capital are highly correlated with each other, complicating the use of categories in the analysis. Additionally, Crass and Peters (2014) find that innovation capital and human capital are complements with respect to productivity. In other words, innovation capital increases productivity only when combined with sufficient levels of human capital—a finding similar to the innovation capability definition of Zawislak et al. (2012).

Another intangible asset composition is provided by Van Ark (2004), who divides it into organizational capital, knowledge capital, ICT capital and human capital. Here, for example, human capital includes formal training, training in the company and experience. Knowledge capital includes, among other things, research and development, patents, brands and technological innovation.

Following Ilmakunnas and Piekkola (2014) and Görzig et al. (2010), I define intangibles as including three-types: broad RD (research and development expenditure assets), ICT (information communication technology assets) and OC (organizational capital assets). The latter combines marketing and management and thus includes all organization of a firm’s relations from employees to customers. Broad RD denotes a more extensive measure of technical development than that denoted by the formal use of the term R&D—section 4 discusses these differences in terms of common investment and gains for product innovation.

The concept of intangibles has been criticized because of the unaccountability of knowledge. However, Brynjolfsson and Yang (1999) justify the existence of IA through the puzzle of stock prices. Brynjolfsson and Yang (1999, pp. 7-8) find that investments in computers (tangible assets) converted to ten times their value in the listed stock price[11] and claim that this follows from an omitted variable problem from IA. Recent research (Carter Bloch, 2008; Piekkola, 2016; Rahko, 2014) explains market valuation by using Tobin’s Q with intangible or knowledge assets. Moreover, Hall (2010) reviews the literature concerning the financing of innovative firms, confirming that due to uncertainty, external finance for intangibles is more expensive than that for tangibles. Thus, we can say that the role of intangibles is recognized in finance.

Furthermore, the management literature recognizes the importance of intangibles. Sánchez, Chaminade, and Olea (2000) highlight that ‘intangibles’ are the only

[11] Brynjolfsson and Yang's (1999) sample covered 820 firms during 8 years.

resource that fulfills Barney's (1991) criteria[12] for competitive advantage. Sánchez et al. (2000) define intangibles very broadly: from intellectual capital to absorptive capability, including human capital. They divide intangibles into three types depending on where the knowledge is maintained at the end of the day: in the employee, the company or the company's relationships with stakeholders. The authors discuss indicators in detail: indicators should be "clear, feasible and useful for the firm," and they can be firm-specific, industry-specific or general (Sánchez et al., 2000, pp. 320-321). From an econometric point of view, firm-specific indicators are infeasible and hard to detect, but unlike Sánchez et al. (2000), the IA literature focuses on how efforts in management, marketing, research and ICT in general contribute to productivity, new products or production.

The production of innovation output is a complex process. Kleinknecht and Reijnen (1993) divided innovation by the level of complexity (high, e.g., rockets; medium; and low, e.g., an improved part to an existing product) and by type. They defined type as a degree of improvement and independence from other product and process innovations. Bloch and López-Bassols (2009) utilize four innovation types: product, process, marketing and organizational innovation. This broader measure of innovation requires a different measurement than that based on patents—one solution is the Community Innovation Survey, CIS, which is used in Bloch and López-Bassols (2009). An innovative firm is defined as one having a novel product in that year that is either new to the market or to the firm (i.e., either market or firm novelty). Prahalad and Hamel (1990) justify the need for a broader view of innovativeness than that provided by patents by pointing out that a new component or product is useless if it does not make its way to the users. A patent itself does not offer a return but needs to be developed into a product, and the product or functionality needs to be communicated to potential customers. Further, Teece (1986) highlights that product innovativeness needs to be combined with other business competences for firm success and survival. Mairesse and Mohnen (2004) suggest CIS as a useful innovation measurement.

The literature discussing productivity gains from innovation is broad. Using the CDM (Crépon, Duguet, & Mairessec, 1998) model with the CIS for four European countries, Griffith, Huergo, Mairesse, and Peters (2006) compare the role of innovations to productivity. A recent article by Hall and Sena (2017) utilizes the CDM model to analyze the UK. Additionally, Hall, Lotti, and Mairesse (2009) discuss innovation in Italy by using unbalanced panel data and first explain innovations and then productivity. This essay contributes by suggesting the causal

[12] Barney (1991, pp. 106-112) defines a *sustainable competitive advantage* as valuable (efficiency enhancing), rare (not common), imperfectly imitable (advantage not threatened by competitors), and non-substitutable (strategic) resources.

indicators supporting product and process innovations. The estimation is close to the second stage of Hall et al. (2009, p. 47): innovation production functions. With intangibles, the first stage is covered by intangible investments. With intangibles, one could directly estimate productivity gains; therefore, the focus of this essay is on testing how intangibles support innovations, considering products and process innovations with different levels of novelty.

Intangibles link to the presented innovation capabilities and innovation outputs as follows. Activities aiming at product and process innovations can be described as needing technological development capability. As IA, these would be placed either within research and development (RD) or ICT capital. Management, on the other hand, includes all operational and management abilities required to coordinate the whole process and bring the product to the markets. Additionally, marketing investments are included in this broad concept of management. Thus, we can expect that intangibles would have a similar effect on the firm's production as would other innovativeness measures. Section four includes a simple logit probability estimation that explains innovation outputs: product and process innovations. Because the IA measure used is based on Danish register data covering all companies in Denmark, there is no need to use the Heckman selection model (Heckman, 1977).

Measurement of intangible assets

Several sources are used to approximate intangible assets (IA). Some studies use balance sheets (Marrocu, Paci, & Pontis, 2012) and patent stocks, focusing on formal R&D (Griliches, 1979), while some use innovation surveys (Crass & Peters, 2014) and others use national statistics or register data (Görzig et al., 2010; Ilmakunnas & Piekkola, 2014; Piekkola, 2011, 2016). Görzig et al. (2010) approximate IA by using the employees' occupation. This choice is motivated by the source of competence: the underlying assumption is that the knowledge is embodied in the employee (Harris & Moffat, 2013) and that an occupation describes the actual work of that employee. Another approach is using purchased intermediate inputs (such as expenditures on consultants or IT programs) and estimating the work needed to employ this knowledge. The intermediate approximation would assign a lower value for IA to firms producing all or most intangibles by themselves. Similarly, the chosen occupational construction of intangible investments would ignore firms with zero own production of intangibles.

Following Görzig et al. (2010), this essay approximates the investments in intangibles from linked employer–employee data from IA-type labor costs.

Following Piekkola (2016), I assume that a certain share of the employees' working time contributes to future periods and thus can be characterized as an investment, i.e., a total of 40 % of OC, 70 % of broad RD and 50 % of ICT work. The last two numbers are from Görzig et al. (2010) who consulted Corrado et al. (2005). Görzig et al. (2010, p. 7) argue that only a small fraction of ICT investments are productive and that accounting tries not to overestimate the value of ICT investments, as the law obligates firms not to overestimate the capital stock and expenditures can be deducted directly from profits to limit taxation. The employment share of OC originates with Piekkola (2016), who doubled the share used in Görzig et al. (2010); the latter approximated OC with the weighted average applicable in the EU, which was calculated using the share of marketing and organizational workers in six countries.

The IA-type occupations are available from the ISCO2008 occupational coding. For example, "Managing Directors and Chief Executives" (code 112) is allocated to organizational occupations. OC occupations are the occupations of management, administration, teaching, marketing, and business professionals (including highly educated social scientists and businessmen); in general, they are intangible-producing occupations. Broad RD occupations range from hard sciences (natural sciences and engineering) to health professionals and otherwise general organizational positions but with an educational background that is not in the social sciences. The last category, ICT occupations, consists of ICT management, telecommunication engineering and ICT professional positions. The yearly earnings are used instead of hours because yearly earnings include bonuses, and the use of hours is unreliable in accounting for the unpaid overtime hours of managers.

Second, we add the expenses to intermediate goods and tangible capital by using a "factor multiplier" constructed from the weighted EU27 mean (Piekkola, 2016) [13]. The intuitive reason behind this approach originates with Görzig et al. (2010), who explain that research has shown that investments in tangible and intangible capital consume some share of own production that to be properly utilized later. Multiplying the factor multipliers and employment shares, Piekkola (2016) reports combined multipliers of 70 % for OC and ICT and 110 % for broad RD investments. When forming the asset stock from yearly investments, we set the depreciation rates to 20 % for OC, 15 % for broad RD and 33 % for ICT. Corrado et al. (2009) use the same depreciation rate for ICT and a slightly higher rate for broad RD, namely, 20 %. For firm-specific knowledge, they use 40 %, which produced

[13] The factor multipliers for wage expenses are 1.76 for OA, 1.55 for RD and 1.48 for ICT (Piekkola, 2016, p. 34)

negative stock in the Finnish part of the INNODRIVE project. Therefore, the 20 % depreciation rate seems more reliable in our approximation.

Thus, for each year, IA equal the investments plus previous intangibles less depreciation. Equation 1 presents this in a mathematical form. N denotes investment; R denotes stock. The subscript i denotes firms, subscript t denotes years, and t=0 upon the first appearance of the firm in our data. Superscript IC captures RD, ICT or OC. However, the tricky part is the approximation of the first year's capital stock.

(1) $R_{i,t}^{IC} = N_{i,t}^{IC} + (1 - \delta^{IC})R_{i,t-1}^{IC}$
(2) $R_{i,t=0}^{IC} = N_{i,t=0}^{IC} /(\delta^{IC} + g)$

The initial stock is obtained by the geometric sum formula (equation 2). The assumptions are that, on average, investments were stable, and we can thus write the current stock in terms of average growth in investment and depreciation. We use the three-year average of intangible investments. The growth rate of intellectual capital, g, is assumed to be 2 %, and the depreciation rate is δ. Another strategy is to set the stock value to zero in a period far before the start of the sample. Corrado et al. (2009), for computer-related resources, set it to zero 15 years before the sample period; for scientific R&D and brand equity, they set it to zero 45 years before, and for firm-specific resources, they set it to zero 27 years before.

Using the concept of intangibles, the data used combines intangibles from the Danish national register (IDA) and the Community Innovation Survey (CIS). In the survey, firms are asked if they have introduced a new product in the two years prior to the survey. For example, if the firm answers the survey in 2010, it is asked about launching a new product between 2008 and 2010. The empirical strategy consists of first simply comparing this innovation input data with the CIS data and then explaining product and process innovations with IA. The analyses use data from CIS 2008–2013 and register data 2007–2013.

Results

This section presents empirical support for using intangible assets, IA, as an innovation capability measure or simply to predict innovations. The following subsections discuss the relation between product or process innovation and IA. Additionally, this section discusses the relation of formal R&D from CIS to IA and product innovations. Subsection 4.1 reports summary statistics and correlations, and section 4.2 reports the marginal effects from the logit estimation that explains different product and process innovations.

Descriptive statistics

Table 1 reports the shares of firms having a product or process innovation. Newness is divided into two categories: new to the firm (imitation) and new to the markets. Additionally, table 1 reports the share of firms having formal R&D expenditures (R&D).

The share of firms reporting a change in marketing is reported under the marketing variable, and organizational change is reported under the organizational variable. This organizational variable includes, for example, information about new alliances outside of the firm and even the development of internal and external communication. Later in this work, this variable is referred to as organizational innovation. The commonness of change in marketing has fluctuated but has remained quite stable: Typically, a quarter of firms experience changes in marketing, and one-third of Danish firms experience organizational changes. Last, the sales of new products as a percentage of existing products range from 30 % to 44 %. Thus, new products are important to sales for Danish firms in the survey.

Table 2.1. Share of innovative firms in Danish CIS 2008–2013

year	firm novelty	market novelty	R&D	marketing	organizing	Share of sales for new or improved products over existing product sales	obs
2008	20 %	14 %	5.0 %	23 %	27 %	30 %	4257
2009	18 %	11 %	5.0 %	23 %	27 %	38 %	4344
2010	21 %	14 %	5.2 %	25 %	30 %	31 %	4135
2011	20 %	12 %	4.6 %	24 %	27 %	43 %	4272
2012	22 %	13 %	5.4 %	27 %	28 %	42 %	4545
2013	21 %	12 %	5.0 %	29 %	30 %	44 %	4545

The data presented at table 1 suggest no change in formal R&D spending, a 3 % increase in the commonness of the organizational innovation. In the last two years, we observe that marketing changes have been as common as organizing changes in the sample. Furthermore, the share of new products over old products has been growing during the observation period.

Table 2 presents innovation activity divided by the shares of firms with a value for intangibles less than or greater than the industry mean. Trade variables show import and export activity, and the results are reported yearly from 2008 to 2013.

Based on the number of observations, it is clear that the firms with a share of intangibles larger than the mean (intangible-intensive firms) are much more likely to innovate. For intangible-poor firms, the share of new-to-the-firm products fluctuates between 21 % and 22 %. However, intangibles are possessed by relatively few firms. For example, in 2010, 695 firms had a value for intangibles above the mean, and in 2108, had a value less than the mean. Thus, IA seem to be concentrated in firms on the right tail. Additionally, the likelihood of having new products is much higher for intangible-intensive firms than for the others, which may also follow from the firms being large in size. The second column shows the share of firms with ICT assets, as ICT assets are the least typical type of intangibles in Denmark. However, for intangible-intensive firms, it is quite common to have ICT: over 90 % of the firms have ICT capabilities. For intangible-poor firms, ICT is even less uncommon than activity in foreign markets (imports or exports). Thus, both product innovations and ICT capabilities are more common for intangible-intensive firms than for other firms.

Table 2.2. Firms separated by intangible intensity.

Year	firm novelty	market novelty	importer	exporter	ICTasset	Obs
Intangibles valued at above the industry mean						
2008	44 %	36 %	54 %	50 %	91 %	664
2009	36 %	27 %	54 %	52 %	90 %	692
2010	35 %	27 %	58 %	55 %	92 %	695
2011	35 %	26 %	59 %	55 %	95 %	686
2012	35 %	23 %	57 %	54 %	97 %	729
2013	36 %	26 %	56 %	54 %	95 %	705
Intangibles valued at below the industry mean						
2008	26 %	19 %	40 %	37 %	25 %	2088
2009	22 %	14 %	37 %	34 %	26 %	2225
2010	22 %	14 %	45 %	41 %	25 %	2108
2011	21 %	13 %	45 %	40 %	27 %	2184
2012	22 %	13 %	45 %	42 %	28 %	2309
2013	21 %	12 %	45 %	42 %	27 %	2178

Table 3 separates firms by product innovativeness. The sample is divided into non-product innovators and product innovators that have launched a product that is new at least to the firm. The table reports sales in Danish kroner, the value added per IA, the value added per capital and the share of firms with marketing and organizational change. Additionally, product innovators report the share of products that are new to others.

