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Impact of Economic Crises on Innovation Activity: Firm Level Evidence from Patent Data

Gustav Martinsson and Hans Lööf

(Division of Economics, Royal Institute of Technology and CESIS)

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Gustav Martinsson[1] and Hans Lööf[2]

Abstract

Based on data from of 2,700 Swedish manufacturing firms, observed through the period 1997-2005, this paper shows that internal finance resources, measured by cash-flow, affect the propensity to apply for a patent as well as the number of patent applications. From a business cycle perspective, cash-flow only plays a role during and after economic contractions. In periods of economic expansion there is no significant association between internal finance and patent applications. Further, the sensitivity of patent applications to cash-flow is limited to firms with low equity-ratio. Among high equity firms the pattern of patent applications are robust over the business cycle.

Keywords: Financing constraints; Innovation; Intellectual property rights, Firm-level panel data

JEL: G32, O31, O34

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[1] Corresponding author Gustav Martinsson, Division of Economics, Royal Institute of Technology, 100 44 Stockholm, Sweden. Email: gusma@infra.kth.se.

[2] Centre of Excellence for Science and Innovation Studies, Royal Institute of technology, 100 44 Stockholm, Sweden. Email: hansl@infra.kth.se.

1. Introduction

The efficiency of the financial market to allocate resources to the economy's most productive industries, firms and projects is often considered to be an important driving force to technological change, innovation, industrial dynamics and growth (Schumpeter, 1911). Firms raise funds for new investments both internally from retained earnings and externally in the financial market through security issues. The corporate finance literature suggests that there is a life cycle-pattern of external financing needs for firms (e.g. Rajan and Zingales, 1998). During a firm's early years, the demand for external funding is substantial, and this demand decreases successively as it matures.

For a mature firm in steady-state equilibrium, the need for *net* external funds is limited and associated with technological shocks, raising the investment opportunities beyond what retained earnings can support. Among entrepreneurial firms a growing empirical literature provides evidence of financing constraints. The capacity to channel resources to young firms and to R&D-intensive firms is supposed to be of particular importance for economic growth, assuming they are successful innovators contributing to Schumpeterian waves of creative destruction. In a study of the Finnish economy, Hyytinen and Toivanen (2002) suggest that capital market imperfections retard innovation and growth for small and medium-sized firms. This finding is in line with the results reported for other countries (see Brown, 1997; Bond et al., 2003; Bougheas et al., 2003; and Hall, 2002 for a survey).

We study capital market imperfections and technological change focusing on the relationship between patenting behavior and short-term economic fluctuations. We apply a corporate finance framework and relate the occurrence of patent applications with firms' financial situation over the business cycle. In particular we are interested in how structural chocks influence innovation activities. The abrupt end of the economic boom characterizing the second half of the 1990s is an example of a structural shock beginning in the IT-sector, which later on disrupted the overall economy.

Using observations from 2,700 manufacturing firms in Sweden over the period 1997-2005 we focus on cash-flow and investigate how it affects firm patenting activity. Roughly 10 percent of the firms in our sample apply for at least one patent.

The major findings are as follows: Using both the negative-binominal estimator and binary-logit estimator we show that firms' patenting activities are positively associated with cash-flow. Taking the business cycle into account we show that the positive correlation between patenting activity and cash-flow is only present in the period after the burst of the IT-bubble. On the contrary, there is no correlation between patenting activity and retained earnings during the economic expansion prior to the bursting IT-bubble. We check the robustness of our results by splitting the sample based on equity ratio. High-equity firms do not display cash-flow sensitivity whereas low-equity firms' patenting activity is highly sensitive to cash-flow. The results are robust to controlling for firm-level sales, bank-loans, size, human-capital intensity, sector-technology level and firm affiliation.

