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Abstract

This paper distinguishes between internal (produced within the firm) and external (produced by other firms) knowledge and studies the effects of both knowledge types on survival in a cohort of computer and electronic product manufacturing companies started in 1991 in the continental US metropolitan statistical areas (MSAs). Estimation results suggest that innovative companies face lower hazard but this effect seems to be driven by company's initial characteristics, as producing more knowledge measured by successful patent applications does not translate into a higher likelihood of survival. In contrast, an innovative environment decreases survival likelihood in the whole sample, yet this result appears to be driven by non-patenting establishments. In the subset of non-patenting firms an innovative environment has a strong negative effect on survival whereas no significant relationship is identified in the subset of innovative firms.

Key words: Firm size, business survival, knowledge creation, patents, innovative environment

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Introduction

Innovation and technological change are at the heart of economic growth (Aghion & Howitt, 2009; Silverberg & Soete, 1993), and new knowledge is at the heart of innovation and technological change (Audretsch & Feldman, 1996). Prominent economic research traditions elucidate the importance of internal (created within a company) and external (produced by other companies) knowledge in a discussion of aggregate growth (Acs & Varga, 2002; Koo, 2005b; Parente, 2001; Romer, 1990) and individual firm performance (Coad & Rao, 2008; Esteve-Pérez & Mañez-Castillejo, 2008; Pianta, 2005; Piva & Vivarelli, 2005). The empirical studies that look at the impacts of internal and external knowledge on business outcomes usually focus on innovative outputs and local knowledge spillovers (LKS) respectively and consider these important factors in isolation. This paper contributes to the literature by testing the effects of innovative outputs and of innovative environment[1] on business performance using a cohort of computer and electronic product manufacturing companies. We provide a more detailed picture of a heterogeneous business response to the two knowledge types in the context of a high-technology industry that is not driven by differences in samples.

This paper focuses on business survival as a measure of business performance. Although firm exit is a fundamental force of industry evolution, which ensures overall efficiency of an economy, understanding factors that promote firm survival are important for policy reasons. The overall economic efficiency achieved by intensive "churn" – failure of companies to survive competition – may be of limited relevance to local and regional (as opposed to national) policy-making. As competition becomes a global phenomenon and local companies mostly compete against outside businesses, exit of local firms weakens their regions' tax base and reduces employment and output. Considerations of national or world economic efficiency are of little importance in such circumstances. Firm survival, then, becomes a more appropriate measure of entrepreneurship in a region for the purposes of regional economic policies (Renski, 2006).

[1] In what follows, the term "innovative output" will be used interchangeably with the term "internal knowledge" and terms "innovative environment" or "knowledge environment" will be used interchangeably with the term "external knowledge".

The relationship between firms' innovative outputs and innovative environment on the one hand and business performance on the other is not clear *a priori*. More innovative companies in general are expected to perform better as the new knowledge produced within a firm often gives it a competitive advantage. This would translate into higher survival likelihood. An opposite view emphasizes the costs of producing new knowledge and the associated risks, which may hinder business performance[2]. With respect to the impact of innovative environments, the agglomeration and local knowledge spillover perspectives suggest that companies located in knowledge-rich milieu tend to be more productive and innovative. These characteristics usually promote survival. In contrast, within the Schumpeterian approach, the 'creative destruction regime' (a process of market transformation characterized by the replacement of incumbent firms and existing technologies by the new ones) implies that more innovative regions should enjoy greater competition and, consequently, higher business turnover.

In this paper we focus on stand-alone companies in the U.S. computer and electronic product manufacturing sector (NAICS334) and, following a number of previous contributions, study business survival (Renski, 2011; Tsvetkova, Thill, & Strumsky, 2014a). Computer and electronic product manufacturing is a high-technology industry that substantially contributes to innovation and offers high-wage employment characterized by sizeable multiplier effects (BLS, 2011; DeVol, Wong, Bedroussian, Hynek, & Rice, 2009; Helper, Krueger, & Wial, 2012). It accounts for about 1.7 percent of the U.S. GDP and more than 10 percent of value added in manufacturing, according to the Bureau of Economic Analysis[3]. It comes as no surprise that many localities in this country provide economic incentives to the NAICS334 (and other high-tech) companies in the form of lower taxes, tax credits and financing assistance among others. For these reasons the understanding of survival determinants within this industry is of practical importance to the economic development policy debate.