Generally, product innovators have more sales than firms without new product(s). These innovators constitute 20–30 % of the representative sample. Product innovators report more process innovations (marketing & organizational innovation) than non-product innovators. Additionally, product innovators have more value added per intangible (1.4-3.9) than non-product innovators (1.3-1.7). However, product innovators are less physical capital intensive (0.3-0.6) than non-product innovators (0.6-1.2).

Table 2.3. Firms separated by product innovation.

Year	Sales(1)	VA per intangibles	VA per capital	Marketing innovation(2)*	Organizational innovation(2)*	New to others*	Obs
Product-Innovators(2)							
2008	17.99	3.91	0.30	0.61	0.63	0.24	843
2009	15.08	1.67	0.58	0.60	0.58	0.20	745
2010	15.23	1.60	0.48	0.58	0.58	0.14	708
2011	14.5	1.68	0.34	0.57	0.56	0.15	700
2012	16.96	1.51	0.47	0.61	0.54	0.12	773
2013	15.6	1.40	0.33	0.70	0.64	0.14	721
Non-Product-innovators(2)							
2008	7.17	1.66	1.24	0.12	0.19		1912
2009	6.73	1.47	0.93	0.15	0.21		2176
2010	5.91	1.42	0.63	0.17	0.24		2108
2011	6.2	1.19	0.57	0.15	0.21		2184
2012	6.55	1.33	0.67	0.16	0.20		2276
2013	6.96	1.29	0.59	0.14	0.20		2174

(1) 10,000,000DKK; value added (VA) corrected by intangible investments; data: IDA and innovativeness. (2) Data obtained from CIS.
* Share of firms.

Table 4 presents the correlations of intangibles with some firm characteristics (value added, sales, tangible capital) and product innovations. The last line shows that all intangibles correlate by 11 %-14 % with the firm having a new product. The correlation is the highest when all intangibles are considered together. OC and broad RD show very similar correlations with value added by 0.41-0.42, while OC has a stronger correlation with sales (0.32) than broad RD (0.21) does.

Tangible capital has a much lower correlation with any of the other variables. Broad RD assets correlate with capital by 0.05, which is the highest correlation among intangible types, and ICT has the lowest correlation with capital by 0.03. This finding is an interesting comparison to table 3, where VA per capital was higher for non-product innovators than it was for product innovators.

Table 2.4. Correlation table for new product innovations.

	VA	sales	intangibles	RD asset	OC asset	ICT asset	Capital
VA	1						
Sales	0.61	1					
Intangibles	0.46	0.25	1				
RD asset	0.42	0.21	0.98	1			
OC asset	0.41	0.32	0.56	0.39	1		
ICT asset	0.21	0.13	0.41	0.34	0.38	1	
Capital	0.07	0.07	0.05	0.05	0.04	0.03	1
New product	0.12	0.12	0.14	0.13	0.12	0.11	0.05

Table 5 presents the missing information: the correlations between intangibles and process innovations. Values for the variables organizing, marketing, and patents (i.e., the firm has filed a patent) are from the Danish Community Innovation Survey, CIS. Organizing is a binary variable for organizational innovation and is assigned the value one if the firm has implemented organizational changes or new methods to organize the work place or if it has negotiated new partnerships. Similarly, for marketing, a firm has marketing innovations if it has established new sales channels, new media or product promotion, a new pricing strategy or a new package. We see that ICT assets correlate with organizing and marketing (innovations) by 14 % and 12 %, respectively. Organizing and marketing (innovations) correlate with patents by 15 % and 14 %, respectively. Meanwhile, broad research and development assets (RD) and (filed) patents have a slightly higher correlation, 17 %, but RD's correlation with organizing and marketing is 12 % and 8 %, respectively. The intercorrelations of these capabilities are also notable: Organizing's correlation with marketing is 48 %, while OC's correlation with ICT is 46 %.

Table 2.5. The correlation of intangible assets with CIS organizational and marketing innovations and patents.

	ICT (1)	OC(1)	RD (1)	organizing(2)	marketing(2)	patents(2)
ICT	1					
OC	0.46	1				
RD	0.33	0.27	1			
organizing	0.14	0.15	0.12	1		
marketing	0.12	0.13	0.08	0.48	1	
patents	0.11	0.08	0.17	0.15	0.14	1

(1) IDA, register data and (2) CIS

The positive correlations may seem small, although ICT correlates moderately with OC and broad research and development assets (RD). However, OC includes marketing efforts, and ICT can be used, for example, in new pricing strategies and monitoring. Additionally, broad RD assets represent an investment in absorptive capability, e.g., being able to follow the frontier in the company's field.

Table 6 reports the correlation between formal R&D and the broader measure of RD used in the IA literature. Formal R&D in the table originates in CIS and consists of R&D expenditures. Formal R&D correlates with broad RD investment by 37 % and with broad RD assets by 39 %. Formal R&D also correlates moderately with our measure of ICT assets (31 %). However, a low correlation with OC assets implies that R&D weakly includes spending on organizing and marketing investments in companies. Thus, research using intangible asset measures covers a much broader range of innovativeness than that covered in traditional R&D spending.

Table 2.6. How formal R&D correlates with intangible assets.

	Formal R&D	RD invest	OC invest	ICT invest	RD asset	ICT asset	OC asset
Formal R&D	1.00						
RD invest	0.37	1.00					
OC invest	0.08	0.18	1.00				
ICT invest	0.19	0.28	0.35	1.00			
RD asset	0.39	0.96	0.19	0.27	1.00		
ICT asset	0.31	0.33	0.31	0.74	0.30	1.00	
OC asset	0.13	0.25	0.93	0.39	0.27	0.38	1.00

Logit estimates of innovations

The main results are divided into the product innovations reported in table 7 and the process innovations reported in table 8. Both use IA as explanatory variables and the logarithm of the number of employees to account for the size of the firm. Furthermore, product innovations use a measure of human capital, the share of highly educated employees (master's degree or higher), as an additional control variable, as a greater value in this factor might make the firm more innovative. Process innovations instead use formal R&D expenses, capturing high levels of product development that might also make the firm more eager to reshape its own production processes than a firm that is not trying to generate a scientific breakthrough. The Heckman (1977) selection model is not used because the broadly measured IA that are used to explain innovations originate with the survey. The main aim is to explain the realized product and process innovations with the innovation capability measure discussed in detail by Görzig et al. (2010).

Equation 1 presents the estimation explaining the probability of innovation $P(inno_n)$, where the subscript n represents the novelty level of the product, i.e., new to the firm, the market or the world. All explanatory variables are lagged by one period. The first three variables are IA and R&Dexp, which is the formal R&D expenditure. The number of employees is captured by emp, as in Mairesse and Mohnen (2004), and the control variables X_t include year and industry dummies.

(1) $$P(inno_{n,t+1}) = \beta_1 \ln(RD_t) + \beta_2 \ln(R\&Dexp_t) + \beta_3 \ln(ICT_t) + \beta_4 \ln(OC_t) + \beta_5 \ln(emp) + X_t$$

Table 2.7. Product innovation explained by intangible assets in logit analyses; marginal effects.

Marginal effects VARIABLES	(1) Firm novelty [1]	(2) Market novelty[1]	(3) World novelty[1]
RD[2] [3]	0.00520***	0.00493***	0.00376***
	(0.000955)	(0.000912)	(0.000789)
R&Dexp[2] [3]	0.0506***	0.0408***	0.0322***
	(0.00349)	(0.00281)	(0.00202)
ICT[2] [3]	0.00695***	0.00541***	0.00315***
	(0.000688)	(0.000617)	(0.000486)
OC[2] [3]	0.00190	0.00185	-6.29e-06
	(0.00127)	(0.00116)	(0.000858)
emp[2] [3]	0.000282	-0.00847**	-0.0142***
	(0.00417)	(0.00367)	(0.00288)
Observations	14,860	14,860	14,385
Industry & year dummies	yes	yes	yes

Standard errors are in parentheses; *** p<0.01, ** p<0.05, * p<0.1; data: [1]CIS and [2] IDA, lagged by one year.[3] Logarithm.

We can see from table 7 that using the approximation of a logarithm, a 1 % increase in broad RD assets increases the probability of firm and market novelty by 0.5 % and of world novelty by 0.4 %. ICT assets support firm novelty (0.007) and market novelty (0.005) and world novelty (0.003). ICT thus provides slightly more support for firm and market novelty than RD does but slightly less support for world novelty. According to these results, OC does not have statistical significance for product innovations. However, it appears that the larger the firm is, the less likely it is to produce market or world novelties. An important finding is that the coefficient of RD assets is close to the coefficient of formal spending on R&D.

While table 7 presents product innovations, table 8 continues to explore the process innovations reported in the Danish CIS. Equation 2 below illustrates this estimation. The explanatory variables are all lagged by one year and in natural logarithm form.

(2) $$\mathrm{P}\left(\mathrm{inno}_{process,t+1}\right) = \beta_1 \ln(\mathrm{RD}_t) + \beta_2 \ln(\mathrm{R\&Dexp}_t) + \beta_3 \ln(\mathrm{ICT}_t) + \beta_4 \ln(\mathrm{OC}_t) + \beta_5 \ln(\mathrm{emp}) + \mathrm{X}_t$$

In table 8, R&D expenditure (R&Dexp) is a control for product innovativeness. It is in a similar format as intangible assets, i.e., the amount of money spent. To control for the size of the firm, we have the number of employees (emp). While having R&D expenditure is more uncommon in firms than is having broad RD assets, it has a larger coefficient than does broad RD assets for its relation with process innovations. As R&D expenditure is less common, firms having it are likely to be keen on technological product development. Additionally, ICT supports process innovation, marketing innovation and organizational change, whereas OC only supports marketing innovations.

Table 2.8. Process & marketing innovations and organizational change explained by intangibles.

Marginal effects VARIABLES	(1) process inno[1]	(2) marketing inno[1]	(3) organizational inno[1]
RD[2] [3]	0.00291***	0.00311***	0.00240**
	(0.000987)	(0.000984)	(0.00102)
R&Dexp[2] [3]	0.0190***	0.0225***	0.0244***
	(0.00356)	(0.00373)	(0.00392)
ICT[2] [3]	0.00385***	0.00553***	0.00596***
	(0.000728)	(0.000742)	(0.000757)
OC[2] [3]	-0.00124	0.00560***	0.00228
	(0.00132)	(0.00146)	(0.00143)
emp[2] [3]	0.0373***	0.0134***	0.0516***
	(0.00433)	(0.00448)	(0.00458)
Observations	14,846	14,846	14,860
Industry & year dummies	yes	yes	yes

Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1; data: [1]CIS and [2] IDA, lagged by one year.[3] Logarithm.

Conclusions and limitations

This article suggests that broadly measured intangible assets can serve as an indicator of innovation capability. Complementing formal R&D, intangibles are able to predict new-to-the-world product innovations; complementing innovation surveys, intangibles are able to predict new-to-the-firm and new-to-the-market products. Moreover, IA predict process innovations: Organizational assets predict marketing innovation but not organizational innovations. Furthermore, ICT assets and research and development (RD) assets predict marketing innovation and organizational change. Thus, intangibles have predictive power for product and process innovations. Therefore, this research supports using intangibles as an innovation capability indicator.

The biggest benefit of being able to use intangibles in future research is the coverage of all firms in the linked employer–employee data sets. This type of register data is unavailable in some countries, limiting the use of intangibles as measured in this article. However, when linked employer–employee data are unavailable, intangibles can optionally be approximated from intermediate inputs. In countries where these are not available, another option is an industry-level measure. Another limitation to the measurement in this paper is related to the size of the firm. In terms of smaller firms, the occupational data of employees might not be precise. An example is a firm with three or five employees and in which the employees can have tasks ranging from product development to day-to-day tasks. For small firms, a more suitable measure could be innovation attitudes, which can best be approached with an innovation survey. The disadvantage of using the survey approach is that the data would no longer cover most firms in the economy.

Intangibles, in particular, increase the coverage of service industries, as unlike companies in the manufacturing industry, these firms do not typically have separate R&D plants. Thus, in a microlevel analysis, intangibles are useful for obtaining more accurate innovativeness data coverage.

References

Barney, J. (1991). Firm resources and sustained competitive advantage. Journal of management, 17(1), 99-120.

Bloch, & López-Bassols. (2009). Innovation Indicators. In Innovation in Firms: A Microeconomic Perspective: OECD Publishing.

Bloch, C. (2008). The market valuation of knowledge assets. Econ. Innov. New Techn., 17(3), 269-284.

Bloch, C., Eklund, C., Huovari, J., & Piekkola, H. (2019). Innovative competences and firm-level productivity in Denmark and Finland. Working paper.

Brynjolfsson, E., & Yang, S. (1999). The intangible costs and benefits of computer investments: Evidence from the financial markets. Paper presented at the Atlanta, Georgia: Proceedings of the International Conference on Information Systems.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. Administrative science quarterly, 128-152.

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.

Corrado, C., Hulten, C., & Sichel, D. (2009). Intangible capital and US economic growth. Review of income and wealth, 55(3), 661-685.

Crass, D., & Peters, B. (2014). Intangible assets and firm-level productivity. ZEW - Centre for European Economic Research Discussion, 14-120.

Crépon, B., Duguet, E., & Mairessec, J. (1998). Research, Innovation And Productivity: An Econometric Analysis At The Firm Level. Economics of Innovation and New Technology, 7(2), 115-158.

de Rassenfosse, G. (2017). An assessment of how well we account for intangibles. Industrial and corporate change, 26(3), 517-534.

Griffith, R., Huergo, E., Mairesse, J., & Peters, B. (2006). Innovation and Productivity Across Four European Countries. Oxford Review of Economic Policy, 22(4), 483-498. doi:10.1093/oxrep/grj028

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. The bell journal of economics, 92-116.

Görzig, B., Piekkola, H., & Riley, R. (2010). Production of intangible investment and growth: Methodology in INNODRIVE. INNODRIVE WP1.

Hall, B. H. (2010). The Financing of Innovative Firms. Review of Economics and institutions, 1(1).

Hall, B. H., Lotti, F., & Mairesse, J. (2009). Innovation and productivity in SMEs: empirical evidence for Italy. Small Business Economics, 33(1), 13-33.

Hall, B. H., & Sena, V. (2017). Appropriability mechanisms, innovation, and productivity: evidence from the UK. Economics of Innovation and New Technology, 26(1-2), 42-62.

Harris, R., & Moffat, J. (2013). Intangible assets, absorbing knowledge and its impact on firm performance: theory, measurement and policy implications. Contemporary social science, 8(3), 346-361. doi:10.1080/21582041.2012.751498

Heckman, J. J. (1977). Sample selection bias as a specification error (with an application to the estimation of labor supply functions). In: National Bureau of Economic Research Cambridge, Mass., USA.

Ilmakunnas, P., & Piekkola, H. (2014). Intangible investment in people and productivity. Journal of Productivity Analysis, 41(3), 443-456.