The paper is organized as follows. Section 2 provides some background supporting our empirical predictions. Section 3 describes the empirical strategy and our variables. Section 4 introduces the data along with descriptive statistics. The econometric results are described in section 5 and section 6 concludes

2. Background and empirical predictions

The period after the burst of the IT-bubble in the beginning of 2000 is characterized by a dramatic decrease of patent applications by Swedish firms. The decrease was substantial with a drop from almost 6,000 filed patent applications in the late 1990s to about 3,500 in the early part of the 2000s. This drop in patent applications was not driven by ICT and/or biotech firms, these sectors experienced similar drops as the overall economy. Instead, the bursting IT-bubble and the subsequent recession hit financially constrained firms in particular as suggested by figure 1.

[Figure 1 about here]

The top line in figure 1 indicates that the decrease of patent applications coincides with the contraction of the economy. However, by simply splitting the firms into two sub-groups based on their equity ratio reveals an interesting finding. The decreasing patent applications are isolated to firms with low equity ratio. The equity ratio is measured as equity divided by total assets. A low-equity firm is at or below the median of average equity-ratio (approximately at or below 0.24). The line for high-equity firms is virtually flat during the rapidly changing economic conditions.

This leads to our main hypothesis. There is a positive relationship between firm patenting activity and internal finance. This correlation is weak or non-existent for financially strong firms and strong for financially constrained firms. To our knowledge, there are no similar studies on corporate finance and patenting activity at the firm-level. We adopt a pecking-order approach (Myers and Majluf, 1984; Stiglitz and Weiss, 1981) inspired by Fazzari et al. (1988), and suggest that if a firm displays a high sensitivity of investment to cash-flow over time, it can be interpreted as a sign of financing constraints. We therefore consider firms displaying high sensitivities of patent applications to cash-flow as being more financially constrained than others.

3. Empirical strategy

3.1. Count and binary regression models

We use two measures of patent applications: (i) count-data reporting the number of patent applications by firm *i* in year *t*, and (ii) an indicator variable showing whether firm *i* has applied for a patent in year *t*.

The general model is a firm-specific-effect model and may be expressed as:

$$y_{it} = \alpha_i + \mathbf{x}'_{\mathbf{it}}\boldsymbol{\beta} + \varepsilon_{it} \qquad (1)$$

where y_{it} denotes patent applications by firm *i* in year *t*, $\mathbf{x}_{\mathbf{it}}$ is a vector of regressors, α_i controls for firm-specific effects that may be fixed-effects (FE) or random-effects (RE), and ε_{it} an idiosyncratic error.

The literature suggests several alternative estimators for count-data estimations. The leading example is the negative binominal model (Cameron and Trivedi, 2008). Some of the standard complications in analyzing count data include the presence of unobserved heterogeneity due to omitted variables, an "excess" of zero observations and overdispersed data. We apply the panel-data negative binominal estimator accounting for both the overdispersed data and the unobserved firm-specific effects.

We also consider a binary-logit model with which we model the propensity of a firm applying for a patent. This binary model specifies that

$$\Pr(y_{it} = 1 | x_{it}, \beta, \alpha_i) = \Lambda(\alpha_i + x'_{it}\beta) \qquad (2)$$

where α_i may be an FE or RE and $\Lambda(z) = e^z(1+e^z)$

A crucial issue is whether the fixed-effects (FE) or the random-effects (RE) model is the appropriate model for our panel-data negative-binominal model. In the FE model, the unobserved firm-specific effects α_i in equation (1) are permitted to be correlated with the regressors $\mathbf{x}_{it}$. In the RE model it is assumed that α_i is purely random, implying that it is uncorrelated with the regressors. We find that the more relevant model for our data is the RE model. This estimator, which corrects for the panel-data complication that the observations are correlated over time for a given firm, makes it possible to estimate the coefficients of both time-invariant and time-varying regressors and can handle a large amount of zero observations of the dependent variables.