The vast majority of existing studies that are relevant to this debate come from Europe. Evidence in the U.S. context is relatively scarce, most likely as a result of limited data

2 The costs of innovative activities within a firm usually refer to innovative inputs, which are beyond the focus of our analysis. As we are primarily interested with the effects of innovative outputs, we expect the relationship between this metric of knowledge creation within a company and its performance to be positive.
3 http://www.bea.gov/industry/gdpbyind_data.htm

availability at individual firm level due to confidentiality concerns. Our study presents firm-level analysis of business survival within computer and electronic product manufacturing in the U.S. MSAs. We consider both innovative (those that file at least one successful patent application) and non-innovative companies and distinguish between internal and external knowledge. The former 'belongs' to a firm in a sense that it is either something employees possess or is developed within a company. The latter type of knowledge is produced by others and can spill over to businesses in proximity. The effects of these two knowledge types are considered simultaneously to capture impacts that could be identical or divergent.

The rest of the paper is organized in the following way. The next section overviews the literature on the effects of innovation on survival. Section 2 introduces the sample followed by a description of the variables in Section 3. Sections 4 and 5 explain econometric approach and present the results, respectively. The final section summarizes the findings and discusses their implications.

1. Literature review

Innovation may have opposing effects on business performance. On the one hand, a firm's ability to come up with new solutions[4] plays a crucial role in superior business performance (Santarelli & Vivarelli, 2007) leading to greater productivity, sales, and profit (Morbey & Reithner, 1990; Zahra, 1996). Innovation may take various forms from developing revolutionary new products and corresponding markets to gradual improvements in operations, technology and management. Maintaining research efforts is a crucial element of a successful technological strategy (Christensen, 1992; Mitchell & Hamilton, 1988) that allows a firm to become and remain an industry leader (Wilbon, 2002). On the other hand, innovation imposes risks associated with potential liquidity constraints, inability to capitalize on the research results, a lack of patent protection and others.

At a more aggregated level, the stock of knowledge accumulated in a region and the regional innovative environment are the most valuable assets in a modern economy (Paci & Usai, 2009). In geographical areas with more intensive private and government-funded research and development activities, economies tend to grow faster (Cassia, Colombelli, & Paleari, 2009; Stough & Nijkamp, 2009), while firms on average are likely to be more innovative (Coronado & Acosta, 2005).

[4] In this sense, innovation is closely related to the notion of Schumpeterian entrepreneurship.

Understanding determinants of firm longevity is important because the majority of start-ups go out of business during the first years of operation. Geroski (1995, p. 435) concludes that exit is 'the most palpable consequence of entry'. In Europe, the likelihood of exit is the highest during the two initial years of operation with about half of the new firms not surviving a five-year mark (Audretsch, Santarelli, & Vivarelli, 1999; Box, 2008; Littunen, 2000). In the United States, between five and ten percent of all firms in a given market exit every year (Agarwal & Gort, 2002). Analysis of manufacturing, services, and retail sectors suggests that 66 percent of new establishments survive for at least two years, half of all start-ups live four years or longer, and only 40 percent continue after a six-year time span (Headd, 2003). In general, roughly 50 percent of new firms, regardless of the country or sector, exit within five years (Audretsch & Mahmood, 1995; Dunne, Roberts, & Samuelson, 1989; Johnson, 2005; Mata, Portugal, & Guimaraes, 1995).

Empirical investigations suggest that innovative activities by firms increase their market value[5] (Hall, Jaffe, & Trajtenberg, 2005), promote asset (Helmers & Rogers, 2011) and sales growth (García-Manjón & Romero-Merino, 2012; Helmers & Rogers, 2011), and reduce probability of exit (Esteve-Pérez & Mañez-Castillejo, 2008; Huergo & Jaumandreu, 2004). Analyses with finer measures of innovation conclude that innovative inputs increase risks, while innovative outputs enhance business longevity (Buddelmeyer, Jensen, & Webster, 2010; Wilbon, 2002). In a number of cases, the effect of R&D is conditional on the type of innovation a firm is engaged in (Manjon-Antolın & Arauzo-Carod, 2008), with process innovation promoting survival (Cefis & Marsili, 2006, 2012). In addition, R&D has dissimilar effect on various modes of exit (Esteve-Perez, Sanchis-Llopis, & Sanchis-Llopis, 2010; Srinivasan, Lilien, & Rangaswamy, 2008).