Kleinknecht, A., & Reijnen, J. (1993). Towards literature-based innovation output indicators. Structural change and economic dynamics, 4(1), 199-207. doi:10.1016/0954-349X(93)90012-9

Mairesse, J., & Mohnen, P. (2004). The importance of R&D for innovation: a reassessment using French survey data. The Journal of Technology Transfer, 30(1-2), 183-197.

Marrocu, E., Paci, R., & Pontis, M. (2012). Intangible capital and firms' productivity. Industrial and corporate change, 21(2), 377-402.

Piekkola, H. (2011). Intangible capital agglomeration and economic growth: An Analysis of Regions in Finland. Retrieved from

Piekkola, H. (2016). Intangible Investment and Market Valuation. The Review of income and wealth, 62(1), 28-51. doi:10.1111/roiw.12149

Prahalad, C., & Hamel, G. (1990). The core competence of the corporation. Harvard Business Review, 68(3), 79-91.

Rahko, J. (2014). Market value of R&D, patents, and organizational capital: Finnish evidence. Economics of Innovation and New Technology, 23(4), 353-377. doi:10.1080/10438599.2013.864923

Sánchez, P., Chaminade, C., & Olea, M. (2000). Management of intangibles – An attempt to build a theory. Journal of Intellectual Capital, 1(4), 312-327. doi:doi:10.1108/14691930010359225

Teece, D. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy, 15(6), 285-305

Teece, D., Pisano, G., & Shuen, A. (1997) Dynamic Capabilities and Strategic Management. Strategic Management Journal, 18(7), 509-533

Van Ark, B. (2004). What Do the Numbers Mean? In Fostering Productivity: Patterns, Determinants and Policy Implications (pp. 29-61): Emerald Group Publishing Limited.

Zawislak, P. A., Cherubini Alves, A., Tello-Gamarra, J., Barbieux, D., & Reichert, F. M. (2012). Innovation capability: from technology development to transaction capability. Journal of technology management & innovation, 7(2), 14-27.

Innovative competences and firm level productivity in Denmark and Finland

Carter Bloch[a], Carita Eklund[a,b,*], Janne Huovari[c]

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

[b]Department of Economics and Business Law, University of Vaasa, Vaasa, Finland.

[c]Pellervo Economic Research, Helsinki, Finland.

[*]Corresponding author

May, 2018

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. Advanced economies have been under pressure from demand shifts, increased competition from globalization and from the severe conditions stemming from the financial crisis. We examine whether the role of intangible assets has changed over time: from the period of fairly stable growth prior to the crisis in 2008 to the more difficult period of recovery afterwards. The productivity analysis is conducted in two stages. First, we derive total factor productivity, and second, we estimate the effects of intangible competencies. Our approach, which is based on the use of occupational classifications from linked employer–employee data, constructs measures for three types of intangibles: R&D assets, organizational assets and ICT assets. The findings imply that organizational competences were higher in Denmark but have fallen in the recovery period. The elasticity of R&D assets with productivity for the both countries was positive and significant. Compared to the period before the crisis, in the recovery period, the elasticities of ICT assets for both countries were higher.

Introduction

The 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. This raises a question: can innovation capabilities help with the recovery from or the adjustment to changing conditions?

With a particular focus on manufacturing, a number of studies have focused on ways forward for firms in advanced economies such as Denmark and Finland. Manyika et al. (2012) argue that a new era is emerging for global manufacturing, and 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). These firms will be able to take advantage of IT advances and to develop the capacity to deal with change, risk and uncertainty. They will also be able to use global connectivity to link capabilities where best needed and to tailor operations to specific markets. While declines in employment have drawn greater attention to manufacturing, these factors are equally relevant to the service sectors.

The new era calls for a holistic understanding of global business, and the need for ongoing change is recognized by Whitefoot and Donofrio (2015), who, in particular, highlight the potential of IT and digitalization. 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 in response to changing conditions, be able to adjust quickly and take advantage of them (Wiengarten, 2016). This includes innovation, meaning the ability to develop new or improve on existing products as well as processes. Within the latter, particular focus has been placed on the implementation of ICT-based technologies such as digitalization or automation. Flexibility involves the ability to enter new markets and the ability to adjust operations to meet changing demand conditions. This requires strong organizational competences.

Mudambi (2008) analyzes the rising share of intangibles in worldwide economies and highlights the crucial role of knowledge-intensive and creative industries in current and future wealth generation. Value creation is increasingly concentrated at the ends of the value chain, i.e., concentrated upstream (in R&D and innovation) and downstream (in design and market introduction), and the organizational competences needed to integrate upstream and downstream activities are increasing in importance.

The complexity of value chains indicates that returns to innovation capabilities depend on many firm-specific and environmental factors (Hall, Mairesse, & Mohnen, 2010; Syverson, 2011). This raises a number of interesting questions concerning actual firm performance. For example, how do innovative competences contribute to firm productivity (Añón 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? Additionally, the literature has identified a "virtuous circle": firms with previously successful innovations tend to succeed again in terms of both inventions and sales from inventions (Bogliacino, Lucchese, Nascia, & Pianta, 2017). Thus, a comprehensive measure of the competences or the intangible assets that firms possess rather than the technological progress that the firms have achieved is needed when analyzing productivity (Cucculelli & Bettinelli, 2015).

The focus in this paper is on the role of intangible assets and market restructuring for economic growth. Carol Corrado, Hulten, and Sichel (2005) have argued that the measurement of capital should include all investments in human capital, R&D expenditure, and indeed any expenditure in which the business has devoted resources, whether it is intangible or tangible, to projects with the intention to increase future rather than current output. Work on the measurement of intangibles has focused on broadening the conceptualization of what constitutes a capital investment by developing measures of intangibles at the macro level and, more recently, also at the micro level for individual firms [14]. Carol Corrado et al. (2005) identify three main categories of intangible assets: economic competencies, innovative property and computerized information. Economic competencies include spending on strategic planning, worker training, redesigning or reconfiguring existing products in existing markets, investment to retain or gain market share and 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 a more broadly defined new product/process R&D. Computerized information essentially coincides with computer software and databases. de Rassenfosse (2017), among others, broadens branding activities to cover design that creates design rights.

Denmark and Finland are both small open economies with populations of approximately 5 million. While between the two countries, there are structural differences, for example, in terms of industry composition and their main trading partners, there are also strong similarities between the two Nordic countries. For

---

[14] See, in particular, the extensive work undertaken on the measurement of intangibles at both the macro and micro level in the EU FP7 project, Innodrive (www.Innodrive.org).

example, the World Economic Forum[15] rates both countries highly in health care, primary and secondary education, training and technological readiness. Furthermore, both countries insure their citizens for different life situations, such as sicknesses, and as is typical in Nordic countries, Finns and Danes have a high levels of trust in other citizens. As the market size is small for both countries, to gain access to a large enough pool of customers, many companies pursue opportunities outside of the home market. This pushes firms to the global markets. Both countries suffered large declines in GDP because of the financial crisis in 2008, with Denmark and Finland experiencing a 5 % and 8 % decline, respectively, in GDP in 2009. Growth rates prior to the crisis were strongest in Finland, while for the Finnish economy, the fall in GDP was also larger and the postcrisis recovery slower.

For manufacturing and service firms in Denmark and Finland, this paper examines the link between innovative capabilities, which we approximate with intangible assets, and productivity. Intangible assets are a novel measurement of the individual firms' knowledge base and knowledge development. In particular, the analysis will examine the role of intangible assets in facilitating the recovery from the financial crisis in 2008 and 2009. Furthermore, we analyze whether investments in intangibles can help to explain differences in the recovery patterns for Denmark and Finland. It is apparent that the use of intangible asset resources by different firms does not follow conventional industrial classifications: for example, retail companies may invest in either fixed capital (buildings), labor, or intangible assets.

Here, intangible assets (IA) are divided into three components, namely, organizational capital assets (OC), R&D assets (RD) and information and communication technology assets (ICT). OC relates to managerial and marketing capabilities and branding. Because these activities require long-term planning, database and software development and the maintenance of ICT networks are included in ICT. As discussed by Denekamp (1995), Braunerhjelm (1996), Bartel, Ichniowski, and Shaw (2007), ICT is used to monitor both the relationships among different production units and the dynamics of vertical integration. Piekkola (2017), Brynjolfsson, Hitt, and Yang (2002) and Piekkola (2016) examine the monitoring of foreign operations. RD covers R&D activities (such as science, engineering and health innovation development). By their construction, OC, RD and ICT can be used as measures of innovation capability, and we use them in explaining productivity differences. We calculate them at the firm level by relying on occupational data that we link with firm-level balance sheet data. We identify

[15] Klaus Schwab (2017) Global Competitiveness Report

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.

The constructed intangibles are then used to explain firm-level productivity and the recovery of productivity. Our analysis covers the period from 2000 to 2013. We employ a productivity analysis (Olley & Pakes, 1996) that is similar to the analysis in Añón Higón et al. (2017) and that utilizes a two-stage estimation method, where total factor productivity (TFP) is estimated in the first stage, while the second stage analyzes 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 the paper.

Intangible assets and productivity – a review

Work on the measurement of investments in intangible assets broadens our understanding of the firms' value in terms of capital formation and hence our understanding of expenses that benefit the firm in the future periods. Some examples of these investment-related and nontangible expenses are the following: education, training, design, marketing, and even certain kinds of production reorganization and marketing expenditures aimed at better utilizing the available technology. Early work by Kendrick (1994) on intangible investment in the United States during the 20th century indeed 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.

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

However, the role of intangibles in the recovery from financial crises remains unclear. Piekkola and Åkerholm (2013) show that labor productivity growth in Finland improved through market restructuring in the period of 2007–2012, enabling high productivity firms to increase their market share. However, during the same period, firms invested less in intangibles in Finland. It remains unanswered how investments in intangible and tangible capital can be decomposed in relation to changes in market structure and internal growth. Moreover, Hannu Piekkola (2016) show that intangible capital (IC)–driven growth was stalled in European industries during the 2008–2013 financial crisis period. It appears that product innovation does not automatically translate into productivity growth and was not able to compensate for Europe's dwindling tangible-capital-intensive manufacturing and job losses during 2008–2013. However, due to the increasing importance of intangible-producing services, broad-based intangible capital assets potentially offer a roadmap for recovery. As indicated above, many of the suggested explanations to the deceleration of productivity growth in Europe allude to the role of intangible investments.

Among the firm-level analyses conducted, extensive work has been done on the relation between R&D and productivity (for a review, see Hall et al. (2010)) and innovation and productivity, while there is less experience with broader measures of intangibles. The econometric analyses of the relation between innovation and productivity build to a large extent on work by Griliches (1979) and Pakes and Griliches (1984), who introduced the concept of the knowledge production function to explain the creation of economically valuable knowledge, which can then be used in the production of goods and services.

More recent work has analyzed the relation between intangibles and productivity, utilizing a variety of different data sources and the categorization of intangible assets. Marrocu, Paci, and Pontis (2012) conduct a firm level productivity analysis of intangibles for six European countries: France, Italy, Netherlands, Spain, Sweden and the United Kingdom. Their measure of intangible capital uses balance sheet information and is based on intangible assets that have been capitalized.

They find elasticities in the range of 0.04-0.06. Bontempi and Mairesse (2015) also rely on the balance sheet data of Italian firms but go beyond the impact of purely capitalized intangible assets to also include other expenditures. They define two types of intangible capital, namely, intellectual capital (mainly R&D and patents) and customer intangible capital (mainly advertising, trademarks).

Crass and Peters (2014) utilize innovation data to construct and analyze measures of intangibles. They utilize innovation survey data from 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, 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 the stock of trademarks. In addition, dummy variables concerning organizational innovations function as proxies for organizational capital.

In this analysis, we draw on the approach developed in the INNODRIVE project (Görzig, Piekkola, & Riley, 2010), where linked employer-employee data (LEED) are used to measure firm-level investments in intangibles. Intangible assets (IA) are classified into three categories[16]:

Organizational capital assets (OC)

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 the organizational know-how of the firm. RD assets are accumulated through the technical activities of the firm, and thus are broader than are measures of R&D expenditures based on the Frascati definition of R&D (OECD, 2015). ICT assets represent the accumulated know-how based on in-house activities to manage, develop and implement ICT activities in the firm.

This approach is based on the assumption that organizational and technical know-how in the three categories are accumulated through the work of personnel in occupations that are relevant to each of the three types. The measures of

[16] Another approach used by Ilmakunnas and Piekkola (2014) measures intangibles investments by focusing on the number of employees of Finnish firms, where worker shares proxy intangible capital in three categories: organizational, RD and ICT.

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 [17] (Managers, Professionals and Technicians and Associate Professionals) are assumed to engage in activities that contribute to the accumulation of know-how within the firm. The actual list of occupational classifications used in the measurement of intangible investments is shown in the appendix. 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 accounts for the share of intermediate input and tangible capital spent for each unit of IA-type labor input. The factor multiplier depends on how labor, intermediate input and tangibles transform into value added in particular business services or ICT industries that produce IA inputs for other industries. Piekkola (2016) provides in equation (1) this value of a combined multiplier A^{IA}, which is time invariant in the expenditure-based approach.

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

Data and variables

This study utilizes the Danish and Finnish firms' register data in the period of 2000-2013. The datasets include all firms [18] having an average of at least ten employees over the period. The samples cover all manufacturing industries and a broad range of market services[19]. 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) investments, fixed capital investments, exports, imports and

[17] ISCO-08, http://www.ilo.org/public/english/bureau/stat/isco/isco08/.

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

[19] The sample includes all market service industries with the exception of construction and financial services; in terms of the NACE Rev. 2 2-digit code, the sample includes industries 10 to 33 (i.e., all manufacturing) and 45 to 74, with the exception of 64-66.

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

Intangible assets are approximated by the number of intangible-producing employees to which we add an estimate of used intermediates 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, R&D and ICT-based capabilities. Managerial and technical staffs are assumed to contribute partly to daily operations and partly to the accumulation of intangible capital. Following the work within the Innodrive project (Görzig el al. 2010), the working shares spent on producing intangibles are assumed to be 20 % for organizational workers, 70 % for RD workers and 50 % for ICT (appendix, table A.1).

Following Piekkola (2016), we include the costs of intermediates and tangible capital used in the intangible production. To evaluate the benefits to the intangible asset construction from these goods, Görzig et al. (2010) look at how intermediate inputs and (tangible) capital create value added in the industries of business services. Appendix A shows the details surrounding the construction of expenditure-based measures of firm-level intangible assets. These figures are linked to how labor, capital and intermediate inputs costs are combined to produce intangible assets (IA) in benchmark industries that are intangible-producing business services. Real intangibles' investments   of type IA, where IA equals OC, RD, and ICT, are as follows:

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

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

[20] We deflated the values from the Danish service industries with the consumer price index, as for the period 1999 to 2013, we did not find deflators for the service industries for the sample.

