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Hain, Daniel S.; Christensen, Jesper Lindgaard

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The Small, the Young and the Innovative. A Panel Data Analysis of Constraints on External Innovation Financing*

Daniel S. Hain and Jesper Lindgaard Christensen

Aalborg University, Department of Business and Management, IKE / DRUID, Denmark

Abstract: This article investigates how access to external financing for innovation activities is affected by firm-specific structural, behavioral and outcome characteristics. External financing represents a critical factor in determining industrial evolution and technical change as well as firm's ability to survive, grow, and engage in innovative activities. Some characteristics of firms particularly associated with innovative and entrepreneurial ventures driving technological change are said to cause information asymmetries between financiers and finance seekers, making them less likely raise necessary external capital to fund innovation projects. Yet, there is little known about how different combinations of these characteristics affects their access to external financing and how contextual factors matter. Deploying a two-stage Heckman probit model on a panel data set spanning the period 2000-2013 and covering 1,169 Danish firms, we test hypotheses derived from the literature regarding the impacts of firms structural, behavioral and outcome characteristics on the firm's likelihood to get constrained in their access to external innovation finance. In line with earlier research we find that indeed the type of innovation matters for the access to external finance, but in a more nuanced way than generally portrayed. While incremental innovation activities have little negative effect on the access to external finance, radical innovation activities tend to be penalized by capital markets.

JEL classification: O31, G23, G24, L25

Keywords: Financial constraints, financing innovation, asymmetric information

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1 Introduction

For many firms access to external financing represents a critical factor in determining a firm's ability to survive, grow, and engage in innovative activities (Beck and Demirguc-Kunt, 2006; Mina et al., 2013; Musso and Schiavo, 2008). Likewise, industry evolution and technological change requires adequate funding, and the structure and governance of financial systems impacts the direction of industrial and technical change (Dosi, 1990; Mazzucato, 2013; Tylecote, 2007). Yet, some characteristics of firms particularly associated with innovative and entrepreneurial ventures driving technological change make them less likely to raise the necessary external capital to fund innovation projects.

Particularly firms who are young, small, and engaged in innovation and other activities characterized by uncertainty, are said to cause information asymmetries between financiers and finance seekers, making them less likely to raise the necessary external capital to fund innovation projects (Carreira and Silva, 2010; Freel, 2007; Hall, 2010). Yet, small and entrepreneurial ventures are important carriers of innovation and the associated industrial and technological change (Audretsch, 2006; King and Levine, 1993a,b; Wennekers and Thurik, 1999), where the existence of financial constraints might be a serious impediment to their future growth and survival (Stucki, 2013).

In this article we investigate how access to external financing for innovation activities is affected by firm-specific structural, behavioral and outcome characteristics. We here term variables describing firms in their objective dimensions such as size, age, location and ownership as structural characteristics, whereas behavioral characteristics are related to firms revealed innovation activities, and outcome characteristics to their realized and projected economic performance. We propose that not a single but rather certain combinations of characteristics and context makes firms more likely to not find their financial needs met. We attempt to identify combinations of firm characteristics associated with potentially innovative ventures that lead to a disproportionate likelihood of credit rationing. Since a large proportion of firms do not demand external finance (Nightingale and Coad, 2014), we also also take into account the heterogeneity

of financial needs. Moreover, in addition to incorporation the demand for finance and focus on combinations of potential characteristics, behavior and outcomes as potential explanations on financial constraints we differentiate our study from existing studies in that we use yearly, consistent innovation and finance surveys over a long time span (14 years). In this sense we contribute to a better understanding of the dynamics of the financing of entrepreneurship and innovation, an area that is generally under-researched (Hall, 2010; Hall and Lerner, 2009).

Using a 2-stage heckman probit model accounting for the heterogeneous need for external finance, we test hypotheses derived from the literature regarding the impact of firms structural, behavioral and outcome characteristics on capital access. We use a unique firm-level dataset composed of longitudinal survey data coupled with performance indicators, allowing us to incorporate micro-level firm characteristics. While the vast majority of existing studies rely on cross-sectional data, our panel data structure also allows us to control for contextual time-variant factors, such as the impact of business cycles. The data comprise a yearly survey of innovation activities and financial constraints that covers 14 years, from 2000 through 2013, with consistent question structure on both demand and supply of external financing. Compared to traditional innovation surveys (such as CIS), the data include more frequent rounds of surveying and a more detailed set of questions on finance. We find evidence that the effect of innovation on capital demand and supply is not uniform, but rather interdependent with other firm characteristics. Specifically, we find that the type of innovation is an important factor. While incremental innovation activities have little effect on the access to external finance, radical innovation activities tend to be penalized by capital markets. This appears to be particularly true for small innovators. We link these findings to how capital markets assess information flows.

The remainder of the paper is structured as follows. In section 2, we first survey the existing literature with respect to earlier, general studies of financial constraints, and derive a set of testable hypotheses on the interplay of innovation intensity, other firm characteristics and contextual factors.. The empirical strategy, data, and variables

are presented and explained in section 3. Section 4 reports and discusses the results, followed by a conclusion in section 5.

2 Financial Constraints - Theory and Hypotheses

2.1 Innovation, information asymmetries, and financial constraints

Investments in innovation – mostly associated with R&D expenditures – are said to embody characteristics making them substantially different from other investments in several respects (Hall, 2010; Hall and Lerner, 2009). From a financier perspective, investing in radically innovative firms vis-á-vis their not or only moderately innovative counterparts, is foremost associated with higher information asymmetries between firm and financier, and related with higher risk and uncertainty (Dosi and Orsenigo, 1988) of investment outcomes.