3.2. Variable selection

The choice of variables to include is inspired by the more developed corporate finance and R&D investment literature (see Brown et al., 2009; Himmelberg and Petersen, 1994; Mulkaly et al., 2001). The dependent variable is *number of patent applications* and as a robustness model we estimate a logit-model with the dependent variable being 0 if firm *i* is not *applying for a patent* year *t* and 1 if they do. We wish to capture the impact of financial resources available internally to the firm on its patent application activity. The standard measure in the investment literature to capture internal finance capacity within the firm is *cash-flow*. We construct the cash-flow variable from after-tax income plus depreciation and amortization. This is the explanatory variable which we devote most interest toward in the empirical study. We also include *sales* and *long-term debt* in the specification. Omitting the sales variable might contribute to the cash-flow variable being overly emphasized in the econometric analysis. A firm's access to long-term debt is a factor which may reduce their cash-flow dependency, and thus failing to control for the impact of long-term debt may also lead us to miss-interpret the cash-flow estimate. These three variables are normalized by total assets in the beginning of the period.

We include a number of control variables in the regressions as well. *Human capital* is regarded as reflecting a firm’s capacity to absorb, assimilate and develop new knowledge and technology (Bartel and Lichtenberg, 1987; Cohen and Levinthal, 1990). Several empirical studies also find that technological change tends to be skill-biased and changes the relative labor demand in favor of highly skilled and educated workers (e.g. Berman et al., 1998; Machin and van Reenen, 1998). The variable human capital, number of employees with university education normalized by total number of employees, is one of the key variables when studying firm-level patenting activity.

We also control for firm *size*, which we measure in terms of the log of employment, which is important for at least two reasons. Our main regressions examine number of patent applications, and a large firm probably applies for more patents than a smaller firm, all else equal. Second, the theoretical literature suggests that the presence of asymmetric information and moral hazard problems may be particularly serious for small firms engaged in innovation activities. Thus, profitability and cash-flow can be expected to be more important for small innovative firms, since they often have limited access to capital markets and difficulties in obtaining external funds. Large firms are expected to be less financially constrained in the capital market (see e.g. Almeida et al., 2004; Himmelberg and Petersen 1994; Gertler and Hubbard, 1989).

We account for the degree of *technology of the sector* the firm is operating in by assigning sectors in to four different classes. A typical argument in the neo-Schumpeterian literature is that the characteristics of a particular sector or industry with which a firm is affiliated may influence its innovation activity. Different sectors have different technology and innovation opportunities and are thus characterized by different technological regimes (Malerba and

Orsenigo, 1993). Our empirical analysis includes sector dummies based on the sector's overall technology intensity. We consider four broad OECD classifications; high technology, high-medium technology, low-medium technology and low technology sectors.

We also add control variables for firm-ownership structure. We distinguish between individual firms and firms belonging to a corporate group. Our data permits us to distinguish between four types of firm affiliation: (i) non-affiliate firm, (ii) uni-national firms, (iii) domestically-owned multinational enterprises (MNE) and (iv) foreign-owned MNEs. Following the literature, we assume there are important differences between MNEs and non-MNEs regarding the sensitivity of innovation investment to fluctuations in financial resources (see Scherer, 1999; Pfaffermayr and Bellak, 2002; Klette and Kortum, 2004).

We also include year dummies to capture unobservable time-varying macroeconomic shocks common to all firms.

4. Data description and sample characteristics

4.1. Sample construction

The firm level data used in this study is originally constructed from audited register information on firm characteristics based on annual reports on surviving and non-surviving firms in Sweden during 1997-2005. We have merged this data with additional data on the educational level of each firm's employees and national and international patents filed by enterprises in Sweden using the EPO Worldwide Statistical Database (PATSTAT). In the merging process we managed to match 76 percent of the firms in PATSTAT data with unique firms in Sweden. Analyzing the remaining 24 percent of the patent applications shows that they mostly consist of micro firms with none or only a small number of employees, thus being irrelevant to our study.

The sample of this paper focuses on manufacturing firms exclusively. We do this for two particular reasons. Most of the patent applications in our sample are made by manufacturing firms. Moreover, a majority of studies on corporate finance and innovation involve exclusively manufacturing firms (e.g. Bond et al., 2003; Brown et al., 2009; Mulkaly et al., 2001). The present paper refers to this literature.