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

The initial IA investment $\overline{N}_{i,t=0}^{IA}$ 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, where the depreciation rate is denoted by δ_{ia} and the growth rate of the intellectual asset is denoted by g. Consistent with the use of the sample average growth rate of real wage costs for IA-related activities, the growth rate g is set at 2 % for all IA. The nominal variables are deflated by using industry-level producer price indexes for firm financial variables. As noted above, the measures of intangible investments are deflated by 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 did price levels in the firms' own respective industries. Much of these assets, such as purchased organizational, R&D and ICT assets, are unaccounted for in national accounts.

Table 3.1. Share of firms having intangible assets .

	Denmark			Finland		
year	Firms with OC	Firms with RD	Firms with ICT	Firms with OC	Firms with RD	Firms with ICT
1999	76 %	42 %	14 %	91 %	84 %	55 %
2000	77 %	46 %	17 %	91 %	84 %	54 %
2001	80 %	51 %	20 %	90 %	84 %	52 %
2002	81 %	59 %	21 %	90 %	83 %	52 %
2003	80 %	60 %	21 %	90 %	83 %	52 %
2004	80 %	61 %	23 %	90 %	82 %	52 %
2005	82 %	64 %	25 %	89 %	81 %	51 %
2006	83 %	66 %	26 %	89 %	81 %	51 %
2007	83 %	66 %	27 %	88 %	79 %	49 %
2008	85 %	68 %	29 %	87 %	77 %	48 %
2009	87 %	69 %	31 %	86 %	75 %	46 %
2010	88 %	70 %	33 %	85 %	73 %	45 %
2011	89 %	71 %	34 %	83 %	70 %	42 %
2012	90 %	73 %	36 %	82 %	68 %	40 %
2013	90 %	73 %	37 %	79 %	65 %	38 %

The following tables report the descriptive statistics of the sample. 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 they do in 1999. The opposite is true for Finland, where shares have declined for all intangible asset types. At the start of the sample, all intangible asset types are more typical in Finland than in Denmark. However, after 2010, the share of firms with RD assets is fairly similar in the two countries. Organizational capital experiences similar developments, though Denmark has a higher share of OC from 2009 onwards.

Table 3.2. Summary statistics.

Variable	Finland	Denmark
Employees	593	522
RD asset	31410	18802
Growth 99-03	5.35	4.93
Growth 03-08	2.68	1.31
Growth 08-13	-3.05	-0.34
Organizational asset	5386	7455
Growth 99-03	5.24	4.16
Growth 03-08	1.49	2.55
Growth 08-13	-4.66	0.53
ICT asset	4739	1022
Growth 99-03	10.98	5.59
Growth 03-08	7.89	2.69
Growth 08-13	-7.18	2.27

Total average annual employment in thousand and intangible assets in million 2010€, exchange rate of Danish crown 0.134.

For Finland and Denmark, table 2 shows size and growth rates in intangible assets for the samples. The average firm size of Finnish firms is somewhat larger, and a larger share of firms in Finland have RD and ICT assets than in Denmark. In contrast, after 2003, Denmark has more organizational assets and larger growth rates in OC. Before 2008, Finland had larger rates of growth in RD assets, but after 2008, the R & D asset growth rate in Finland decreased by 3 %, while the decrease was less than 0.5 % in Denmark. Similar patterns exists in Finland for OC and ICT: Organizational assets experienced almost a 5 % decrease, while ICT assets decreased by 7 %. For Denmark, growth rates were positive both before and after 2008. [21]

Further, the growth rates of ICT assets are interesting. From 1999 to 2003, the growth rate was almost 11 % in Finland and 5.6 % in Denmark. From 2003 to 2008, ICT assets grew approximately 8 % in Finland and 3 % in Denmark. Then, the growth rate in Finland, - 7 %, turned negative, and the growth rate in Denmark, 2 %, remained positive.

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 the total factor productivity estimation and limitations.

Analysis method

The framework of most previous studies is the production function approach that employs the Cobb and Douglas (1928) production function[22]. Cobb and Douglas (1928) suggest modeling production as in equation 3, where Y denotes production, L denotes labor and K denotes capital. α and β are output elasticities.

(3) $Y = AL^{\alpha}K^{\beta}$

We follow this path, widely used with intangibles (such as Añón Higón et al., 2017; Corrado et al., 2014; Cuneo & Mairesse, 1983): following Añón Higón et al. (2017), we estimate the production function by utilizing a two-stage approach. First, we estimate a standard Cobb-Douglas 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. In addition, we examine whether compared to the effects of intangible assets in the postcrisis recovery period, the effects of intangible assets in the strong growth period prior to the 2008 financial crisis differ. The empirical strategy primarily draws on Bontempi and Mairesse (2015), Piekkola (2011b), Añón Higón et al. (2017), and Crass and Peters (2014).

Production Function Estimation

We assume that the production function follows Cobb and Douglas (1928) as in equation 3, where Q denotes value added, L denotes labor, and K denotes capital. Ƞ is an error term and lower case letters denote logarithms. Schankerman (1981)

[21] For more, see appendix.
[22] An exception here is Bontempi and Mairesse (2015) who use a constant elasticity of substitution function.

and Hall and Mairesse (1995) have shown that the estimated elasticity of R&D is downward biased if one does not correct for double counting. In what follows, labor excludes IA-type workers. Firms choose their capital and labor accounting for the following periods. Here, they use their knowledge of forthcoming shocks v_{it} that are a part of the error term η in equation (3). In a micro level analysis, we need an approximation of these firm-specific shocks (or asymmetric observation of shocks) that affect the firms' dynamic optimization (Parrotta, Pozzoli, & Pytlikova, 2014). As we are explaining value added, intermediate inputs are not used in the production function. The underlying assumption is that intermediates do not contribute notably more value to the final product than their own price does.

(4) $$q_{it} = a + \alpha \cdot l_{it} + \beta \cdot k_{it} + \eta_{it}$$

We follow Olley and Pakes (1996), henceforth OP, and assume that firm specific shocks are a strictly increasing function of investments (Van Beveren, 2010; Yasar, Raciborski, & Poi, 2008). The OP method is chosen over the Levinsohn and Petrin (2003), henceforth LP, method in which due to practical reasons, intermediate inputs are used as proxy variables. First, we lack data on the intermediate inputs for the first years of the sample and second, investments had more nonzero values than did the intermediate inputs in our sample. More importantly, some of the intermediate inputs would be used in intangible investments, thus causing multicollinearity problems.

Olley and Pakes (1996) and Levinsohn and Petrin (2003) model the investment decision as a function of capital, labor and the productivity shock. Assuming that investments are strictly increasing in productivity, we can take the inverse of the investment function and write shock v_{it}, which is defined as a nonparametric function (Ackerberg, Caves, & Frazer, 2015). Thus, the object function of the firm becomes:

(5) $$\begin{aligned} & v_{it} = f^{-1}(k_{it}, l_{it}, inv_{it}) \\ & \rightarrow q_{it} = a + \alpha \cdot l_{it} + \beta \cdot k_{it} + v_{it} + \varepsilon_{it} \end{aligned}$$

One advantage in the OP (and LP) model is the attrition correction for the exit effect: OP accounts for firms exiting the sample[23]. Thus, we avoid one selection problem. From here, we obtain an approximation for total factor productivity, TFP. We use these TFP values to estimate the effects of intangible assets on productivity in the last stage of the analysis. We utilize OLS for this second stage. We calculate intangible assets based mainly on the employees in certain

[23] In an unbalanced panel such as the one we use, the firm's exit decision can be a function of unobservable productivity shocks.

occupations listed in the appendix; thus, the employees are not as directly linked to the tangible investment decision in the firms. Nevertheless, to minimize the correlation, the employees used in the production function estimates exclude IA-producing employees.

From Intangible Assets to Productivity

As in Hall and Mairesse (1995, p. 278), to avoid endogeneity problems, we explain TFP from the first estimation with the beginning of the year values[24] of intangibles. 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 (5) where TFP denotes total factor productivity, rd_{it} denotes the lagged logarithm of RD assets, and oc_{it} and ict_{it} denote organizational and ICT assets. X_{it} includes controls, year and, as in Añón Higón et al. (2017), firm size dummies. Year dummies control for macroeconomic changes from the error term, whereas the size dummies control partly for the communication environment and other size related advantages and are statistically significant. RD, ICT and organizational assets are constructed from the linked employer-employee data, FLEED for Finland and IDA for Denmark, and are described both above and in appendix A. Moreover, organizational occupations include (non-ICT) management, administrative and marketing positions; RD mostly includes positions related to technology, and ICT includes ICT professionals and managers. 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 the new tight situation in access to finance and changes in demand The crisis period tests the firms' capabilities to be agile and flexible when needed or even their capacity to innovate their way out under pressure. The structural break helps to test whether the financial crisis affects the productivity gains from intangible assets and whether these gains can explain why Denmark has recovered better from the crisis than has Finland.

(6) $$tfp_{it} = \beta_0 + \beta_1\, rd_{it} + \beta_2\, oc_{it} + \beta_3\, ict_{it} + \beta_4\, A\, rd_{it} + \beta_5\, A\, oc_{it} + \beta_6\, A\, ict_{it} + X_{it} + \varepsilon_{it}\ ,$$

where the variables in small letters imply a logarithmic form. Equation (5) is the final regression, where A is a dummy with a value of 1 when the year is greater than 2008 and zero otherwise[25].

[24] At the beginning of the year, the assets are the same as the assets at the end of the previous period. This means that the depreciation and investments of year t have not happened but that the depreciation and investments of time t-1 have occurred.
[25] Results are essentially unchanged if the break is set at 2008 instead of 2009.

A high share of firms have organizational assets while smaller shares also have other types of intangible assets, particularly ICT assets. Hence, while it is not problematic to restrict the sample to firms with organizational assets, the sample of firms with all three types of assets may be less representative of the full population. To examine this, we also employ a RD asset restriction in addition to an OC asset restriction. The following section presents the results.

Results

This section presents the results of the analysis. First, we discuss the production function estimates of both countries. We report the OP production model, although 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.

Production Functions

Table 3 presents the Olley and Pakes (1996) production function estimation for Denmark and Finland. We are aware that although the number of hours worked might be even more highly correlated with our intangible assets estimation, using the number of employees as a measurement indicator might be problematic [26]. We correct the double counting of labor by subtracting the employees who are involved in producing intangibles. Cuneo and Mairesse (1983), Schankerman (1981) and Hall and Mairesse (1995) show that without this correction, the elasticity of R&D is downward biased. Thus, we apply the correction with the broader measure of innovation capability, intangible assets. Table 3 reports the production function coefficients for all firms and for firms that have OC in at least one year during the estimation period.

[26] We first used the ACF correction (suggested by Ackerberg et al. (2015) to improve the Olley and Pakes (1996) and Levinsohn and Petrin's (2003) production function estimates, which for both countries, might suffer from a functional dependence problem, but as the use of the correction was infeasible with industry dummies and mostly affected the dummy coefficients, we decided not to use it.

Table 3.3. Olley-Pakes Production function estimates from value added.

	DK	DK (*)	FI	FI (*)
log(employees)	0.2498***	0.2658***	0.3078***	0.3065***
	(0.0131)	(0.0097)	(0.0082)	(0.0115)
log(capital)	0.1293***	0.1202***	0.1200***	0.1246***
	(0.0136)	(0.0139)	(0.0096)	(0.0098)
N	78800	82800	104000	66000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are in parentheses: to minimize correlation, employees exclude IA-type workers. (*) denotes firms with only OC and RD.

The coefficient of the log of employees is larger in Finland than in Denmark. For both countries, the sum of coefficient estimates for labor and capital are far from one. Hence, the results indicate decreasing returns to scale for both countries. From this first stage, we save the residuals as a measure of (the logarithm of) total factor productivity (TFP). In TFP, we have examined the effects of extreme values by removing the 99th and 1th distribution from the model. This does not alter the basic findings, but lowers the standard deviation of the coefficients.

Results of TFP estimation

Based on the approximation of TFP in equation (6), we obtain the following results for Denmark and Finland (table 4). The model is estimated by using OLS with year and size dummies. The intangibles are in logarithmic form and lagged by one year. To examine whether elasticities are different before and after the crisis, each of the intangible assets are interacted with a dummy that is zero before 2008 and one afterwards (namely, OC after, RD after, and ICT after).

As previously mentioned, we restrict the sample to firms having (1) organizational capital assets and (2) organizational capital and RD assets at least in one year in the estimation period and use total factor productivity as the dependent variable. This restriction minimizes the bias that would follow from including firms without any intangible assets, as we are not currently able to adequately model the decision to invest in intangibles. Hence, a moderate restriction of the sample provides a pragmatic approach to address this.

Table 3.4. TFP from Olley and Pakes (1996) estimation explained with intangibles.

	Finland(1)		Denmark(1)		Finland (2)		Denmark (2)	
RD	0.0257***	0.0256***	0.0300***	0.0266***	0.0300***	0.0343***	0.0265***	0.0227***
	(0.0005)	(0.0007)	(0.0003)	(0.0003)	(0.0007)	(0.0010)	(0.0004)	(0.0004)
OA	0.0229***	0.0227***	0.0229***	0.0241***	0.0384***	0.0470***	0.0353***	0.0323***
	(0.0007)	(0.0009)	(0.0004)	(0.0005)	(0.0011)	(0.0015)	(0.0006)	(0.0007)
ICT	0.0189***	0.0161***	0.0198***	0.0183***	0.0190***	0.0157***	0.0207***	0.0199***
	(0.0005)	(0.0006)	(0.0003)	(0.0004)	(0.0006)	(0.0007)	(0.0003)	(0.0004)
RD after 2008		-0.0003		0.0090***		-0.0075***		0.0201***
		(0.0009)		(0.0005)		(0.0013)		(0.0009)
OC after 2008		0.0001		-0.0034***		-0.0148***		0.0135***
		(0.0013)		(0.0008)		(0.0019)		(0.0013)
ICT after 2008		0.0070***		0.0024***		0.0084***		-0.0004
		(0.0009)		(0.0006)		(0.0010)		(0.0006)
size_10_19	-0.6918***	-0.6955***	-0.7080***	-0.7071***	-0.6808***	-0.6751***	-0.6922***	-0.6836***
	(0.0081)	(0.0081)	(0.0053)	(0.0053)	(0.0089)	(0.0090)	(0.0059)	(0.0059)
size_20_49	-0.4110***	-0.4126***	-0.3867***	-0.3877***	-0.3801***	-0.3767***	-0.3756***	-0.3718***
	(0.0067)	(0.0067)	(0.0045)	(0.0045)	(0.0071)	(0.0071)	(0.0047)	(0.0047)
size_150_499	0.5451***	0.5438***	0.4772***	0.4814***	0.5148***	0.5085***	0.4625***	0.4602***
	(0.0094)	(0.0093)	(0.007)	(0.007)	(0.0096)	(0.0097)	(0.0071)	(0.0071)
size_500	1.1557***	1.1535***	0.9934***	0.9998***	1.0987***	1.0869***	0.9760***	0.9683***
	(0.0135)	(0.0135)	(0.0123)	(0.0123)	(0.0140)	(0.0141)	(0.0124)	(0.0123)
year &industry dummies	Yes	yes	Yes	yes	yes	yes	yes	yes
N	71300	71300	94100	94100	59900	59900	75300	75300
R Squared	0.6220	0.6224	0.7229	0.7241	0.6030	0.6039	0.6961	0.7001

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are in parentheses. (1) denotes firms with OC; (2) denotes firms with OC and RD in at least one year in the sample

If we consider first the results for the larger sample on the left side column (where all firms have OC but may or may not have RD), the elasticities are very similar for the two countries. We see that the RD and ICT elasticities are slightly higher in Denmark than in Finland. The elasticity of organizational assets is similar in Finland and in Denmark.