Asymmetric information has been long recognized as a generic source of market failure in buyer-seller (Akerlof, 1970) commodity markets as well investor-investee (Myers and Majluf, 1984) capital markets. Such information asymmetries can be assumed to increase with rate and radicalness of the firm's innovation activities. This is because the information required to correctly assess innovative ventures is usually (i) private, and thus only given voluntarily (Moro et al., 2014) since firms may fear misuse and be reluctant to share it (Anton and Yao, 2002); (ii) complex, thus requiring in-depth knowledge regarding applied technologies or market circumstances; (iii) to a large extent tacit, thus requiring spatial proximity and face-to-face contact with financiers in order to be transferred (Arrow, 1962; Von Hippel, 1994); and (iv) innovation processes are reliant upon and embedded in human capital, which is often volatile and not easily maintained in the firm. The intangible nature of many innovation processes, and the fact that they have long time lags from initiation to returns, means that financiers are faced with projects for which they have little possibility of estimating the returns, as well as poor options to cover the risk by way of collateral.

Due to these informational deficiencies, and their often weaker balance sheets and frequent lack of fixed assets that could act as collateral, innovative firms are said to have a greater need to communicate their merits to financiers. The means of doing this vary greatly. In the literature on relationship banking (e.g. Berger and Udell, 2002), it is argued that repetitive communication and transactions lead to the building of trust, which in turn facilitates smooth communication and reduces both information asymmetries and the likelihood of moral hazard. An emerging literature on financial signaling focuses on the patenting behavior of firms as a mean of overcoming these informational barriers (Harhoff, 2011; Häussler et al., 2014), especially in the early stage of development (Hoenen et al., 2014).

The proposition that innovative firms are somewhat more likely to face financial constraints is supported by a growing body of empirical evidence. Westhead and Storey (1997) identify the most technologically sophisticated firms as much more likely to report that continual financial constraints had impeded firm growth. Czarnitzki and Hottenrott (2011) report similar findings especially for small R&D intensive firms. Freel (1999) identifies innovating firms as more likely to seek but less likely to obtain bank loans. Later, Freel (2007) added to earlier results, clarifying that even though a little innovation seems to be a good thing, more intensively innovating and small firms appear to be less successful in obtaining external financing.

The majority of studies have used firms in R&D-intensive industries, patenting firms, or the simple separation of firms into innovative and non-innovative categories as proxies for innovation. For example, Hall (2010) argues that using R&D as a proxy for innovation is justified because it makes up a major portion of innovation expenditures in firms in CIS-like surveys. However, despite the fact that R&D expenditures are a substantial part of innovation expenditures, only a minority of innovating firms has any R&D at all. Many of the changes in products, processes, and services are incremental, new-to-firm innovation. Consequently, it is important to recognize that innovation is ubiquitous and depends often on modes of doing and using technologies rather than being based on science or R&D (Jensen et al., 2007). Mina et al. (2013)

report firms engaged especially in process innovation (often associated with efficiency increasing incremental innovation) to attract more capital, while innovation projects with long-payoff periods deter financiers. They further highlight the limited validity of using R&D expenditure as sole measurement which relates firm level innovation with financial constraints.

Similarly, it is likely that these problems are exacerbated by the innovation intensity of firms, rather than being dependent on whether firms are innovative or not. This is easily seen if the perspective of the financier is taken: in a mediocre innovative firm where innovation activities make up a small share of turnover, the information asymmetries and uncertainty related to innovation will not pose substantial difficulties in assessment of creditworthiness. This changes when investing in firms generating a major share of their turnover with outcomes of recent innovation projects. It can be concluded that the relationship between innovation and financial constraints might be more nuanced than commonly depicted (Bellucci et al., 2014), particularly with respect to the intensity and type of innovation activities, and the combination with other firm characteristics. From this discussion we derive that we should not approach the analysis by just using a dichotomous variable indicating if the firm displays innovation activities or not, but rather a scale reflecting the firm's innovation intensity. Moreover, the radical innovation projects involve additional asymmetries of information and time-lags between investments and outcome, again meaning a higher likelihood of financial constraints.

Hypothesis 1

a Firms with a higher innovation intensity show a higher probability of being financially constrained.

b This effect is more pronounced for firms engaged in radical vis-á-vis incremental innovation activity

2.2 Structural characteristics: The liability of newness and smallness

Though it is often highlighted as a major barrier to business development (Bottazzi et al., 2014; Musso and Schiavo, 2008), the mere existence as well as economic significance of credit rationing, and so-called debt gaps for SMEs, is also contested (Berger and Udell, 2003; Cressy, 2012; Levenson and Willard, 2000). However, literature stemming from the strand of SME finance consistently identifies two characteristics of firms as being associated with asymmetric information, and consequently more financial constraints: being young and/or small. Reasons put forward are among others the liabilities of newness and size limitations, asymmetric information, agency problems, and the high, fixed costs of screening and monitoring such firms when compared to the potential profit for the financing institution (Beck and Demirguc-Kunt, 2006; Canepa and Stoneman, 2008; Carreira and Silva, 2010; Fazzari et al., 1988; Murray, 1999).

As illustrated above, in the case of innovation-intense firms, traditional investors with only a limited understanding of firms' processes, products, and markets face huge difficulties in assessing the quality of their innovation processes without undertaking substantial efforts in gathering tacit information. Until this point, we assumed the financier to be in need of understanding the very essence of the firm's innovation activities. However, traditional financiers such as banks, representing the major source of external capital to firms, also rely to a high degree on the available factual, or "hard", information, such as a firm's financial history, capital structure, and available collateral, when assessing creditworthiness. By doing so, they leave the selection of opaque innovation projects to the firm, if the firm fulfills other requirements based on hard information. In this sense, hard and soft information regarding the firm can serve as imperfect substitutes for an assessment of creditworthiness without directly taking the nature of its innovation projects into account. Yet, in the case of small and/or young firms, which tend to be more opaque to financiers (Berger et al., 2001), salient hard information such as rated debt, certified financial statements, annual reports, and other forms of codified signals and track records are often not available (Uzzi, 1999; Uzzi and Lancaster, 2003). In the absence of both hard and soft information,

firms may face substantial obstacles in obtaining external financing, especially for their innovation projects. Consequently, we expect the effects of size, age, and the frequency of innovation projects to interact in a multiplicative rather than additive way, thus more than proportionally worsening a firm's access to external financing.