Since the data include the entire firm population in Sweden we are confronted with some unique data management issues. First, we must exclude firms with obvious erroneous observations. In line with Brown et al. (2009), Fazzari et al. (1988) and Scellato (2007), all firms with negative sums of cash-flow-to-assets during the sample period are dropped. This reduces the variance within the firms in the sample. Due to the many micro firms present in the sample we still face great variance in our sample, and in order to make the empirical analysis more relevant we exclude all firms with average employment below 10 during the sample period.[3]

The key ratios; cash-flow, sales and long-term debt are trimmed at the 10 percent level. Trimming at 10 percent is unusual, but due to the nature of our data we need to be strict in terms of excluding erroneous values. Even after these relatively strict sample construction constraints we have fairly high variance within our sample. Following the sample construction we end up with an unbalanced panel of about 2,700 firms during the period 1997-2005. About 10 percent of the firms have at least once applied for a patent during the sample period.

4.2. Descriptive statistics

[Table 1 about here]

[3] The results are robust to considering alternate cut-offs around 10 employees

This study focuses on relatively few variables. Our main explanatory variable is the cash-flow ratio. Table 1 displays summary statistics for the whole sample in columns 1-3 and for firms which have applied for at least one patent during the sample period in columns 4-6. The patent-applying firms are similar to the overall means and medians of the overall sample. The average cash-flow ratio of patenting firms is 0.065 compared to 0.054 for the overall sample. The sales ratios of patenting firms are lower than for the overall sample, a feature which is visible in the empirical results through a negative sales-ratio coefficient.

We emphasize the equity ratio in the empirical analysis as an important control variable if the cash-flow sensitivity is a result of financing constraints or simply reflecting future investment opportunities. The equity ratio is equity divided by total assets. The equity-ratio of patenting firms is somewhat higher than for the overall sample implying somewhat better financial health of patenting firms.

There is large variability in the control variables we use. The human capital variable is 0.159 for the whole sample and 0.237 for the patenting firms. The patent applying firms are also larger expressed as the log of employment. In terms of sector belonging, 30 percent of the firms in the overall sample operate within low-technology sectors compared to only 13 percent for patenting firms. We also have data on ownership structure across firms. The firms are either owned by a foreign or domestic multinational enterprise (MNE), or is only operating within Sweden but has subsidiaries or is a subsidiary (we refer to those firms as uni-nationals), and finally there are the remaining firms which are categorized as non-affiliated. 35 percent of the firms in the overall sample belong to an MNE, foreign or domestic. However, among the patent applying firms the same figure is 68 percent. The share of non-affiliated firms among the patenting firms is only 15 percent compared to about 30 percent in the whole sample.

The affiliation of the firm is closely linked to the financing side of patenting as well as the size of the firm. A large firm is less likely to face binding financing constraints than a small firm (see e.g. Almeida et al., 2004; Gertler and Hubbard, 1989). Belonging to a group such as an MNE implies that potential financing troubles can be mitigated. It could be from additional funding from the mother company or because of the lower costs of obtaining external finance based on its affiliation (see for instance Hoshi et al., 1991), or the fact that firms acquired by MNEs are already successful firms. The descriptive statistics highlight that the control variables we use are relevant due to the differences between the overall sample and the patent-applying firms. We now proceed with formal econometric analysis in section 5.

5. Econometric analysis

5.1. Baseline estimation results

[Table 2 about here]

Table 2 presents the count-data results of applying a negative binomial regression model to Swedish manufacturing firms. Column 1 contains the specification with only our financial variables. All three financial variables display large and statistically significant effects. Cash-flow, our ratio of most interest, displays the largest parameter-estimate. In column 2 we add the control variables and examine how the cash-flow variable is affected. In column 5, when all the relevant factors are controlled for, cash-flow is still significant and relatively large in size. The original estimate of cash-flow in column 1 of 0.478 has dropped to 0.318. The increase of the p-value of cash-flow in column 5, compared to column 1, indicates that we have large heterogeneity influencing the precision of the parameter-estimate. This is further explored with a battery of sample splits which are conducted in order to explore where, and to what extent, internal financing resources matter for firm-level patent applications.