RD output elasticities seem to be quite similar for the two countries before the financial crisis. The results do not show a difference for Finland after the crisis, while the elasticity for RD is significantly higher for Denmark after the crisis. These values for RD assets are less than the values found in previous studies. However, our estimates for RD exceed those for Añón Higón et al. (2017) in explaining TFP[27]. Our measure of RD assets is also somewhat broader than are the measures based on R&D expenditures. This would thus suggest that the returns of other technical innovation activities (that are not formally R&D according to the Frascati definition by OECD (2015)) are important and potentially similar to that of formal R&D investments. Note also that 30-40 % of the productivity growth comes from IAs other than RD, as OC and ICT are 32 % of RD in Finland and 45 % of RD in Denmark and their elasticities do not much differ from those of RD.

ICT asset elasticity is positive and significant. Finland experienced an IT bubble in the 2000s where companies appear to have over invested in ICT, making ICT company prices skyrocket. For example, the price of Nokia stock fell from 60€ in 2000 to 12€ in 2004, a drop equaling to 80 %[28]. Thus, it is interesting that the elasticity of ICT after is larger in Finland than in Denmark.

When we look at RD intensive firms on the right side of the table 4 (where all firms have both OC and RD in at least one year), we see similar results, although the differences before and after the crisis are more pronounced. In this restricted sample, the RD elasticity is higher for Finland, but there is now a significant decline in the elasticity of RD after the crisis. In contrast, for Denmark, the RD elasticity increases after the crisis. A similar pattern can be seen for organizational assets in both countries.

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

[27] Añón Higón et al. (2017, p. 874) report significant coefficients from 0.002 to 0.006 for R&D stock.
[28] See http://www.ts.fi/uutiset/talous/1073977134/Itkupla+oli+porssitaivaan+musta+aukko .

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 approach follows that used for the occupational-based measure of intangibles in Squicciarini and Le Mouel (2012) and developed in the INNODRIVE and COINVEST projects, though our paper is novel in utilizing this approach in a firm-level regression analysis of intangibles and productivity. 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. While the method is very data-intensive and requires further validation to evaluate comparability across countries, it can be, in principle, applied in any country with linked employer–employee data (LEED) and an international occupation classification of employees. An additional novel element of our analysis is that we examine the role of intangibles in the economic recovery after the crisis, considering their role after the crisis in relation to their role in the quite stable growth period prior to the crisis. Our estimation covers the period from 2000 to 2013.

Based on occupational data, IA are classified into three categories: organizational capital assets (OC), research and development (RD) and information communication technology (ICT) assets. OC are accumulated through investments in management and marketing activity, as we assume that these activities result in a build-up of organizational know-how for the firm. RD are accumulated through the technical activities of the firm, and thus our measure is broader than those based on the Frascati definition of R&D (OECD, 2015). ICT assets represent accumulated know-how based on in-house activities to manage, develop and implement ICT activities in the firm.

Our main results are as follows. First, the productivity elasticities of RD found for Denmark and Finland are typically in the range of 0.025-0.034. These results are thus quite comparable to those found in other recent analyses that use different measurement approaches. For example, in production function estimations, Marrocu et al. (2012, p. 395) report that the coefficient of intangibles varies depending on industry from 0.2 to 0.7, while ours are 0.068 for Finland and 0.046 for Denmark. Bontempi and Mairesse (2015) report the coefficients of intellectual capital with different methods to range from 0.011 to 0.051, while in total factor productivity estimates, Crass and Peters (2014) report R&D coefficients ranging from 0.031 to 0.056, training coefficients, from 0.039 to 0.061, and marketing coefficients, from 0.030 to 0.047. This similarity is interesting given that our RD assets' measure, which include non-R&D activities that are directly related to innovation development and implementation (OECD & Eurostat, 2005), is broader than measures based on formally defined R&D expenditures and innovation expenditures. For instance, based on our measure, approximately two-thirds to three-quarters of all firms (with 10 or more employees) have RD assets, 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 the technical know-how that contributes positively to firm performance.

Our method in particular offers an approach for measuring organizational assets, which has proven very elusive for firm-level analysis. Danish firms focus more on managerial, organizational and nontechnical aspects of innovation than Finnish firms do. Finland is almost twice as RD intensive as Denmark, although in the postcrisis period, Denmark has been catching up to the Finnish level. Our results show remarkable similarities between the Finnish and Danish economies with regard to the output elasticities of IAs. Our approach of using OP to compute TFP as a residual and then explaining TFP by OLS appears to avoid the overestimation of the effects of IAs.

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 prefinancial crisis period level in 2018.

Lome, Heggeseth, and Moen (2016) find that in Norway, R&D-intensive firms performed significantly better during the financial crisis, but we find that the output elasticities of RD decline or stay unchanged in Finland, while increasing in Denmark. While the productivity of ICT improved in the post-crisis period, Finland experienced a 7 % annual decline in ICT investment. The increase in output elasticity of Finnish ICT in the post-crisis period could also be explained by the higher marginal returns for the remaining ICT. Denmark is more organization-capital-assets intensive than is Finland, and it seems that productivity improved in Denmark after the crisis among RD-intensive firms. Given their similarities in production, Finnish firms should benefit from investing more in managerial ability to reap the gains accruing to Denmark. Denmark has the clear potential to combine its strength in OC with RD activity, but it is somewhat a follower to Finland in regard to RD and ICT investment.

In general, in Denmark, we find positive and significant elasticities of organizational assets that are in some cases larger than those for RD assets. However, the larger differences between the countries are in the post crisis period's elasticities of ICT and RD. In Denmark, the RD elasticities have risen, while in Finland, they have remained quite stable. However, for both countries, the elasticity of ICT has risen since the financial crisis started. A more in-depth analysis of the data is needed to assess the comparability of the LEED data across the two countries. While we have utilized the same approach in both countries, further analysis is needed to assess whether there are differences in data quality or perhaps in reporting practices 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.

References

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

Añón Higón, D., Gómez, J., & Vargas, P. (2017). Complementarities in innovation strategy: do intangibles play a role in enhancing firm performance? *Industrial and Corporate Change*.

Awano, G., Franklin, M., Haskel, J., & Kastrinaki, Z. (2010). Measuring investment in intangible assets in the UK: results from a new survey. *Economic & Labour Market Review, 4*(7), 66-71.

Bartel, A. P., Ichniowski, C., & Shaw, K. L. (2007). How Does Information Technology Affect Productivity? Plant-Level Comparisons of Past Trends and Projections in Wages, Work, and Occupations 63 Product Innovation, Process Improvement and Worker Skills. *Quarterly Journal of Economics, 122*(4), 1721-1758.

Bogliacino, F., Lucchese, M., Nascia, L., & Pianta, M. (2017). Modeling the virtuous circle of innovation. A test on Italian firms. *Industrial and Corporate Change, 26*(3), 467-484. doi:10.1093/icc/dtw045

Bontempi, M. E., & Mairesse, J. (2015). Intangible capital and productivity at the firm level: a panel data assessment. *Economics of Innovation and New Technology, 24*(1-2), 22-51. doi:10.1080/10438599.2014.897859

Braunerhjelm, P. (1996). The relation between firm-specific intangibles and exports. *Economics Letters, 53*(2), 213-219.

Brynjolfsson, E., Hitt, L. M., & Yang, S. (2002). Intangible assets: Computers and organizational capital. *Brookings papers on economic activity, 2002*(1), 137-198.

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). Multilateral comparisons of output, input, and productivity using superlative index numbers. *The economic journal, 92*(365), 73-86.

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

Cohen, J., Cohen, J., Cohen, P., West, S. G. A., Leona, S., Patricia Cohen, S. G. W., & Leona, S. A. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (0805822232). Retrieved from

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2013). *Applied multiple regression/correlation analysis for the behavioral sciences*: Routledge.

Corrado, C., Haskel, J., & Jona-Lasinio, C. (2014). Knowledge spillovers, ICT and productivity growth.

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, 29*(2), 261-286.

Corrado, C., Haskel, J., Jona-Lasinio, C., & Iommi, M. (2014). Intangibles and industry productivity growth: Evidence from the EU. *Manuscript available at www. intan-invest. net.*

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, 45*(2), 329-350.

Cuneo, P., & Mairesse, J. (1983). Productivity and R&D at the firm level in French manufacturing. In: 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, 26*(3), 517-534.

Denekamp, J. G. (1995). Intangible Assets, Internalization and Foreign Direct Investment in Manufacturing. *Journal of International Business Studies, 26*(3), 493-504.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The bell journal of economics*, 92-116.

Görzig, B., Piekkola, H., & Riley, R. (2010). *Production of Own Account Intangible Investment: Methodology in Innodrive Project.*

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

Hall, B. 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.

Ilmakunnas, P., & Piekkola, H. (2014). Intangible investment in people and productivity. *Journal of Productivity Analysis, 41*(3), 443-456.

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

Lee, F. C., & Tang, J. (2001). Multifactor productivity disparity between Canadian and US manufacturing firms. *Journal of Productivity Analysis*, 115-128.

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. o. 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, 55*(3), 686-716.

Marrocu, E., Paci, R., & Pontis, M. (2012). Intangible capital and firms' productivity. *Industrial and Corporate Change, 21*(2), 377-402.

Mudambi, R. (2008). Location, control and innovation in knowledge-intensive industries. *Journal of economic Geography, 8*(5), 699-725.

Niebel, T., O'Mahony, M., & Saam, M. (2016). The contribution of intangible assets to sectoral productivity growth in the EU. *Review of Income and Wealth*.

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

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

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

Pakes, A., & Griliches, Z. (1984). Patents and R&D at the firm level: a first look. In *R&D, patents, and productivity* (pp. 55-72): University of Chicago Press.

Palia, D. (2001). The endogeneity of managerial compensation in firm valuation: A solution. *Review of Financial Studies, 14*(3), 735-764.

Parrotta, P., Pozzoli, D., & Pytlikova, M. (2014). Labor diversity and firm productivity. *European Economic review, 66*, 144-179.

Piekkola, H. (2011a). Intangible capital - INNODRIVE perspective. In H. Piekkola (Ed.), *Intangible capital - driver of growth in Finlan* (Vol. 167 of Proceeding of the University of Vaas. Reports). Vaasa: University of Vaasa.

Piekkola, H. (2011b). Intangible capital agglomeration and economic growth: An Analysis of Regions in Finland. *INNODRIVE Working Paper*.

Piekkola, H. (2016). Intangible investment and market valuation. *Review of Income and Wealth, 62*(1), 28-51.

Piekkola, H. (2016). *Intangible Investments in Europe*. Paper presented at the 11th International Conference Challenges of Europe: Growth, competitiveness and inequality, Hvar, Croatia.

Piekkola, H. (2017). Broad-based intangibles as generators of growth in Europe. *Economics of Innovation and New Technology*, 1-24.

Piekkola, H., & Åkerholm, J. (2013). The Productivity Mystery.

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., & 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.

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.

Squicciarini, M., & Le Mouel, M. (2012). *Defining and Measuring Investment in Organisational Capital Using US Microdata to Develop a Task-based Approach* (1815-1965). Retrieved from Paris:

Syverson, C. (2011). What determines productivity? *Journal of Economic literature, 49*(2), 326-365.

Van Ark, B., Hao, J. X., Corrado, C., & Hulten, C. (2009). Measuring intangible capital and its contribution to economic growth in Europe. *EIB papers, 14*(1), 62-93.

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

Whitefoot, K. S., & Donofrio, N. M. (2015). *Making Value for America: Embracing the Future of Manufacturing, Technology, and Work*: National Academies Press.

Wiengarten, F. (2016). Risk, risk management practices, and the success of supply chain integration. *International journal of production economics, 171*, 361-370. doi: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.

Appendix A. Intangible capital measurement

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

Organizational work

Managing Directors and Chief Executives 112 (112)

Administrative and Commercial Managers 12 (123 all)

Business Services and Administration Managers 121, Sales, Marketing and Development Managers 122

Managing, mining, construction and distribution managers 13, 131 (122)

Manufacturing, mining, construction and distribution managers 132 (122)

Professional services managers 134 (122)

Teaching Professionals 23 (23)

Business and Administration Professionals 24 (241 all)

Finance Professionals 241, Administration Professionals 242, Sales, marketing and public relations professionals 243

Legal, Social, Cultural and Related Associate Professionals 34 (all) (242)

Legal, social and religious associate professionals 341 (343), Sport and fitness workers 342 (347), Artists, cultural and culinary artist professionals, 343 (347)

Business and Administration Associate Professionals 33 (excluding 335):

Financial and Mathematical Associate Professionals 331 (343), Sales and Purchasing Agents and Brokers 332 (342), Business Services Agents 333 (342)

Administrative and Specialized Secretaries 334 (332)

Other R&D work and an education field in the social sciences and business and 2,21,22,3,31,32

RD work

Technical and mathematical work professional R&D managers 1223 (1237)

Science and Engineering Professionals 21 (excluding telecommunication engineering 2153)

Physical and earth science professionals 211 (211), Engineering Professionals 212 (212) Mathematicians, Statisticians, Life-science professionals 213 (212), 214 (212), Electrical, Electronics Engineering 2151, 2152 (212), Architects, Planner 216 (212)

Health professionals 22

Medical doctors 221 (222), Nursing and Midwifery Professionals 222 (223), Other Health Professionals 226 (223), 22 (isco3 not available)

Science and Engineering Associate Professionals 31

Physical and Engineering Science Technicians 311 (311), Life Science Technicians and Related Associate Professionals 314 (321)

Other OC work and an education field not in the social sciences and 1,12,13,23,24,34

ICT work

ICT managers 133 (1236)

Telecommunication engineering 2153 (213)

Information and Communications Technology Professionals 25

Information and Communications Technicians 35 (312)

Nursing and Midwifery Associate Professionals 226 (322)

Other IC work and Isced2011 within computing and 2,21,22,3,31,32

Other IC work and Isced2011 within computing and 1,12,13,23,24,34

Regarding the top three major groups, employees with other classifications are classified into the ICT category if their education is ICT-related and into the Organizational category if their education is within the social sciences. For employees whose occupation data is not available in a given year, their occupation data was imputed by using the past year's occupation. If this is not available, the employees are assumed to contribute to one of the three types of intangibles investments if their education level is a bachelor's degree or higher and if their education field is within a relevant area.