Hypothesis 2

a Firms that are young and innovative show a disproportionally high probability of being financially constrained.

b Firms that are small and innovative show a disproportional high probability of being financially constrained.

c Both the effect of newness and smallness are more pronounced for firms engaged in radical vis-à-vis incremental innovation activity

2.3 Outcome characteristics: Performance and expectations

Whether a firm obtains external financing or not could in a world with perfect information be a simple function of self-assessed economic performance. In the absence of information asymmetries, a firm's expectation regarding its future financial performance is a perfect forecast and coincident with the banks assessment. However, in a real world asymmetric information and moral hazard drive a wedge between the borrowers and lenders ability to assess creditworthiness, and thus between supply and demand for external capital. Assuming the firm to be in possession of the most complete information set available to evaluate the performance of its innovation projects (Kon and Storey, 2003; Stiglitz and Weiss, 1981), the own projection of current and future financial performance should still serves as suitable approximation for its creditworthiness.

As a major source of information asymmetries, we expect a firms' innovation intensity to increase the wedge between a firm's self-assessed current and future financial performance and the access to external finance. We expect this to be particularly true for the case of positive performance projections, which are only partially received by the financier and lead to a situation of capital undersupply, as illustrated in the

Stiglitz and Weiss (1981) model. However, this might also work the other way. Since this information is discounted by financiers and determines the lending decision and its conditions, firms have an incentive to act opportunistically and find ways to bias financiers in their favor, such as overstating progress in new product development or concealing critical strategic or technical details. This would lead to a situation such as the one depicted in the (De Meza and Webb, 1987) model, in which financiers arbitrarily provide credit to good and bad borrowers and lead to an oversupply of capital. It could be argued that financiers are primarily concerned with the financial performance of their portfolio firms. However, information on this is not easily available to the financier *ex ante*. We therefore posit that:

Hypothesis 3

a: A firms' current and projected economic performance influences their likelihood to meet financial constraints.

b: The relationship between economic performance and financial constraints is weaker in firms with higher innovation intensity.

Performance is here seen as how firms report their short-term profit expectations. A major merit of operationalizing financial performance according to the firm's own perceptions and expectations is that, in the case of innovative firms, this fully captures all their knowledge and their belief in the profitability of their innovation project, which cannot be captured by ex-post financial statements due to endogeneity issues. Innovation intensity is operationalized as firms' number of innovations which are new to the market as opposed to innovations only new to the firm (see also section 3 on variable description).

3 Econometric Modeling of Credit Demand and Supply

3.1 Data sources and context

Our primary data come from surveys of the management teams of a representative panel of private firms with at least five employees in North Jutland, Denmark. Re-

spondents were interviewed[1] about their views of the past and future development of variables like production, employment, profit, innovation activities, and access to financial capital. To ensure a shared understanding, the questions on innovation were posed only to a sub-sample of the population of private sector firms, such as those in the manufacturing industry and business services. The phrasing of the questions largely followed the form in which Community Innovation Surveys (CIS) pose questions on innovation and finance (e.g. Canepa and Stoneman, 2008; Pellegrino and Savona, 2013), making the results comparable to studies based on CIS data. The data are not fully representative of the total private business sector in the region, but within the sectors, there is a good match between the realized sample and the population of firms. Due to the focus of the survey, we only included firms reporting that they currently engage in innovation activities or plan to do so in the future.

Our case region is located in the north of Denmark, which is characterized as a peripheral area. This is illustrated by the fact that it has been an EU support Objective 2 area for years. There is one urban center, Aalborg, and the industry structure is somewhat different within the region, with the majority of R&D-based firms being in the Aalborg area. The total population in the region is around 600,000. One previous study on financial constraints in this region (Christensen, 2007) resembles our study; however, it was focused on a pre-crisis period and did not incorporate all constraints and statistical controls.

3.2 Variable description

The following subsection briefly describes the variables utilized in the empirical analysis and gives suggestions regarding their impact. An exhaustive description of all variables can be found in table 4.

[1] In 1999-2010, data were collected through telephone interviews, whereas they were thereafter collected by means of a web-based questionnaire. This change has affected response rates negatively while not necessarily affecting representativeness to the same degree.

Dependent variables

Our main dependent variable of interest (*constraints*) is dichotomous and derived from the survey answers whether the firm experienced constraints in raising external capital to finance innovation projects in the corresponding period (0:No, 1:Yes). Additionally, in our selection model we consider a variable (*demand finance*) which represents the firms' general need for external capital to finance innovation projects. On a five-point Likert scale, firms where asked to rate the importance of external finance for their innovation activities (5: very high, 4: high, 3: medium, 2: low, 1: very low/none). We transformed it in a dichotomous variable taking the value of one for firms that report external finance to have at least some importance. We employ this variable in the first step of our analyses to take into account endogenous selection of firms seeking external finance.

Independent variables

Behavioral variables: Innovation intensity In the survey, firms list whether they have introduced new products, processes, or services that are either new only to the firm (*incremental innovations*) or to the market/world (*radical innovations*)[2] and if, how many. Since incremental innovations are in contrast to radical innovations already to some extend known to the market, we associate them with less uncertainty and a greater capacity to be understood by the financier. As such, they are expected show a somewhat smaller effect on the firm's access to external financing.

However, we do not posit a linear relationship of *innovation intensity* and the following structural variables (*size, age*) and the likelihood of facing financial constraints, but rather one with decreasing marginal effects. Once a firm develops a track record for a number of years, asymmetric information problems stemming from a lack of historical data are likely to be alleviated, and further benefits from aging only manifest in possible reputational effects and increasing strength of the financier-firm relationship. We suggest the same pattern for size, where at a certain size legal disclosure

[2]This distinction is in line with what is commonly used in innovation studies using CIS surveys.

requirements and the establishment of professional finance and accounting management eliminate a substantial share of information asymmetries. While innovation is considered as a source of information asymmetries, we also expect this effect to soften with increasing innovation intensity. Firms that frequently engage in a high number of innovation projects are likely to develop routines to manage this process in a more structured way, which may be associated with increasing documentation and therefore higher transparency. Therefore, the variables incremental and radical innovation intensity are used in all models as the logarithmic transformation of the number of new products, processes, or services introduced in the corresponding observation period.