[Table 3 about here]

In order to check the robustness of our results we estimate the same baseline regression model as in table 2 but with another dependent variable. In this section we estimate a logit-model with the dependent variable being 0 if firm *i* is not applying for a patent year *t* and 1 if they do. Column 1 shows a clear and large sensitivity of the propensity to apply for a patent to cash-flow. The point estimate is twice as large as in the count-data baseline model of table 2. The cash-flow estimate displays a similar development as in table 2 with the count-data model. When we add all control variables the cash-flow estimate decreases somewhat in size and also in precision. By examining the propensity to apply for a patent as well we learn that the impact of cash-flow is not only important to the number of patent applications. We proceed with the negative-binomial estimator since it allows us to control for unobserved firm effects unlike the binary-logit estimator.

5.2. Macro-effects and financing constraints

[Table 4 about here]

We now move on to consider macro-related events affecting the sensitivity of patent applications to cash-flow. Even though we include time-dummies in our regressions we still decompose the sample period in to distinct periods. The nature of the time period which our sample covers makes this decomposition relevant. In columns 1 and 2 we analyze the period 1997-2000 and 2001-2005 periods respectively. The first period covers the inflating of the IT-bubble which was a time when the Swedish economy grew rapidly. The second period covers the aftermath of the bursting IT-bubble and the later years of the second time period also include years with annual GDP-growth rates above 3 percent.

In line with our expectations, we see no financial effects from cash-flow or long-term debt in column 1, i.e. during 1997-2000. This was a period when expectations regarding high-tech and innovation were high and lots of seed money and venture capital was readily available which might have relaxed otherwise binding financing constraints. Applying the rationale behind cash-flow sensitivities, this is a plausible explanation to the non-significant cash-flow estimate for 1997-2000. However, the size estimate is almost twice as large for the 1997-2000 sample than for the 2001-2005 sample. The cash-flow estimate of the 2001-2005 is economically as well as statistically significant. This implies a rising sensitivity of patent applications to cash-flow during the aftermath of the bursting IT-bubble. One reason for the difference in cash-flow sensitivity might be that after the IT-bubble there was an increase in risk aversion which made additional funding sources, other than internal finance, scarcer. The size estimate, mentioned above is also relevant. The size estimate of the 2001-2005 period is half the size as it was in 1997-2000 implying that the increased sensitivity of patenting to cash-flow could simply reflect that smaller firms were by then applying for patents.

The last 4 columns of table 4 comprise sample splits based on the median of firms' average equity-ratio. Column 4 displays a large cash-flow estimate for low-equity firms, in line with our story of financing effects affecting patent applications. Firms with high equity-ratio, column 3, display no sensitivity of patent applications to cash-flow. In the final two columns we observe the bottom and top quartiles of firms in terms of equity-ratio. The bottom quartile represents firms with average equity-ratio at or below 0.24, i.e. 24 percent, or less, of their assets is financed via equity. The top quartile represents firms financing at least 58 percent of their assets through equity. The bottom quartile reports a very high sensitivity of patent applications to cash-flow at 2.081 with a p-value of 1 percent. This is the largest and most precisely estimated effect reported. The sample splits on equity-ratio strengthen our argument that there are financial effects impacting firm-level patenting activity.

The sub-samples of above and below median firms in terms of equity-ratio display the same distribution across firm affiliations as for the whole sample. This is important to highlight in order to confirm that the split on equity-ratio is not simply capturing firm affiliation. We have also checked so that our results are not driven by the ICT and/or biotech sectors. Especially the ICT sectors since they were most directly affected by the bubble-economy around the shift of the millennium. The ICT and biotech firms only account for about 10-15 percent of our sample and they also constitute a similar share in terms of patent applications. These sectors display similar trends as for the whole sample implying that these sectors are not acting as drivers of our results.

6. Conclusion

We estimate count data regression models for manufacturing firms in order to examine the impact of internal finance capacity on firm-level patenting activity. Internal finance capacity is measured by cash-flow. As dependent variable we use the number of patent applications per firm and year.