Calculations are made based on wage income and a multiplier that accounts for the fact that not all work activities contribute to knowledge creation and that nonlabor expenditures constitute intangibles' investments. H. Piekkola (2016) provides the value of a combined multiplier A^{IC} presented in equation (1), which is time invariant in the expenditure-based approach. The share of worker income that produces intangible goods is set at 20 % for organizational occupations (twice the share used in (Görzig et al., 2010)), 70 % for RD occupations and at 50 % for ICT occupations. The factor multiplier from the intermediate and capital costs is set to represent the entire EU27 area and is a weighted average of the factor multipliers for Germany (40 % weight), the United Kingdom (30 % weight), Finland (15 % weight), the Czech Republic, and Slovenia (both countries have weights of 7.5 %).[29] The factor multipliers employed account for the use of capital, and intermediate inputs are 1.76 for organizational wage expenses, 1.55 for R&D wage expenses, and 1.48 for ICT wage expenses. Labor costs are annual earnings instead of hourly wages because (1) the earnings include performance-related pay and (2) workers in managerial positions are not paid for overtime hours. As a result, the managers' recorded hours are consistently lower than the actual number of hours worked. Table A.1 summarizes the combined multiplier A^{IC} (the

[29] The input-output tables are from the EU KLEMS database, and the countries are covered with LEED data from INNODRIVE, which is the product of the 6th framework research project financed by the European Commission to analyze productivity in the European Union at the industry level.

approximate product of the share of effort devoted to IC production and the factor multiplier) and the depreciation rates that we employed.

Table A3.1. Combined multipliers for OC, RD and ICT in the expenditure-based approach and their depreciation

	OC	R&D	ICT
Employment shares	20 %	70 %	50 %
Combined multiplier A^{IC}	35 %	110 %	70 %
Depreciation rate	20 %, 25 % for service industries	15 %	33 %

Organizational and ICT investments represent 70 % of the labor costs in the occupations that we consider (in ICT, the figure is an approximation of the combined multiplier of 0.74). In RD activities, the total wage costs are close approximations of the total investment, and they have a combined multiplier of 110 %.

Table A3.2. Intangibles per employee in thousands of Euros[30].

Denmark	RD per employee		OC per employee		ICT per employee		employees	
year	mean	median	mean	median	mean	median	mean	median
1999	54	23	17	11	12	3.1	45	19
2000	43	17	15	10	9.3	2.3	49	20
2001	44	16	15	9.3	8.8	2.1	50	20
2002	42	13	15	8.5	8.3	1.9	48	20
2003	37	9.4	14	7.0	7.8	1.5	46	19
2004	36	8.6	13	6.9	7.9	1.4	46	19
2005	36	8.6	14	7.2	8.0	1.4	47	20
2006	35	8.5	13	7.1	8.3	1.3	49	20
2007	34	8.3	14	7.0	8.3	1.3	49	20
2008	36	10	15	7.6	8.4	1.4	49	20
2009	41	11	16	8.9	10	1.6	46	20
2010	41	11	17	9.3	10	1.7	47	20

[30] The yearly exchange rates from Denmark's central bank http://nationalbanken.statbank.dk/nbf/100249 .

2011	40	11	17	9.2	10	1.8	49	20
2012	43	11	18	10	11	1.8	50	21
2013	43	11	18	10	11	1.8	52	21

Finland	RD per employee		OC per employee		ICT per employee		employees	
year	mean	median	mean	median	mean	median	mean	median
1999	46	21	10	5.0	8.4	2.0	99	27
2000	48	21	10	5.1	8.9	2.0	104	29
2001	49	22	10	5.3	9.5	2.1	111	30
2002	51	22	10	5.3	10	2.1	107	31
2003	52	23	10	5.4	10	2.2	109	31
2004	54	24	11	5.5	10	2.3	110	32
2005	56	25	11	5.6	10	2.4	110	32
2006	56	27	11	5.5	10	2.3	121	35
2007	57	27	11	5.7	11	2.4	123	35
2008	58	28	12	5.8	11	2.6	125	36
2009	59	30	11	5.9	11	2.8	121	35
2010	62	32	12	5.9	12	3.0	122	34
2011	63	32	11	5.7	12	3.1	125	35
2012	65	34	12	6.1	12	3.3	125	36
2013	68	37	12	6.2	13	3.6	123	36

Why do some SME's become high-growth firms? The role of employee competences

Carita Eklund

University of Vaasa

Abstract

High-growth firms generate a large share of new jobs and are thus the key drivers of innovation and industry dynamics. As the employees' education supports innovation and productivity, this article's hypothesis is that employee competences explain high growth. We approach this by examining intangible capital and specialized knowledge, such as design and engineering, to evaluate how these characteristics support the probability of becoming a high-growth firm. The estimation uses linked employer–employee data from Danish registers from 1999 to 2013. The use of the size-neutral Birch index enables us to define high growth, allowing the examination of the determinants of high growth across different size classes. The findings imply that intangible assets relate positively to the firm's high growth in the subsequent three years.

Keywords: high education, firm growth, high growth, fast growth, employment, intangible capital

Introduction

What are the main factors driving the rapid growth in firm size? The firms experiencing this type of growth are often called high-growth or fast-growing firms, and they are the biggest generators of new jobs (Hölzl, 2013; Schreyer, 2000) and thereby strengthen the business environment. High growth is an especially important topic in Nordic countries, where a high level of employment is needed to finance the expensive welfare state.

For (total factor) productivity growth, new firms represent one channel, where the entrepreneur has either a new idea, a strong network, or the conviction that he or she could earn more on his or her own than he or she could through stable employment. Previous literature has found a significant relationship between the owners' education and high growth (Almus, 2002; Bates, 1990). However, limiting us to owner characteristics limits our ability to assess the gains from diversity and teams. Furthermore, growth presents new challenges when an organization and production expand. To handle these challenges, firms need a range of competencies. For example, Parrotta, Pozzoli, and Pytlikova (2014) explained firm productivity in Denmark with educational, ethnic, and demographic diversity. They find that educational diversity supports productivity. As high growth could result from a firm being more productive than other firms, educational differences should be able to explain a firm's growth rate exceeding the market's growth rate.

While educational diversity supports productivity (Parrotta et al., 2014), the share of highly educated employees supports firm innovation (Østergaard, Timmermans, & Kristinsson, 2011). Indeed, the innovation literature highlights the role of knowledge-intensive employees, as knowledge resides in people (Harris & Moffat, 2013). Education is also an important pillar for absorptive capacity (Nelson & Phelps, 1966). Absorptive capacity is needed to remain updated regarding new trends in the industry or to gain access to publicly produced knowledge, the understanding of which requires the ability to decode scientific results and to engage in collaboration. The innovation literature sees absorptive capability as an important part of the development process (Cohen & Levinthal, 1990). Further, Daunfeldt, Elert, and Johansson (2016) find that for high growth, knowledge intensity matters more than does R&D intensity.

The objective of this essay is to determine whether there are different and diverse types of human capital resources needed for high growth. It aims to broaden the literature of high-/fast-growth firms by including the role of higher education among all employees rather than just owners. Education has been used to explain the growth of a firm but not the high-growth phenomenon. Furthermore, we account for the position of educated employees. For example, a person with a master's degree can put his or her knowledge to better use when he or she works in a more knowledge-intensive position, e.g., a position in management rather than as a cashier. The concept capturing this distinction is called intangible capital, and it approximates the knowledge capital generated by employees performing activities in research and development (RD assets), marketing and management (organizational capital, OC, assets) and information communication technology (ICT assets).

The remainder of the paper is structured as follows. The next section reviews the previous literature on high-growth firms and discusses related theories. Section 3 presents the hypothesis, and section 4 reviews methods and data. Section 5 presents the results, and the last chapter discusses their implications.

Literature review

High-growth firms can be defined in multiple ways, as reflected by the broad literature discussing plausible definitions (D. G. Birch, 1979; Coad & Hölzl, 2012; Eurostat-OECD, 2008; Hölzl, 2013; Sutton, 1997). First, one needs to choose which form of high growth to measure: sales or employment. As also argued by Hölzl (2013), employment is a more future-oriented measure than sales, as changes in employment mirror the expected future sales of the firm. Second, one needs to choose how growth is measured: in absolute growth (exact number of new employees) or relative growth (in percent growth). Relative versus absolute measures have been shown to select differently sized high-growth firms. The most recent literature is concerned with the overrepresentativeness of small firms as high-growth firms. Absolute growth, i.e., the number of new employees, favors large companies, whereas relative growth, the share of new employees, favors small firms. Thus, a common solution is to exclude firms smaller than 10 or 20 employees from the sample (Hölzl, 2013). D. G. W. Birch (1979) solved this by using both relative and absolute growth in her index. The 5 % to 10 % highest index-valued firms are then chosen to be the high-growth firms. To account for these definition issues, the primary definition follows Birch's index, while the OECD definition is used as a robustness test.

(1) $B_{index} = (size_t - size_{t-3}) * \frac{size_t}{size_{t-3}}$

The use of the Birch index is challenged by the fact that combining or separating business areas will produce different groups of HGF. A way around this is to use a definition independent of other companies. Eurostat-OECD (2008) defines companies with a 20 % yearly growth in sales or employment during three subsequent years as high-/fast-growing firms if they also fill certain criteria, including a minimum of 10 employees at the start of those three years and an age of over one year. These limitations are established to limit biases from small size firms (e.g., doubling employment by employing one more person) and to recognize the problems of a firm's first year in the markets (Eurostat-OECD, 2008). Young firms have another measurement: the gazelle designation. A firm is called a gazelle if it is at most five years old and if it has achieved an average growth of 20 % over three subsequent years. Each of these definitions has its own benefits, but here, the primary focus is on the Birch index due to its size neutrality. Gazelles are a very different group of firms than are Birch high-growth firms and thus are only touched upon in the results.

Denmark is an interesting business area to study, as recent research finds that many SMEs in Denmark end up trapped at a specific size (Calvino, Criscuolo, & Menon, 2015; European Commission, 2017). For example, Calvino et al. (2015:24) note that during the recession, the exit rates peaked when Danish firms reached ages 3 and 4. The turbulent exit rate peak for Finnish firms is 6-7 years. Moreover, the start-up rates are lower in Denmark than in many other countries (Calvino et al., 2015:18). Based on this observation, we also hypothesize that the initial size might matter.

Gibrat's law

The relation between firm size and growth has earned much attention. Gibrat's law states that the growth rate of a firm should be independent of its size. Thus, if the growth rate is statistically normally distributed, the current size will be the sum of all previous shocks at the limit. As presented in Coad (2009, p. 39) and Sutton (1997), firm size is a function of independent and identically distributed (i.i.d.) shocks and the previous year size:

(2) $size_t = (1 + \varepsilon)size_{t-1}$

Substituting the previous year size in the equation in a similar manner, taking logs, and assuming that log (1+x) approximately equals log(x) given that x is close to zero, we obtain:

(3) $log\ (size_t) \approx \log(size_0) + \sum_{s=1}^{t} \varepsilon_s$

The literature testing Gibrat's law is broad. For example, Lotti, Santarelli, and Vivarelli (2003) discuss the case of small new firms. They find that during the first year, the rule fails, but when a critical mass in age and size is achieved, the law holds. Furthermore, Almus (2002) explained that a firm grows faster before it reaches a minimum efficient scale. Earlier empirical investigations found that larger firms grow faster than small firms; however, later research finds the opposite (Coad, 2009, p. 41). In Denmark, firm exit rates peaked at age three during the recession, and Calvino et al. (2015) label this a growth trap. This research accounts for size by looking at the Birch index but also by including the logarithmic number of employees at the start of the HGF-counting periods.

The industrial organization literature has discussed how much firm size matters for further growth in size. While Gibrat's law opened the discussion by identifying size independence, empirical studies have mixed results. Young firms need a critical mass to remain in the markets, and growth might be the key. A theoretical model of Jovanovic (1982) shows how small new firms grow fast or fail. An extension of this model is presented by Hopenhayn (1992), where productivity follows a Markov process. Thus, high growth is closely linked to the productivity puzzle, endogenous growth theory and the theory of entrepreneurship. In other words, high growth is about realized competitive advantage.

Knowledge

Diversity in knowledge

There are many diversity indices that can be used for measuring different types of diversity. To approximate diversity in variety, Harrison and Klein (2007) suggests the Blau index. The Blau index, also known as the Gini-Simpson index, assumes that "members differ from one another qualitatively" (Harrison & Klein, 2007, p. 1204). This assumption fits well with educational data, as the chosen field is a qualitative measure. As presented in equation 4, the index is calculated as one minus the sum of the squared category shares and obtains values between zero and one.

(4) $blau = 1 - \sum_{k=1}^{K} {p_k}^2$

Thus, the Blau index is formed with diversity in the educational field only. The field, e.g., the category, is constructed from the Danish Statistics, which identify a field by using six digits. For example, there are 14 different six-digit numbers within the broader design field and one six-digit number within finance. The different number of codes per the upper category field is another reason to utilize the Blau index: it does not reflect the distance between the chosen observations. Again, design is a good example: five of the codes start with 5, and nine start with 30, whereas all the humanities codes start with 24, and engineering is located between 44 and 59. Therefore, a category utilizes the six digits only to identify a difference between the areas of education.

Intangible capital

The use of intangible capital to approximate the knowledge capital in a firm is a fairly new concept. Eklund (2018) discusses how intangibles are linked to innovativeness measures in the CIS. The results suggest that firms with an intangibles' value above the industry mean have a tendency to launch more new-to-the-world, new-to-the-market and new-to-the-firm products, thus supporting pure product innovation and different levels of imitation. Intangibles also have a positive and significant relation to process innovation, i.e., they improve the production process by making it quicker or more efficient in terms of using less materials and other inputs, such as storage space.

Following Görzig, Piekkola, and Riley (2010), intangibles are divided into three parts: research and development assets (RD), organizational capital assets (OC) and information communication assets (ICT). For each intangible type, the current value of the capital equals the investment plus the share of the previous year's capital that has not depreciated. There are at least two routes to approximate investments for intangibles presented in Görzig et al. (2010): either from the use of intermediate inputs and assuming a constant share of the firms' own labor used or from the firms' own labor and assuming a fixed share of the intermediates used. To better reflect internal intangibles, this article uses the firms' own labor rather than purchased external intangibles. This choice is in line with the theoretical assumption that knowledge resides in people (Harris & Moffat, 2013).