Structural characteristics: Firm size and age We include the firm specific structural characteristics most commonly associated with financial constraints, *size* (in number of employees) and *age* (in years), and coined these two variables respectively the liability of newness and liability of smallness. As discussed above, to account for assumed decreasing marginal impact as well as the skewedness of the variables distribution, size and age enter the model in their natural logarithm.

Outcome: Perceived current and future performance Firms were asked about the development of their realized profits in the current period (increased, same, decreased). A reported realized increase in profits in the observation period obviously represents a positive signal for financiers, which should decrease the firm's likelihood of being financially constrained, and *vice versa*.[3] We code this question in two dummy variables, first $real\ result\ +$ indicating positive, and $real\ result\ -$ indicating negative self-reported results in the current period. We introduce a dynamic perspective on external innovation finance by way of also incorporating the firm's self-reported expected future performance of the firm. Here, we utilized another question, where firms reported their predicted development of profits for the next period (increase, same, decrease), which we also code in two dummy variables, indicating positive ($exp\ result\ +$) and negative ($exp\ result\ -$) profit expectations. Assuming the firms to have the most complete set

[3]However, this only holds true for the minimum level of documentation and accounting transparency that enables a firm to convincingly prove its credibility to external financiers.

of information to make prediction regarding their future performance, in absence of information asymmetries we associated positive profit expectation with less financial constraints.

Conditions for innovation We further utilized the answers to additional questions on general opinions and impressions of the firm that might provide insights regarding the type of innovation likely to be produced. *Imp. tech* represents a dummy variable taking a value of one if the firm believes that technological knowledge is of high or highest importance to its business (on a five-point Likert scale), indicating that the firm is technology based. *Imp. IPR* relates to the firm's assessment of the importance of intellectual property protection, and is an indicator for more technology-based firms operating in an environment where innovation outcomes can be codified and protected. Finally, *Imp. market* is about the belief that market knowledge is vital for the firm, indicating competitive, complex, and changing market conditions.

Control variables

The region: First, the firm's environment is assumed to influence its access to external financing. Denmark's North Jutland region can be categorized as a fairly peripheral one. Modern instruments of innovation finance such as private equity and venture capital are scarcer there, which leaves debt as the predominant form of external innovation finance. Since the assessment of small, young, and innovative firms can be facilitated by tacit knowledge exchange and social proximity, we expect firms in regions outside the Aalborg region, North Jutland's urban core, to be more likely to face financial constraints. Therefore, in some models we also include further dummy variables indicating the firm is located in the inner Aalborg metropolitan region (*region 1*), or the larger, relatively less densely (but compared with the rest of northern Jutland still high) populated region around Aalborg (*region 2*).

The industry: Firms in the manufacturing industry usually embody a higher share of tangible assets suitable to serve as collateral, and thus are favored by asset-based

creditability evaluation techniques. Furthermore, production processes and their output may be better understood and valued than the somewhat intangible work of service firms. Therefore we suggest firms in the manufacturing industry to be less likely to face financial constraints.

Ownership structure and legal form: We also expect the firm's ownership structure to matter. If it is a *subsidiary*, it may be nurtured by its parent company, and thus be less in need of external financing. Additionally, it may draw on the reputation and credibility of its parent company, which eases the way to obtaining external financing. The firms' *legal form* makes them likely to differ in demand and access to external capital. Publicly traded companies obviously finance themselves on public capital markets for the most part and therefore have less demand for other sources of external financing than firms of other legal forms. Among privately owned businesses, we assume limited liability firms to be more likely to experience financial constraints than sole proprietorship, in which the firm's credit is backed by the private wealth of the entrepreneur.

3.3 Data Analysis and Descriptive Statistics

The refined data set represents an unbalanced panel containing 8,447 observations of 2,723 unique firms. Only a subpopulation of firms was asked to answer the set of innovation and financial constraints-related questions relevant for this study, which leaves us with 2,822 observations of 1,169 unique firms, whose participation in the different survey waves ranges from 1 to 12, where about 25% of firms participated in 2 or fewer and 95% in 7 or fewer waves. The participation by wave ranges from 135 in 2013 to a peak of 316 in 2010. The distribution of firms over years, regions, and industries can be found in table 5 in the appendix.

Table 1 provides some descriptive statistics at the firm level through the different waves. 63% of the firms in our sample express the need for external finance at all, while the others prefer to finance innovation projects by internal means. 17% report that they experienced financial constraints in external innovation finance in the correspond-

Table 1: Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min.	Max.
Dependent Variables					
need finance	2,822	0.63	0.48	0	1
constraints	2,093	0.17	0.38	0	1
Independent Variables					
$size_{count}$*	2,822	49.78	95.79	1	1600
age_{count}*	2,822	17.66	12.68	1	135
planned inno	2,822	0.68	0.47	0	1
inc. $inno_{count}$*	2,822	4.06	10.6	0	100
rad $inno_{count}$*	2,822	1.59	6.3	0	99
imp. tech	2,822	0.09	0.29	0	1
imp. ipr	2,822	0.09	0.29	0	1
imp. market	2,822	0.23	0.42	0	1
real result +	2,822	0.39	0.49	0	1
real result -	2,822	0.23	0.42	0	1
exp result +	2,822	0.39	0.49	0	1
exp result -	2,822	0.16	0.37	0	1
Control Variables					
region 1	2,822	0.40	0.49	0	1
region 2	2,822	0.58	0.49	0	1
firm subsidiary	2,822	0.23	0.45	0	1

*: For the sake of clarity, firm size (employees),age (years), incremental and radical innovation intensity (innovation count) in full number and not in logarithmic transformation.

ing observation period, which is about a quarter of firms expressing financial needs. This result roughly match with comparable studies. The average firm has slightly fewer than 50 employees and an age of about 17 years, where both characteristics skew high and positive. Over 40% report that they introduced at least one product, process, or service new to the firm in the corresponding period, while a slightly higher percentage introduced innovations new to the industry and the market, and roughly 70% planned to start new innovation projects in the next year, what sums up to an average of 4.06 incremental and 1.59 radical innovations per firm and year. About a quarter of the firms consider knowledge on market conditions as crucial to their success, whereas only 9% think so regarding technological knowledge and IPR. 39% of firms are optimistic about their current or future development of profits, while 16% are pessimistic about future profits, which indicates on average a healthy business climate, despite the financial crisis during the observation period.