The study mainly concerns evaluating the impact of cash-flow on the number of patent applications. The results are robust to considering the propensity to apply for a patent. We find that cash-flow plays a non-trivial role in determining the number of patent applications at the firm-level. The baseline regression controls for firm-size, human-capital intensity, the technology level of the sectors, and firm affiliation. We also include the stock of long-term debt and sales, and the regression models are applied to a sample of manufacturing firms in Sweden in 1997-2005. The results show that firm patenting activity is highly sensitive to variation in cash-flow.

Our data allows us to examine a booming economy separately from a contracting one. This makes our study unique since we analyze how exogenous shocks affect firm-level patenting. We, therefore, examine the sub-sample 1997-2000, the build-up of the IT-bubble, separately, from 2001-2005, the aftermath of the bursting IT-bubble. During 1997-2000 the sample displays no sensitivity of patent applications to cash-flow, a sign that firms are not constrained based on internal finance resources. In contrast, in the 2001-2005 sample, there is a large and statistically significant cash-flow effect implying that when overall economic activity declines firms are more dependent on internal finance. We also show that firms with little equity financing display the highest sensitivity of patent applications to cash-flow. Firms with high equity-ratio do not display a sensitivity of patent applications to cash-flow, thus corroborating our initial evidence presented in figure 1.

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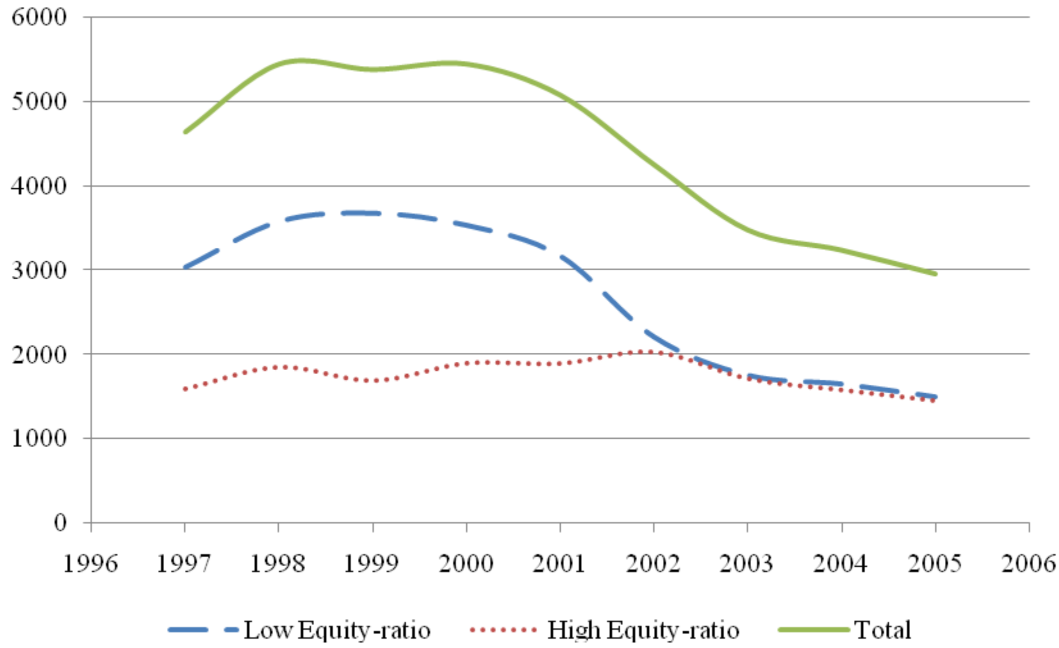
Figure 1 – Number of patent applications by Swedish manufacturing firms 1997-2005



Sources: Calculations based on PATSTAT and the Swedish firm-level data from Statistics Sweden