Thus, this article utilizes linked employer–employee datasets with the education and the occupation of employees to identify intangible capital-producing employees. Then, a share of their time is assumed to be of an *investment nature*, thus contributing to the firm's performance in the subsequent periods. The measured investment also accounts for an average share of the intermediate inputs used. Görzig et al. (2010) report a combined multiplier that can be used to approximate the total investment in intangibles from the employees' wages. The combined multiplier is 35 % for OC, 110 % for RD and 70 % for ICT assets. Equation (5) presents the capital formulation of intangibles, where $R_{i,t}^{IC}$ is the intangible assets capital at time t=0 for firm i, N denotes investments and δ the depreciation rate that varies from 15 % to 33 %[31]. To approximate the first year's capital stock, a geometric sum formula is used and presented in equation (6). The first year's investments in intangible capital assets are divided by the sum of the depreciation rate and growth rate of intangible capital.

[31] The depreciation rates are as follows: the OC rate is 20 % in non-service and 25% in service industries; the RD rate is 15 %; and the ICT rate is 33%.

(5) $R_{i,t}^{IC} = N_{i,t}^{IC} + (1 - \delta^{IC})R_{i,t-1}^{IC}$

(6) $R_{i,t=0}^{IC} = N_{i,t=0}^{IC} / (\delta^{IC} + g)$

The main advantage of using intangible assets is that it treats knowledge efforts as investments and capitalizes them. Hence, we account for knowledge efforts supporting productivity in the following periods.

Hypothesis development

Building upon the theory of absorptive capability (Cohen & Levinthal, 1990), the creation of new products, services and processes requires the capabilities to use what is out there already. In other words, the ability to use external knowledge is required for innovation development. The key to accessing external knowledge is usually seen as higher education. Nelson and Phelps (1966) develop a theoretical model of how education affects the rate of technological diffusion, proving that education is more beneficial in dynamic economies with technologically high rates of progress. Thus, in Denmark, we can expect the following:

Hypothesis 1a. Highly educated employees matter for a firm's high growth probability.

Another aspect to consider is that high education might not produce the full benefits possible if the employee is not working in the area of his or her expertise or is located low in the firm hierarchy. Thus, his or her skills can remain undetected for a longer time. To account for these possibilities and for the capitalization of knowledge, we can expect the following:

Hypothesis 1b. Intangible capital has a positive relation with the firm's high growth probability.

Intangible capital is a beneficial factor for several reasons. First, knowledge is capitalized such that the benefits from intangibles, such as a new marketing strategy produced by organizational and marketing personnel, also affect the current period. Second, intangible capital construction methods imply that the employee is in a position in which he or she can create intangible capital. Third, we assume that his or her level and field of education fit with his or her position in the firm. Eklund (2018) discusses how intangible capital can be used as a measure for innovation capability and that there exists a relation between innovativeness and lagged intangible assets.

To complement hypothesis 1a, one might think that the field of education could bring different gains. Some might even argue that we do not know if the level of education signals the employees' higher abilities even before the actual education or if *education adds capabilities and useful knowledge*. Optionally, if only the academic way of thinking supports plausible development, then we should not see a difference in the contribution between degrees with different majors. Thus, this article tests some specializations, namely, design and engineering. Design is a part of an arts education that can be quite easily utilized in firms, whereas engineering is a part of a science education that is crucial in product development.

Furthermore, different perspectives could create something new, as Østergaard et al. (2011) discuss in their paper about diversity in innovation. Based on the possible gains to innovation, we can hypothesize that diversity in education can support at least innovation-based high growth. Thus, we develop the following hypothesis.

Hypothesis 2. Different specializations in education should support high growth.

Methods and data

High-growth firms are the fastest growing businesses in the economy in a given period. They are measured by using either sales or employment growth, and I choose to concentrate on the latter because employment is a more future-oriented measure than sales. The main explanatory variable is the Birch index (Birch, 1979) that is the closest to the size-neutral measure. As discussed previously, size may affect firm growth rates negatively, positively, or not at all.[32] Using the Birch index, following the Eurostat-OECD (2008) definition, I define a latent variable that is given the value one when the firm is among the fastest growing 5 % of firms during a three-year period,. Otherwise, the latent variable y equals zero.

The explanatory variables of the analyses consist of the employees' education—master's or PhD degree and a degree from the fields of finance, design, humanities or engineering—and measures for diversity. Diversity is measured with dummies and the Blau index. The control variables include investments, employees, and dummies for the year and industry.

Table 1 reports the data. The strength of Birch is that we can include all firms that have a positive number of employees. The independent variable's value originates at the time before the high-growth status was achieved, t-3. The share of high-

[32] Firms without sales or employees are excluded from the analyses.

growth firms is slightly over 5 %, probably resulting from taking data points at the boundary into the HGF category.

Table 4.1. Comparison of means.

Variable[1]	N	Mean	Var	Sd	Min	Max
HGB 5 %	394046	0.05	0.05	0.22	0	1
HGB 10 %	394046	0.10	0.09	0.31	0	1
Blau index	395894	0.88	0.036	0.19	0	1
ShareHighEdu	394046	0.05	0.02	0.13	0	1
AvTenure	394046	2.02	3.36	1.83	0	11
Firms with designers	394046	7 %	0.07	0.26	0	1
Firm with engineers	423908	23 %	0.08	0.28	0	1
Firm age	394046	17.58	155.07	12.45	3.00	144

[1]Explanatory variables report years from 2005 to 2011, as they are used in the regressions

Table 1 describes the distribution of the Blau index, with a minimum value of -2.5 and a maximum of 1. The share of highly educated employees (ShareHighEdu) is, on average, 5 %. The average tenure of an employee (AvTenure) is slightly over 2 years in each firm. Average tenure is calculated from the sample and is thus limited to a range of 0 to 11. Naturally, tenure is slightly correlated with the age of the firm, ranging from 3 to 144 years. The average age of the firm is slightly over 17 years. Firms with designers and engineers both represent less than 25 % of the sample. The appendix reports more precise summary statistics categorized by the high-growth status.

The function to be estimated is presented in equation 5, where HGF stands for the latent variable denoting a high-growth firm. The intangible capital variables are RD, OC and ICT, which represent research and development, organizational assets capital (including both management and marketing investments) and ICT capital. They are included in the logarithm that is replaced to equal zero when the asset itself is zero. Blau stands for the Blau diversity index. ShareHighEdu is a variable for the share of employee(s) with a master's or PhD degree. Similarly, ShareDes and ShareEng are the shares of employees with a degree in design, or engineering, respectively. AvTenure is the average tenure of employees at the firm. $HGF_{i,t-3}$ is a previous high growth status. Expinten describes the share of sales going outside Denmark, and lnemp represents the logarithm of employment. Finally, Age is the age of the firm. The control variables are industry and year dummies.

$$(5) \quad HGF_{i,t} = lnRD_{i,t-3} + lnOC_{i,t-3} + lnICT_{i,t-3} + Blau_{i,t-3} + ShareHighEdu_{i,t-3} + ShareDes_{i,t-3} + ShareEng_{i,t-3} + AvTenure_{i,t-3} + HGF_{i,t-3} + Expinten_{i,t-3} + lnemp_{i,t-3} + Age_{i,t-3}$$

The estimation method is the probit probability estimation, where industry dummies are used as controls. The sample is split into three parts to examine a firm becoming a high-growth firm from 2005 to 2007, from 2008 to 2010, and from 2011 to 2013. The last column combines these three ranges by using year dummies. The next chapter presents and discusses the results. Thus, we can detect whether some firm characteristics support high growth better in recessionary (financial crisis) periods or in recovery period than they do overall. This detail might allow the best potential job creators to be identified for different circumstances, thus helping policymakers to support the most efficient job creation.

Results and discussion

This chapter reports the results by using a maximum likelihood estimation with a natural cumulative probability distribution function, as discussed in the previous chapter. The following tables present the marginal effects. Tables 2 and 3 report the estimation of a Birch-defined high-growth firm (HGB). Table 2 defines the top 5 % highest growing firms as Birch high-growth firms, and table 3 defines the top 10 % highest growing firms as Birch high-growth firms. As a robustness check, table 4 reports OECD sales-defined high-growth firms as an example of the sales-based high-growth phenomenon[33].

Each table has four regressions divided by the period. Columns (1)-(3) consist of a three-year measure of high growth. For example, HGB 0507, in table 2, reports estimations for the probability of a firm being a Birch-defined top 5 % high-growth firm during 2005 to 2007. The next regression is for high growth in 2008 to 2010, and the third is for high growth in the period 2011 to 2013. The last regression combines the measurement periods. Similarly, table 3 reports the top 10 % highest growing firms based on the Birch index, and table 4 reports the OECD sales-defined high-growth firms (HGF).

The tables report high-growth firms as the dependent variable, and the independent variables consist of knowledge measures, as in equation 2. All independent variables are lagged by three years from the year when the firm is evaluated for high growth. For example, column (1) has independent variables in 2005, and Birch high growth is evaluated based on the three subsequent years 2005–2007.

[33] The goodness of fit tables are available on request.

Table 2 reports the marginal effects influencing the Birch measure-based membership of the 5 % highest growing firms. We can easily see that having intangible capital supports the probability of high growth. The marginal effects from the logarithm of research and development (RD) seems low, 0.001-0.0006, but are statistically significant in all periods other than 2011–2013. The intangibles are calculated in Danish kroner. The coefficients for organizational capital assets (OC) and ICT assets (ICT) are larger in size and statistically significant at the 1 % level in all subsections and throughout the whole period of observation, as seen in column (4). Contrary to our hypothesis on diversity, the Blau index has negative values in each column, suggesting a negative correlation between educationally diverse firms becoming high-growth firms three years after. Further, firms with a longer average tenure of employment (Avtenure) have a negative probability of becoming a top 5 % growth firm. This result might be correlated with the age of the firm, which has a negative and significant effect as well. However, the firm's starting size as measured by the number of employees (emp) has a positive relation to high growth in all sub periods. Thus, the results do not support Gibrat's law: size seems to correlate with high growth. The share of employees with a design degree (ShareDes) has positive and statistically significant coefficients in 2005–2007 and 2011–2013 but a negative and significant coefficient in the middle period. The entire period effect stays positive, at approximately 0.03, and statistically significant at the 1 % level. The presence of engineers also has a strong positive prediction power, but in 2011–2013, the coefficient is nonsignificant. This might reflect the positive developments in electronics in many fields. Furthermore, export intensity (expinten) has no statistical significance, and age has a negative relation with the probability of high growth. Further, a previous high growth (HGF5) status seems to increase the likelihood of a firm being a high-growth firm three years after.

Table 4.2. Marginal effects on a Birch-defined 5 % HGF

VARIABLES	(1) HGB 2005-2007	(2) HGB 2008-2010	(3) HGB 2011-2013	(4) HGB all years
log RD [(1)]	0.000563**	0.000312	0.000593**	0.000488***
	(0.000249)	(0.000265)	(0.000270)	(0.000151)
log OC [(1)]	0.00312***	0.00402***	0.00342***	0.00359***
	(0.000336)	(0.000350)	(0.000351)	(0.000199)
log ICT [(1)]	0.00161***	0.00125***	0.00195***	0.00157***
	(0.000311)	(0.000329)	(0.000321)	(0.000185)
Blau index [(1)]	-0.115***	-0.112***	-0.109***	-0.111***
	(0.00481)	(0.00475)	(0.00442)	(0.00268)
ShareHighEdu [(1)]	-0.0289	0.0156	0.0193	0.00959
	(0.0264)	(0.0193)	(0.0173)	(0.0114)
ShareDes [(1)]	0.0493***	-0.0325**	0.0387***	0.0255***
	(0.00902)	(0.0137)	(0.0103)	(0.00621)
ShareEng [(1)]	0.00659**	0.0128***	0.000736	0.00684***
	(0.00260)	(0.00382)	(0.00370)	(0.00188)
AvTenure [(1)]	-0.000962	-0.00392***	-0.00254***	-0.00275***
	(0.000736)	(0.000507)	(0.000379)	(0.000276)
HGF5 [(1)]	0.0316***	0.0277***	0.0280***	0.0287***
	(0.00224)	(0.00247)	(0.00233)	(0.00135)
expinten[(1)]	0.0161*	0.000586	0.000387	0.000340
	(0.00838)	(0.00256)	(0.000323)	(0.000295)
log emp[(1)]	0.0227***	0.0163***	0.0197***	0.0195***
	(0.00108)	(0.00111)	(0.00108)	(0.000627)
age[(1)]	-0.000548***	-0.000120**	-0.000469***	-0.000346***
	(0.0000603)	(0.0000506)	(0.0000607)	(0.0000325)
Observations	72,188	71,279	71,991	215,514
Industry dummies	yes	yes	yes	
Industry & year dummies				yes

Standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1; [(1)] lagged by 3 years. HGB stays for Birch-defined high-growth firm. Years (such as 2005-2007) reflect the three-year period during which the growth was evaluated. In case of column (1), a high growth status is given in 2007 based on the growth from 2005.

Table 3 reports the marginal effects for the first robustness check to the estimation. The difference between it and table 2 is that table 3 captures the top 10 % highest growing firms instead of the top 5 % highest growing ones. There are some interesting differences. First, the research and development assets (RD) are statistically significant for the 2005–2007 and 2011–2013 period, but for the entire period, column (4) also remains statistically significant. Organizational capital (OC) assets and ICT assets keep their positive and significant relation to high growth. The relations between high growth and the shares of highly educated employees (ShareHighEdu), designers (ShareDes) and engineers (ShareEng) are close to the same as those in table 2 with some exceptions. The share of highly educated employees is related positively to Birch-measured high growth (10 %) and was statistically significant in the middle period. The share of designers is insignificant in the middle period and the share of engineers is weakly significant in 2011–2013. Further, age, the Blau index, size (log emp) and HGF10 have the same patterns as those in table 2. Thus, intangible capital assets relate positively to the firm's high growth, i.e., hypothesis 1B. However, we do not find proof for hypothesis 1A: the relation of high growth and the share of highly educated employees is insignificant. We obtain some support for hypothesis 2: different educational specializations should support high growth. Specifically, both design and engineering backgrounds supported high growth. However, educational diversity as measured with the Blau index negatively relates to high growth.

However, the results for the share of tenure are worrisome from a policy perspective. The results imply that the longer people work in the same place, the less likely the firm will be a high-growth firm. This correlation does not arise solely from the age of the firm, although that correlation is likely. It seems that employee turnover is good for the extreme case of high growth[34].

[34] Average tenure is chosen for analysis in the tables instead of a different measure such as new employees because the average tenure supported the predictive power of the model. The goodness of fit tables are available on request.

Table 4.3. Marginal effects on a Birch-defined 10 % HGF.