Table 5 in the appendix provides a breakdown of the firms need for finance, experienced financial constraints, and incremental and radical innovation activity by year, region and industry. Financial constraints show to peak in the years 2003, 2009 and 2012, when (related) demand for external finance for innovation projects is also at it's

high as is the average intensity of radical innovation. The manufacturing industry appears to be the most innovative and therefore has also the highest demand for innovation finance. The results of a bivariate analysis, presented in a pairwise correlation matrix in Table 3, provide the first insights into the general interplay among innovation intensity, the need for financing, and credit constraints.

Table 2: Correlation Matrix

		(1) need finance	(2) constraints	(3) region_2	(4) size	(5) age	(6) subsidiary	(7) inno inc
(1)	constraints	0.451*						
(2)	region 2	-0.065*	-0.060*					
(3)	size	-0.080*	-0.106*	-0.044*				
(4)	age	-0.062*	-0.054*	-0.037	0.230*			
(5)	subsidiary	-0.108*	-0.0779*	0.023	0.045*	0.076*		
(6)	inno inc	0.008	-0.007	0.026	0.194*	0.051*	0.013	
(7)	inno rad	-0.006	0.037	0.020	0.060*	-0.031	-0.038	0.430*
(8)	imp tech	0.007	-0.015	0.028	0.006	0.008	0.017	-0.004
(9)	imp ipr	0.033	-0.002	0.033	-0.003	-0.070*	-0.039	0.060*
(10)	imp market	0.012	-0.034	0.015	0.054*	0.012	-0.002	0.072*
(11)	real result +	-0.065*	-0.042*	0.055*	0.008	0.004	-0.045*	0.031
(12)	real result -	0.060*	0.075*	-0.055*	0.000	-0.008	-0.014	0.039
(13)	exp result +	0.035	0.039	0.072*	-0.027	-0.099*	-0.017	0.094*
(14)	exp result -	0.008	0.010	-0.047*	-0.020	0.031	-0.037	-0.030

		(8) inno rad	(9) imp tech	(10) imp ipr	(11) imp market	(12) real result +	(13) real result -	(14) exp result +
(8)	imp tech	0.005						
(9)	imp ipr	0.105*	0.142*					
(10)	imp market	0.049*	0.114*	0.251*				
(11)	real result +	0.053*	0.011	0.012	0.017			
(12)	real result -	0.005	0.015	-0.015	0.003	-0.430*		
(13)	exp result +	0.097*	0.017	0.025	0.028	0.115*	0.116*	
(14)	exp result -	-0.033	-0.015	-0.040	-0.013	-0.020	0.129*	-0.341*

*: $p < 0.01$, two-tailed Pearson correlation

As expected, both age and size are negatively correlated with the need for external finance as well as with financial constraints. Surprisingly, neither the intensity of incremental innovation nor of radical innovation shows non-negligible correlation coefficients in magnitude or significance. This is in line with Christensen (2007), who in a bivariate setting found no evidence that innovative firms are particularly affected by financial constraints. No strong correlation indicating collinearity can be found.

3.4 Model Setup and Empirical Strategy

Our data set represents an unbalanced panel, where roughly half of the firms participated in one wave and the other half in two to twelve, regressively developing. Since the methods available for unbalanced panel data regressions with selection and

dichotomous dependent variables are very limited, we instead choose to use pooled data and include year dummies to capture year effects. To address the issue of serial correlation among multiple observations of the same firm, we relax the assumption that standard errors are independently and identically distributed by clustering them at the firm level, which allows for within-group correlation. Furthermore, we used multivariate imputation techniques in the rare cases of missing data on firm characteristics and survey question replies of the independent variables, where for every single variable less then 5% of observations show missing cases.

The dichotomous nature of our dependent variable and the very nature of our survey data suggest the use of a probit model. To analyze the interplay between supply and demand for external financing for innovation, we chose a two-stage model with endogenous selection, which allowed us to construct a consistent model for decisions both to seek and to obtain financing for innovation projects, where the former obviously represents the prerequisite for the latter. This is done with a technique equivalent to the well-established two-stage Heckman correction in linear models (Heckman, 1979), applied for bivariate probit models (Van de Ven and Van Praag, 1981) and estimating a firm's likelihood to experience financial constraints by full maximum likelihood.

We execute our econometric analysis as follows. Model one includes control variables for the corresponding year, the firm's industry affiliation and its legal form, some basic firm characteristics, its incremental and radical innovation intensity (hypothesis 1a,b), and its perceived importance of some factors associated with innovation. In model two, we add an interaction term between the firms' incremental innovation intensity and its structural characteristics size and age ($inc.\ inno{*}size^{ref}$, $inc.\ inno{*}age^{ref}$). To test the interplay between innovation intensity and the liability of newness and smallness, we reverse the magnitude of both age and size to have high values for young and small firms, and *vice versa*. We do the same in model three for radical innovation intensity ($rad.\ inno{*}size^{ref}$, $rad.\ inno{*}age^{ref}$). In both models we test if young and small firms are over-proportionally affected by the assumed negative impact of innovation intensity on the access to external finance (hypothesis 2a,b), and by their comparison

if the type of innovation activity matters (hypothesis 2c). Then in model four we add first the firms reported increase (*real result +*) or decrease (*real result -*) in profits in the current period, and in model five the firms expectation for the next period (exp result +, exp result -) to test the interplay between realized and perceived firm level outcomes and different forms of innovation intensity (hypothesis 3a,b).