Table 1 - Summary statistics for manufacturing firms during the period 1997-2005

	All firms: 12,368 observations			Patenting firms: 2,370 observations		
	Mean	Median	Std dev	Mean	Median	Std dev
Cash-flow	0.051	0.030	0.096	0.060	0.037	0.105
Sales	2.295	2.170	1.092	1.932	1.994	0.993
L debt	0.250	0.206	0.229	0.247	0.204	0.232
Log size	3.507	3.218	1.192	4.251	4.051	1.450
Equity-ratio	0.375	0.351	0.201	0.405	0.382	0.200
Human cap	0.159	0.120	0.152	0.214	0.173	0.144
HT	0.068	0.000	0.253	0.088	0.000	0.285
HMT	0.321	0.000	0.466	0.509	0.000	0.500
LMT	0.321	0.000	0.467	0.274	0.000	0.447
NAF	0.297	0.000	0.457	0.121	0.000	0.326
UNINAT	0.341	0.000	0.474	0.183	0.000	0.387
FMNE	0.121	0.000	0.106	0.229	0.000	0.428
DMNE	0.239	0.000	0.426	0.458	0.000	0.498

Notes

Cash-flow, sales and long-term debt are normalized by beginning of the period total assets.
Size is log employees.
Equity-ratio is expressed as equity/total assets
HT is high technological firms, HMT is high-medium technology firms, LMT is low-medium technology firms.
Hum cap is number of employees with at least 3 years of education as a fraction total employment.
UniNat is a uninational corporation i.e. firms only operating domestically but may have or be a subsidiary. FMNE and DMNE are foreign and domestic multinational enterprises respectively. The intercept represents non-affiliated firms.

Table 2 - Negative binominal regressions: Baseline results

	(1)	(2)	(3)	(4)	(5)
Cash-flow	0.478	0.459	0.425	0.318	0.318
	(0.029)**	(0.033)**	(0.035)**	(0.046)**	(0.056)*
Sales	-0.369	-0.392	-0.333	-0.253	-0.230
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
L debt	0.300	0.330	0.458	0.351	0.318
	(0.003)***	(0.001)***	(0.000)***	(0.000)***	(0.001)***
Log size			0.315	0.363	0.317
			(0.000)***	(0.000)***	(0.000)***
HT [a]			1.187	1.002	0.961
			(0.000)***	(0.000)***	(0.000)***
HMT [a]			0.874	0.866	0.841
			(0.000)***	(0.000)***	(0.000)***
LMT [a]			0.971	0.997	0.910
			(0.000)***	(0.000)***	(0.000)***
Human cap				2.728	2.601
				(0.000)***	(0.000)***
UNINAT [b]					-0.126
					(0.473)
FMNE [b]					0.443
					(0.012)**
DMNE [b]					0.656
					(0.000)***
Observations	12874	12874	12832	12768	12768
Firms	2695	2695	2693	2672	2672

Notes

Dependent variable is number of patent applications
*** significant at 1%; ** significant at 5%; * significant at 10%.
p values in parentheses.
Cash-flow, sales and long-term debt are normalized by beginning of the period total assets.
Size is log employees. HT is high technological firms, HMT is high-medium technology firms, LMT is low-medium technology firms.
Hum cap is number of employees with at least 3 years of education as a fraction total employment.
UniNat is a uninational corporation i.e. firms only operating domestically but may have or be a subsidiary. FMNE and DMNE are foreign and domestic multinational enterprises respectively. The intercept represents non-affiliated firms.
(a) Reference is low technology firms
(b) Reference is domestic non-affiliate firms. Year dummies included.

Table 3 – Logit regressions: Baseline results

	(1)	(2)	(3)	(4)	(5)
Cash-flow	1.074	1.227	1.225	1.086	0.967
	(0.047)**	(0.025)**	(0.031)**	(0.059)*	(0.092)*
Sales	-0.483	-0.491	-0.429	-0.351	-0.321
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
L debt	0.668	0.609	0.799	0.744	0.679
	(0.006)***	(0.012)**	(0.002)***	(0.003)***	(0.007)***
Log size			1.383	1.333	1.198
			(0.000)***	(0.000)***	(0.000)***
HT [a]			2.360	1.858	1.818
			(0.000)***	(0.000)***	(0.000)***
HMT [a]			2.251	2.199	2.130
			(0.000)***	(0.000)***	(0.000)***
LMT [a]			1.397	1.555	1.485
			(0.000)***	(0.000)***	(0.000)***
Human cap				4.149	3.754
				(0.000)***	(0.000)***
UniNat [b]					-0.081
					(0.752)
FMNE [b]					0.713
					(0.016)**
DMNE [b]					0.770
					(0.003)***
Observations	12874	12874	12832	12768	12768
Firms	2695	2695	2693	2672	2672