VARIABLES	(1) HGB 2005-2007	(2) HGB 2008-2010	(3) HGB 2011-2013	(4) HGB all years
log RD [(1)]	0.00149***	-0.000356	0.00142***	0.000858***
	(0.000344)	(0.000370)	(0.000375)	(0.000210)
log OC [(1)]	0.00548***	0.00691***	0.00671***	0.00657***
	(0.000452)	(0.000476)	(0.000479)	(0.000271)
log ICT [(1)]	0.00208***	0.00196***	0.00407***	0.00266***
	(0.000463)	(0.000495)	(0.000475)	(0.000276)
Blau index[(1)]	-0.195***	-0.168***	-0.172***	-0.178***
	(0.00701)	(0.00719)	(0.00652)	(0.00398)
ShareHighEdu [(1)]	-0.0293	0.0689**	0.0131	0.0266
	(0.0355)	(0.0284)	(0.0276)	(0.0170)
ShareDes [(1)]	0.0426***	-0.0295	0.0654***	0.0313***
	(0.0149)	(0.0183)	(0.0146)	(0.00912)
ShareEng [(1)]	0.0148***	0.0320***	0.00888*	0.0188***
	(0.00408)	(0.00529)	(0.00505)	(0.00279)
AvTenure [(1)]	0.00174*	-0.00788***	-0.00516***	-0.00506***
	(0.000978)	(0.000700)	(0.000510)	(0.000374)
HGF10[(1)]	0.0463***	0.0301***	0.0345***	0.0355***
	(0.00281)	(0.00315)	(0.00294)	(0.00170)
expinten[(1)]	0.0388***	0.00221	0.00100*	0.000846*
	(0.0118)	(0.00419)	(0.000531)	(0.000479)
log emp[(1)]	0.0385***	0.0232***	0.0267***	0.0293***
	(0.00155)	(0.00164)	(0.00158)	(0.000916)
age[(1)]	-0.000991***	-0.000119*	-0.000840***	-0.000580***
	(0.0000846)	(0.0000725)	(0.0000856)	(0.0000458)
Observations	72,188	71,279	72,001	215,514
Industry dummies	yes	yes	yes	
Industry & year dummies				yes

Standard errors are in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$, [(1)] Denotes that variables are lagged by 3 years. HGB stays for Birch-defined high-growth firm. Years (such as 2005-2007) reflect the three-year period during which the growth was evaluated. In the case of column (1), the high-growth status is given at 2007 based on the growth from 2005.

Finally, table 4 reports an estimation with OLS for Birch 10 % HGF for robustness. All intangible capital coefficients are similar to those in table 3. Overall, in the probability estimation, there are only minor differences: there are differences in statistical significance in 2011–2013 for share of engineers, export intensity and in 2008–2010, for the firm age.

Table 4.4. OLS estimation of a Birch-defined 10 % HGF

VARIABLES	(1) HGB 2005-2007	(2) HGB 2008-2010	(3) HGB 2011-2013	(4) HGB all years
log RD[(1)]	0.00129***	-0.000975***	0.000957***	0.000454**
	(0.000348)	(0.000366)	(0.000367)	(0.000208)
log OC[(1)]	0.00370***	0.00558***	0.00486***	0.00487***
	(0.000432)	(0.000456)	(0.000453)	(0.000258)
log ICT[(1)]	0.00555***	0.00348***	0.00705***	0.00533***
	(0.000556)	(0.000561)	(0.000547)	(0.000320)
Blau index[(1)]	-0.274***	-0.214***	-0.218***	-0.232***
	(0.00847)	(0.00854)	(0.00762)	(0.00472)
ShareHighEdu [(1)]	-0.0156	0.118***	0.0361	0.0510***
	(0.0356)	(0.0345)	(0.0309)	(0.0194)
ShareDes [(1)]	0.0489***	-0.0286	0.0760***	0.0344***
	(0.0170)	(0.0176)	(0.0163)	(0.00981)
ShareEng [(1)]	0.0155***	0.0340***	0.00965**	0.0201***
	(0.00434)	(0.00505)	(0.00476)	(0.00271)
AvTenure [(1)]	0.00770***	-0.00495***	-0.00192***	-0.00156***
	(0.000926)	(0.000629)	(0.000440)	(0.000331)
HGF10[(1)]	0.0794***	0.0476***	0.0542***	0.0581***
	(0.00347)	(0.00370)	(0.00350)	(0.00205)
expinten[(1)]	0.0489***	0.00247	0.00146**	0.000904*
	(0.0130)	(0.00457)	(0.000623)	(0.000529)
emp[(1),(2)]	0.0621***	0.0354***	0.0429***	0.0460***
	(0.00175)	(0.00182)	(0.00177)	(0.00102)
age[(1)]	-0.000938***	-6.47e-05	-0.000923***	-0.000632***
	(0.0000821)	(0.0000818e)	(0.0000837)	(0.0000477)
Constant	0.0587***	0.194***	0.181***	0.170***
	(0.0218)	(0.0122)	(0.00873)	(0.00537)
Observations	72,189	71,28	72,05	215,519
R-squared	0.092	0.046	0.066	0.062
Industry dummies	yes	yes	yes	yes

Standard errors are in parentheses,
*** p<0.01, ** p<0.05, * p<0.1, [(1)] Denotes variables are lagged by 3 years. HGB stays for the Birch-defined high-growth firm. Years (such as 2005-2007) reflect the three-year period during which the growth was evaluated. In case of column (1), high growth status is given at 2007 based on the growth from 2005.

Thus, some characteristics of firms have prediction power for the rare event of high growth, as measured during three years with the size-neutral Birch index. The most important explanatory factors for high growth are knowledge variables such as the share of engineers and organizational capital assets. Interestingly, the share of tenure has a negative relation with high-growth probability. This effect does not come from employing more new employees: adding them reduced the prediction power of the model. The negative effect might in part be due to a relation to the age of the firm, which also has a negative coefficient. A possible but depressing conclusion could be that as an organization ages, employees become too used to their roles and start to counteract large changes in the organization. Testing this possible conclusion would require a closer evaluation of employee mindsets in the firms, which is beyond the scope of this research.

Conclusion

This article has evaluated the gains from innovativeness to firm high growth, measured using a size-neutral employee definition, namely, the Birch index. We find that intangible capital supports the probability of high growth. The share of designers in firms supported high growth in periods other than the financial crisis years, but the share of engineers supported it in all years, although the coefficient was only weakly significant in the recovery period. Further, we find no support for Gibrat's law in the context of high growth or growth measured by the Birch index. Size relates positively to high growth.

The results can be to some degree Denmark specific. First, the sample is formed by Danish firms. Thus, this article explains the high-growth phenomenon in the context of the Danish business environment. However, Denmark is an interesting example of an environment with a high price level. Many global firms struggle to be more efficient than competitors located in low-price-level countries. When a firm is located in a high-price-level country, such as the Nordic countries, its exports need to be either more innovative than the competing cheaper products are or produced more efficiently in the use of inputs than are the competitors' products. Another option would be to aim for markets with a similar high price level. However, there, the firm will meet similar price competition due to some degree of free trade.

The results report some current trends in Nordic countries and developed countries. One example is the significance of ICT assets, which support the development of the internet of things and the overall development of (phone) applications. The importance of engineering also signals that large developments in technology are now frequent. Furthermore, the importance of design is clear.

This result mirrors the increased attention to consumer experience and how it feels to use a product. It could also signal the trending design-thinking practice (Brown, 2008; Kazmierczak, 2003).

To conclude, innovation capabilities can support high growth, as seen in the results for intangible capital and the share of highly educated employees in the estimation. This result can be interpreted as innovativeness creating more jobs in the economy, as high-growth firms do generate the most new jobs (Hölzl, 2013; Schreyer, 2000). Future research could consider whether these high growth-supporting competences also helped firms to survive the financial crisis period.

References

Almus, M. (2002). What characterizes a fast-growing firm? *Applied Economics, 34*(12), 1497-1508.

Bates, T. (1990). Entrepreneur human capital inputs and small business longevity. *The review of Economics and Statistics*, 551-559.

Birch, D. G. (1979). The job generation process.

Birch, D. G. W. (1979). The Job Generation Process. *MIT Program on Neighborhood and Regional Change, 302.* Retrieved from https://ssrn.com/abstract=1510007

Calvino, F., Criscuolo, C., & Menon, C. (2015). Cross-country evidence on start-up dynamics.

Coad, A. (2009). *The growth of firms: A survey of theories and empirical evidence*: Edward Elgar Publishing.

Coad, A., & Hölzl, W. (2012). Firm growth: empirical analysis. *Handbook on the economics and theory of the firm.*

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative science quarterly*, 128-152.

Daunfeldt, S.-O., Elert, N., & Johansson, D. (2016). Are high-growth firms overrepresented in high-tech industries? *Industrial and corporate change, 25*.

Eklund. (2018). Innovation Capability from Intangible Assets. *Working paper.*

EuropeanCommission. (2017). *Country Report Denmark 2017: Communication from the Commission to the European Parliament, the Council, the European Central Bank and the Eurogroup*. Retrieved from Brussels:

Eurostat-OECD. (2008). Eurostat-OECD Manual on Business Demography Statistics.

Görzig, B., Piekkola, H., & Riley, R. (2010). Production of intangible investment and growth: Methodology in INNODRIVE. *INNODRIVE WP1*.

Harris, R., & Moffat, J. (2013). Intangible assets, absorbing knowledge and its impact on firm performance: theory, measurement and policy implications. *Contemporary social science, 8*(3), 346-361. doi:10.1080/21582041.2012.751498

Harrison, D. A., & Klein, K. J. (2007). What's the difference? diversity constructs as separation, variety, or disparity in organizations. *Academy of Management Review, 32*(4), 1199-1228. doi:10.5465/amr.2007.26586096

Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica: Journal of the Econometric Society*, 1127-1150.

Hölzl, W. (2013). Persistence, survival, and growth: a closer look at 20 years of fast-growing firms in Austria. *Industrial and corporate change, 23*(1), 199-231.

Jovanovic, B. (1982). Selection and the Evolution of Industry. *Econometrica: Journal of the Econometric Society*, 649-670.

Lotti, F., Santarelli, E., & Vivarelli, M. (2003). Does Gibrat's Law hold among young, small firms? *Journal of Evolutionary Economics, 13*(3), 213-235.

Nelson, R. R., & Phelps, E. S. (1966). Investment in humans, technological diffusion, and economic growth. *The American economic review, 56*(1/2), 69-75.

Parrotta, P., Pozzoli, D., & Pytlikova, M. (2014). Labor diversity and firm productivity. *European Economic review, 66*, 144-179.

Schreyer, P. (2000). *High-Growth Firms and Employment* (Vol. 3). Paris: OECD Publishing.

Sutton, J. (1997). Gibrat's legacy. *Journal of economic literature, 35*(1), 40-59.

Østergaard, C. R., Timmermans, B., & Kristinsson, K. (2011). Does a different view create something new? The effect of employee diversity on innovation. *Research Policy, 40*(3), 500-509. doi:http://dx.doi.org/10.1016/j.respol.2010.11.004

Appendix

The tables below report the data in detail, separated by a high-growth measure.

Table A4.1. Summary of high-growth statistics

	mean	median	sd	N	min	max
Not HGF at 5 %						
log RD[(1)]	3.21	0	3.78	281094	-1.95	15.77
log OC[(1)]	3.75	4.03	3.39	281094	-4.96	13.96
log ICT[(1)]	0.84	0	2.20	281094	-2.81	13.23

Blau[(1)]	0.88	0.94	0.18	280144	0	1.00
ShareHighEdu [(1)]	0.0041	0	0.035	280152	0	1
ShareDes [(1)]	0.012	0	0.070	280144	0	4
ShareEng [(1)]	0.23	0.13	0.29	280144	0	8
AvTenure [(1)]	2.59	2.17	2.20	280144	0	38
HGF5[(1)]	0.047	0	0.21	207144	0	1
HGF10[(1)]	0.098	0	0.30	207144	0	1
expinten[(1)]	0.64	0.28	1.26	281094	-53.46	11.69
log emp[(1)]	2.17	2.08	1.08	281094	0	10.08
age[(1)]	15.24	11	12.38	281094	0	141
Yes HGF at 5 %						
log RD[(1)]	4.29	4.75	4.21	15785	-0.69	15.61
log OC[(1)]	4.82	5.57	3.82	15785	-2.06	13.75
log ICT[(1)]	1.90	0	3.14	15785	-2.62	12.90
Blau[(1)]	0.82	0.97	0.30	15535	0	1
ShareHighEdu [(1)]	0.0074	0	0.066	15536	0	1
ShareDes [(1)]	0.015	0	0.083	15535	0	2
ShareEng [(1)]	0.23	0.096	0.35	15535	0	22.33
AvTenure [(1)]	1.71	1.23	1.89	15535	0	23
HGF5[(1)]	0.23	0	0.42	8828	0	1
HGF10[(1)]	0.32	0	0.47	8828	0	1
expinten[(1)]	0.64	0.28	1.65	15785	-53.46	11.69
log emp[(1)]	2.61	2.56	1.83	15785	0	9.68
age[(1)]	13.50	9	13.76	15785	0	135
No HGF at 10 %						
log RD[(1)]	3.18	0	3.77	265700	-1.95	15.47
log OC[(1)]	3.73	3.98	3.382239	265700	-4.96	3.41
log ICT[(1)]	0.82	0	2.16	265700	-2.81	12.89
Blau[(1)]	0.88	0.94	0.18	264871	0	1
ShareHighEdu [(1)]	0.0040	0	0.034	264878	0	1
ShareDes [(1)]	0.011	0	0.070	264871	0	4
ShareEng [(1)]	0.23	0.14	0.28	264871	0	8
AvTenure [(1)]	2.63	2.2	2.20	264871	0	38
HGF5[(1)]	0.045	0	0.21	197865	0	1
HGF10[(1)]	0.095	0	0.29	197865	0	1
expinten[(1)]	0.63	0.28	1.26	265700	-53.46	11.69
log emp[(1)]	2.16	2.08	1.06	265700	0	10.08
age[(1)]	15.35	11	12.30	265700	0	141
Yes HGF at 10 %						
log RD[(1)]	3.97	3.82	4.16	31179	-0.86	15.77
log OC[(1)]	4.51	5.17	3.71	31179	-2.35	13.96

log ICT[1]	1.59	0	2.93	31179	-2.63	13.23
Blau[1]	0.83	0.96	0.28	30808	0	1
ShareHighEdu [1]	0.0067	0	0.059	30810	0	1
ShareDes [1]	0.014	0	0.081	30808	0	2
ShareEng [1]	0.24	0.11	0.33	30808	0	22.33
AvTenure [1]	1.83	1.39	1.94	30808	0	37
HGF5[1]	0.16	0	0.36	18107	0	1
HGF10[1]	0.25	0	0.43	18107	0	1
expinten[1]	0.65	0.28	1.43	31179	-53.46	11.69
log emp[1]	2.44	2.40	1.63	31179	0	9.68
age[1]	13.44	9	13.65	31179	0	138