4 Results and Discussion

4.1 Demand for external innovation finance

In the first stage of the model to be found in table 6 in the appendix, we test the likelihood of having demand for external capital to finance innovation projects. Even though this stage is not of main interest for our analysis, it is necessary for endogeneity reasons and results may be interesting in themselves. Surprisingly, demand for external innovation finance appears at first glance to be quite inelastic to firm characteristics and innovation intensity, which holds true for incremental and radical innovation alike. Firms that are a subsidiary have a significantly lower demand for external finance, probably because they are likely to be supplied with funding by their parent company. The variable *region*2 (firms in the wider, less densely populated Aalborg area) has a negative sign and is significant in all models indicating that demand for external finance of innovation is not as widespread among firms in these regions as is the case in the inner urban area. Realized positive profits decreases the demand for external finance. This indicates that, in line with the pecking order theory (Myers and Majluf, 1984) and findings of Mina et al. (2013), firms indeed prefer to finance innovation activities with internal funds such as accumulated profits. Contrary to initial expectations, the firm's size and age have no significant effect on its demand for financing, which appears puzzling at first glance, since the majority of theories and evidence claim that small and young firms are in greater need of external financing. Overall, we see a somewhat limited explanatory power of traditional firm characteristics and innovation indicators alike for the financial needs of firms in our sample. It should, however, be reiterated

that the bulk of the earlier literature has focused on the supply side rather than on demand. Yet, while appreciating the importance of considering the interplay between demand and supply of capital, our focus in this analysis lays on the constraints firms meet to their innovation financing.

4.2 Supply for external innovation finance

In the second stage, we test the firm's likelihood to experience financial constraints. In model one, we see that size matters to obtaining financing, as increasing size reduces the chances of being constrained, significant at least at a 5% level. In line with hypothesis 3a, radical innovation intensity is associated with a higher probability of being financially constrained, significant on 5% level. Yet, this holds not true for incremental innovation, which shows a negative but not significant coefficient, lending support to hypothesis 3b, and at the same time calling for more nuanced understanding of the relationship between different types of firm level innovation activities and financial constraints. Indeed, while financiers seem to generally cope with "new-to-the-firm" incremental innovation, more radical and uncertain "new-to-the-world" activities appear to deter them.

In model two, we introduce interaction terms with the structural characteristics age and size and the behavioral variable $(inc.inno * size^{rev}, inc.inno * age^{rev})$[4]. We do not find an significant effect of being small and at the same time displaying a high innovation intensity $(inc.inno * size^{rev})$, leading to a rejection of hypothesis 2a. In contrast, the interaction with $size^{rev}$ indeed shows a positive coefficient significant at the 5% level, indicating in favor of hypothesis 2b that high innovation intensity and smallness indeed amplify each others negative effect on access to external finance.

In model three we introduce interaction terms of again the firm's age and size with its intensity in radical innovation activity (*inno rad*). While young and radically innovative firms do not display a statistically significant tendency to face experience financial constraints, their small and radically innovative ones do again, with even a

[4]The *ref* superscript indicates the variable to be reversed, so that originally highest values now represent the lowest ones, and *vice versa*.

Table 3: Regression table – Probit model with endogenous selection. Dependent Variable: Financial Constraints

	I			II			III			IV			V		
	Coeff.	SE	AME	Coeff.	SE	AME	Coeff.	SE	AME	Coeff.	SE	AME	Coeff.	SE	AME
region 1	0.018	(0.119)	0.008	0.005	(0.119)	0.010	0.027	(0.116)	0.030	0.015	(0.095)	-0.054	0.014	(0.115)	-0.018
region 2	-0.157	(0.134)	-0.056	-0.155	(0.131)	-0.061	-0.145	(0.131)	-0.072	-0.186*	(0.094)	-0.024	-0.195	(0.118)	-0.047
age	0.038	(0.362)	0.011	0.024	(1.263)	0.041	-0.454	(1.932)	0.019	-0.181	(0.263)	-0.039	-0.024	(0.347)	0.005
size	-1.326**	(0.467)	-0.466	-5.468***	(1.456)	-0.406	-6.728**	(2.104)	-0.464	-1.248***	(0.293)	-0.391	-1.397***	(0.355)	-0.446
subdidiary	-0.146	(0.174)	-0.053	-0.133	(0.158)	-0.054	-0.083	(0.154)	-0.052	-0.265***	(0.080)	-0.053	-0.214	(0.134)	-0.052
imp tech	-0.126	(0.146)	-0.043	-0.130	(0.145)	-0.044	-0.134	(0.142)	-0.046	-0.0611	(0.119)	-0.036	-0.113	(0.146)	-0.043
imp ipr	-0.086	(0.152)	-0.029	-0.069	(0.151)	-0.020	-0.080	(0.147)	-0.020	-0.001	(0.123)	-0.025	-0.052	(0.151)	-0.028
imp market	-0.182	(0.101)	-0.063	-0.178	(0.101)	-0.061	-0.171	(0.100)	-0.061	-0.120	(0.083)	-0.061	-0.168	(0.106)	-0.061
inno inc	-0.192	(0.265)	-0.064	2.262*	(1.085)	0.787	-0.171	(0.245)	-0.044	0.011	(0.196)	-0.040	-0.147	(0.269)	-0.071
inno rad	1.022**	(0.345)	0.352	1.190***	(0.342)	0.402	4.227**	(1.501)	1.483	0.627*	(0.268)	0.407	0.888*	(0.422)	0.351
inno inc*age^{rev}				0.138	(1.537)										
inno inc*size^{rev}				5.475**	(1.759)										
inno rad*age^{rev}							0.616	(2.140)							
inno rad*size^{rev}							6.307**	(2.273)							
real result +										-0.051	(0.077)	0.002			
real result -										0.189*	(0.086)	0.082			
exp result +													0.138	(0.091)	0.035
exp result -													0.075	(0.115)	0.022
Year controls	Yes			Yes						Yes			Yes		
Industry controls	Yes			Yes						Yes			Yes		
Legal controls	Yes			Yes						Yes			Yes		
athrho	-0.040	0.748		-0.134	0.606		0.575	-0.600		4.623	60.858		0.803	0.520	
rho	-0.040	0.747		-0.133	0.595		-0.329	0.512		0.999	0.023		0.391	0.680	
N stage 1	2,093			2,093			2,093			2,093			2,093		
N stage 2	1,061			1,061			1,061			1,061			1,061		
Wald chi2	48.160			53.300			47.460			82.680			61.520		
Prob > chi2	0.010			0.006			0.022			0.000			0.001		
log-likelyhood	-2050			-2,045			-2,046			-2,047			-2,049		