Notes

Dependent variable is 1 if firm applied for at least one patent year t and 0 otherwise
*** significant at 1%; ** significant at 5%; * significant at 10%.
p values in parentheses.
Cash-flow, sales and long-term debt are normalized by beginning of the period total assets.
Size is log employees. HT is high technological firms, HMT is high-medium technology firms, LMT is low-medium technology firms.
Hum cap is number of employees with at least 3 years of education as a fraction total employment.
UniNat is a uninational corporation i.e. firms only operating domestically but may have or be a subsidiary. FMNE and DMNE are foreign and domestic multinational enterprises respectively. The intercept represents non-affiliated firms.
(a) Reference is low technology firms
(b) Reference is domestic non-affiliate firms. Year dummies included.

Table 4 – Negative binominal regressions: Sample splits on business cyclicality and firm equity-ratio

	(1)	(2)	(3)	(4)	(5)	(6)
	1997-2000	2001-2005	High equity-ratio	Low equity-ratio	Top 25% equity-ratio	Bottom 25% equity-ratio
Cash-flow	0.022	0.714	-0.072	0.788	-0.031	2.081
	(0.858)	(0.004)***	(0.634)	(0.060)*	(0.634)	(0.012)**
Sales	-0.292	-0.238	-0.068	-0.286	-0.118	-0.303
	(0.000)***	(0.000)***	(0.301)	(0.000)***	(0.318)	(0.002)***
L debt	-0.004	0.253	0.198	0.337	1.016	0.601
	(0.984)	(0.012)**	(0.215)	(0.004)***	(0.152)	(0.004)**
Log size	0.781	0.465	0.587	0.221	0.789	0.554
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
HT [a]	0.841	1.799	0.678	1.569	0.935	1.686
	(0.004)***	(0.000)***	(0.015)**	(0.000)***	(0.017)**	(0.002)***
HMT [a]	0.763	1.335	1.036	1.317	1.223	1.849
	(0.002)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
LMT [a]	0.925	1.027	0.585	1.456	0.828	1.806
	(0.000)***	(0.000)***	(0.014)**	(0.000)***	(0.011)**	(0.000)***
Human cap	2.983	2.863	1.964	3.538	2.509	3.982
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
UniNat [b]	-0.691	0.004	-0.133	-0.106	-0.238	-0.166
	(0.005)***	(0.987)	(0.627)	(0.641)	(0.550)	(0.617)
FMNE [b]	0.101	0.465	0.569	0.214	0.669	0.253
	(0.587)	(0.045)**	(0.039)**	(0.352)	(0.138)	(0.410)
DMNE [b]	0.281	1.049	0.883	0.356	0.948	0.344
	(0.066)*	(0.000)***	(0.000)***	(0.081)*	(0.014)**	(0.252)
Observations	5048	7720	4942	7826	2128	3480
Firms	2184	2246	2425	1574	760	1235

Notes

Dependent variable is number of patent applications
*** significant at 1%; ** significant at 5%; * significant at 10%.
p values in parentheses.
Cash-flow, sales and long-term debt are normalized by beginning of the period total assets.
Size is log employees.
HT is high technological firms, HMT is high-medium technology firms, LMT is low-medium technology firms.
Hum cap is number of employees with at least 3 years of education as a fraction total employment.
UniNat is a uninational corporation i.e. firms only operating domestically but may have or be a subsidiary. FMNE and DMNE are foreign and domestic multinational enterprises respectively. The intercept represents non-affiliated firms. High equity-ratio firms are firms with average equity/total assets above the median and low equity-ratio firms are subsequently at or below the median of average equity/total assets. Top 25% equity-ratio implies the 0-25 percentiles firms in terms of equity-ratio and bottom 25% subsequently implies the 75-100 percentiles.
(a) Reference is low technology firms
(b) Reference is domestic non-affiliate firms. Year dummies included.