*, **, *** indicate significance at 10, 5, 1 percent level

higher amplitude (average marginal effects more than 3 times higher) than their incrementally innovating peers. This finding is in line with hypothesis 2c, indicating again that the type of innovation indeed influences financiers capital allocation decisions interdependent with other firm characteristics.

Model four tests for the additional effect of being a firm reporting to be a good or a bad performer, which we operationalized by the positive or negative development of profits in the observation period. While good performance in this model leads to no benefits in accessing external finance, bad performance indeed appears to be penalized by capital markets. The coefficient for negative profit development shows significance at 10% level, lending partial and weak support to hypothesis 3a. However, while realized outcomes appear to at least slightly matter, we see no significant effect at all for the firms profit expectations introduced in model five. Interestingly, when including realized and expected outcome characteristics, in both model four and five the coefficient as well as significance of radical innovation intensity decreases. This might indicate a more nuanced relationship between innovation activity and outcome related to technology. Yet, the firms forward looking assessment of its economic development seems to not influence the capital allocation decisions by financiers, indicating persistent information asymmetries and/or different methods of projection.

4.3 Robustness tests

To evaluate the robustness of our findings, we carried out additional robustness tests. First, we ran only the supply model (stage 2) in a fixed effects probit model. For our structural and innovation variables, we also tried different transformations (other than the here applied logarithmic one) such as the squareroot, and also the non-transformed terms. For our outcome variable, we also replaced the self reported profits by balance sheet data from Danish register data (which is unfortunately only available for a subset of firms). While mostly not as pronounced, all results point in a similar direction. The period we analyze span across the financial crisis and it can be presumed that this has an effect on conditions for obtaining external finance (Cowling et al., 2012; Vermoesen

et al., 2009). In our empirical analyses we included year dummies to capture potential effects from changes in business cycles but additionally we introduced a number of macroeconomic business cycle indicators but found no effect from this.

5 Conclusion

Our approach in this study was to build on previous theories and studies on demand and constraints for financing for different types of firms and to add new, improved ways of analyzing this problem area. Our hypotheses were built to render a more nuanced picture of the financial constraints problem than has been presented to date. We were able to analyze this problem area from a longitudinal perspective, and although our overall results are in contrast to some previous findings in the literature we did find new insights that contribute an additional understanding of financial constraints.

It has been claimed that by and large firms who apply for credit gets it (Nightingale and Coad, 2014) but that some types of firms may be financially constrained. Regarding the demand side our results indicate weak systematic patterns in which types of firms are demanding external finance. Unsurprisingly, the realized, positive economic results decreases demand for external finance as does the firms' status as subsidiary.

Our analysis on the supply of external capital revealed that the effect of innovation *per se* on capital demand and supply is not uniform, but rather interdependent on other firm characteristics. We furthermore find the type of innovation to matter. While incremental innovation is rewarded by financiers, the results for more radical or technology-based innovations are more ambiguous.

It is likely that in a small and dense region, where innovation activities are primarily incremental and not science-based, financiers are better able to cope with asymmetries of information and other reasons for credit rationing. Hence, static, non-innovative firms are, in our analyses, financially constrained, while firms with some innovation are rewarded, and technology-based, high-tech innovation firms are constrained. This is congruent with some earlier studies that posit that "some, not too much, innovation is good" (Freel, 2000, 2007).

Our findings lead us to question the generalization of existing theories in the field. Whereas financial markets are often seen as prime examples of full information and extended mobility of production factors, our results indicate that the demand and supply of the finance nexus is nuanced and highly contextual. As mentioned, another, complementary interpretation is that capital markets work differently in small, dense environments because information flows more easily and networks of firms and of financiers facilitate both mitigating information asymmetries and the insourcing of knowledge on capital market reactions (Sorenson and Stuart, 2001). This is consistent with (Bellucci et al., 2014) who find that when financiers have well-established lending relationships with firms, they evaluate innovation positively, whereas the innovation variable has a negative impact on access to credit for firms that are more likely to suffer from information asymmetries. Proximity is, in turn, a facilitator of reducing asymmetric information, hence increasing access to financing. It is likely that the regional context is a powerful explanation as to why existing theories do not seem to fit our case. This does not disprove these established theories, but points to the need to take contextual factors into account and to evaluate these theories differently in different regional settings.

The findings not only complicate the theoretical understanding of access to financing, but may also have policy implications. Most public support programs for access to financing place restrictions on eligibility; most often their financing is available only to firms that are young, small, innovative, or some combination thereof, at least in some regions. The results of our study indicate a need for careful consideration of these criteria.

A number of limitations apply to how far we can go in drawing universally valid conclusions. The study was confined to a small region in a small country. As we have argued, entrepreneurial finance is to a large extent contextual (Ning et al., 2015), and the results may have been different in another financial system. We also treated financiers and types of financing as if they were homogeneous. In reality, there are vast differences between, for example, venture capital and bank financing, and different

results might be seen if the analyses were confined to only one type of capital (Brown et al., 2012).

For further research, we suggest continuing to explore the impact of innovation types on financial constraints. For example, the latest round of CIS-survey results show that North Jutland has now moved up from the bottom of the rankings to become the most innovative region in Denmark, despite still being the one with the lowest rate of R&D activities. Furthermore, these survey results show that the major difference between other regions and North Jutland is that the latter's firms have been engaged in organizational change to a larger extent. The capital markets may view such innovations particularly positively.

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Appendix

Table 4: Variable Descriptions

Variable	Type	Description
		Dependent Variables
demand finance	dichotomous	Firm in need for external finance
constraints	dichotomous	Firms experienced finance constraints
		Behavior: Innovation intensity
inc. inno	continuous	Firms number of introduced incremental innovation, natural logarithm: ln(1+x)
rad. Inno	continuous	Firms number of introduced radical innovation, natural logarithm: ln(1+x)
inno planned	dichotomous	Firm plans innovation in next period
		Structure
size	continuous	Firms employees, natural logarithm: ln(x)
age	continuous	Firms age in years, natural logarithm: ln(x)
		Outcome: Performance
real result +	dichotomous	Firms realized profits positive
real result −	dichotomous	Firms realized profits negative
exp result +	dichotomous	Firms expected profits positive
exp result −	dichotomous	Firms expected profits negative
		Behavior: Innovation intensity
imp. technology	dichotomous	Perception: High importance of access to technology
imp. IPR	dichotomous	Perception: High importance of IPR
imp. market	dichotomous	Perception: High importance of market knowledge
		Controls
region 1	dichotomous	Firm located in the central Aalborg region
region 2	dichotomous	Firm located in a metropolitan region
industry	dichotomous	Firm industry, (0) others, (1) manufacturing, (2) service, communication and finance
legal form	categorical	Firm legal form, (0) others, (1) public traded, (2) limited liability, (3) private
subsidiary	dichotomous	Firm is a subsidiary

Table 5: Descriptive Statistics by Categories

Category	N	Percent	demand finance, mean	constraints, mean	inc. inno intensity, mean	rad. inno intensity, mean
Total	2822.00	100.00	0.63	0.17	4.06	1.59
Distribution and characteristics of firms by year						
2000	207.00	7.34	0.71	0.18	3.20	1.13
2001	200.00	7.09	0.74	0.16	4.45	2.24
2002	179.00	6.34	0.69	0.11	3.41	1.53
2003	188.00	6.66	0.76	0.21	5.80	2.90
2004	196.00	6.95	0.61	0.18	5.62	2.06
2005	187.00	6.63	0.66	0.13	4.57	1.32
2006	193.00	6.84	0.66	0.12	4.34	1.20
2007	179.00	6.34	0.67	0.12	4.18	1.46
2008	200.00	7.09	0.72	0.18	4.80	1.30
2009	260.00	9.21	0.76	0.25	7.44	3.71
2010	316.00	11.20	0.48	0.18	2.47	0.82
2011	212.00	7.51	0.48	0.16	1.89	0.69
2012	170.00	6.02	0.48	0.23	1.41	0.61
2013	135.00	4.78	0.48	0.15	2.69	0.83
Distribution and characteristics of firms by industry						
manufacturing	1442.00	51.10	0.68	0.17	4.73	1.89
service & finance	555.00	19.67	0.48	0.19	3.18	1.26
others	825.00	29.23	0.65	0.16	3.50	1.29

Note: incremental and radical innovation intensity (innovation count) in full number and not in logarithmic transformation.

Table 6: Regression table – Probit model with endogenous selection. 1^{st} stage. Dependent Variable: Need for external finance

	I		II		III		IV		V	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
region 1	0.280*	0.131	0.280*	0.131	0.276*	0.131	0.231	0.122	0.274*	0.132
region 2	-0.276**	0.089	-0.275**	0.089	-0.272**	0.089	-0.250**	0.087	-0.272**	0.089
size	0.756	0.971	0.750	0.944	0.782	0.939	0.155	0.855	0.580	0.998
age	0.940	0.747	0.935	0.742	0.967	0.738	0.562	0.667	0.849	0.763
subdidiary	-0.294***	0.064	-0.294***	0.064	-0.295***	0.064	-0.287***	0.064	-0.292***	0.064
$age * size$	-2.562	1.568	-2.548	1.554	-2.635	1.545	-1.765	1.391	-2.357	1.603
exp inno	0.028	0.137	0.037	0.129	0.056	0.125	-0.089	0.097	-0.016	0.133
inno inc	0.212	0.162	0.213	0.162	0.211	0.162	0.173	0.161	0.206	0.163
inno rad	0.030	1.271	0.002	1.145	0.111	1.111	0.918	1.019	0.377	1.226
real result +	-0.142	0.077	-0.144	0.077	-0.145	0.075	-0.104	0.073	-0.129	0.080
real result -	0.041	0.101	0.047	0.096	0.059	0.093	0.036	0.086	0.012	0.100
exp result +	0.152	0.080	0.150	0.080	0.146	0.080	0.145*	0.072	0.170*	0.084
real result -	0.054	0.099	0.054	0.099	0.054	0.098	0.040	0.089	0.062	0.099
imp tech	0.025	0.099	0.025	0.099	0.024	0.099	0.024	0.099	0.027	0.099
imp ipr	0.105	0.106	0.105	0.106	0.104	0.106	0.094	0.106	0.103	0.106
imp market	0.001	0.070	0.000	0.070	0.000	0.070	0.011	0.070	0.003	0.070
$inno\ rad * age^{rev}$	-1.380	1.730	-1.350	1.464	-1.462	1.411	-2.624*	1.270	-1.923	1.607
$inno\ rad * size^{rev}$	0.984	1.456	0.996	1.452	0.926	1.454	0.792	1.364	0.984	1.442
athrho	-0.041	0.748	-0.134	0.607	0.575	-0.600	4.623	60.859	0.804	0.520
rho	-0.041	0.747	-0.134	0.596	-0.330	0.513	1.000	0.023	0.392	0.680
N stage 1	2,093		2,093		2,093		2,093		2,093	
N stage 2	1,061		1,061		1,061		1,061		1,061	
Wald chi2	48.160		53.300		47.460		82.680		61.520	
Prob > chi2	0.010		0.006		0.022		0.000		0.001	
log-likelyhood	-2,050		-2,044		-2,046		-2,046		-2,049	

*, **, *** indicate significance at 10, 5, 1 percent level