New firm survival rates differ substantially across regions perhaps because regional conditions determine the local resource base a firm may draw upon in order to survive and prosper (Acs, Armington, & Zhang, 2007). Evidence on the effects of innovative environment (as opposed to firm's own inventions) on survival probability is very scarce. There are just a few studies that focus on this relationship or consider it in passing. For example, Renski (2006) explores the effects of localization, urbanization, and industrial diversity in a number

[5] Some authors argue, though, that patenting by a firm in the U.S. does not affect its value in contrast to Europe where patents have a strong effect (Belenzon & Patacconi, 2013).

of industries in the continental U.S. His discussion is framed within arguments put forth by Marshall (1920 [1890]) and Jacobs (1969). Innovation and knowledge are mentioned as important components of observed relationships, although the author does not test the effects of innovation directly. The study suggests two paths via which external economies may affect firm survival, namely local knowledge spillovers (greater likelihood of survival) and increased competition (increased hazard). The empirical results of the study are mixed and depend on industry, sector, and the geographic radius of the effects taken into account. Tsvetkova et al. (2014a) use a non-parametric approach to investigate the survival likelihood of non-patenting stand-alone establishments in two U.S. sectors. The authors find that innovative milieu increases hazard in computer and electronic product manufacturing, while the opposite is true for the healthcare services. The negative effect of innovative environment on survival for the former industry is reversed in the most dense metropolitan areas and metropolitan areas with favorable conditions measured by the number of computer and electronic product manufacturing start-ups. Another contribution by the same authors (Tsvetkova, Thill, & Strumsky, 2014b) focuses on computer and electronic product manufacturing only. The results of a parametric analysis confirm the findings of the previous study for smaller firms, whereas the hazard faced by larger firms does not depend on innovative environment.

2. The sample

Economic processes within sectors and industries differ considerably. In order to avoid aggregation bias, this paper focuses on one U.S. industry, Computer and Electronic Product Manufacturing (NAICS 334), which includes NAICS 3341 (Computer and Peripheral Equipment Manufacturing), NAICS 3342 (Communications Equipment Manufacturing), NAICS 3343 (Audio and Video Equipment Manufacturing), NAICS 3344 (Semiconductor and Other Electronic Component Manufacturing), NAICS 3345 (Navigational, Measuring, Electromedical, and Control Instruments Manufacturing), and NAICS 3346 (Manufacturing and Reproducing Magnetic and Optical Media). The highly innovative nature of the industry (BLS, 2011) should provide fertile ground for the study of innovation effects on firm performance (Coad & Rao, 2008).

This paper studies a cohort of NAICS334 stand-alone start-ups established in the continental metropolitan statistical areas in 1991. The National Establishment Time Series

(NETS) Database[6] is the main data source. The companies that do not have missing observations between the start year and the year of exit are retained for the analysis. They are tracked till their exit indicated in the database or year 2008, whichever happens first. The sample drawn from the NETS is matched to patent data available from the U.S. Patent and Trademark Office (PTO) on the basis of establishment (assignee) name and location. Individual geographical and industrial identification in NETS is utilized to supplement the estimation file with regional and industry-level variables derived or calculated from the data provided by the U.S. Census Bureau, the Bureau of Labor Statistics (BLS), the Integrated Postsecondary Education Data System (IPEDS), Economic Modeling Specialist International (EMSI)[7] and the NETS Database[8].

To reduce unobserved heterogeneity in the sample, establishments that started with more than 100 employees, had more than 200 patents, or experienced merger or acquisition[9] during the time of the study are excluded from the analysis. The final sample consists of 1,644 non-patenting and 134 patenting firms (1,778 companies; about 68 percent of the total number of NAICS334 start-ups in the country in 1991).

The companies included in this analysis are selected by flow sampling; it ensures that all firms started during a specified time period (in this case year 1991) are included in the analysis and the effects of interest are studied using all information on both successful and failing enterprises. Flow sampling is the necessary condition for avoiding the stock-sampling, or survivor, bias, which arises when only existing businesses are considered. In such a case, the focus is inevitably on the subset of more viable firms, those that managed to survive to the time of analysis.

3. Variables and data sources

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[6] The NETS Database contains data on all establishments that ever were recorded as active by Dun & Bradstreet. The establishment-level information includes location, the number of employees, the first and the last years in operation, and other indicators.

[7] EMSI data is a proprietary dataset that provides yearly information on employment, earnings, and the number of establishments in the U.S. counties at 4-digit NAICS codes.

[8] Description of the variables and data sources are given in Section 4.

[9] The companies that went through M&A are likely to be more successful. Such companies would be an interesting subject of a study that aims at understanding firm-level business performance determinants. A very small number of M&A firms in our original data set (only 12 establishments) prevents us from paying special attention to these firms.

The set of models presented and estimated in Section 4 estimates survival function, which is competed by the software and does not require to be entered as a separate dependent variable in the data set. The main explanatory variables are the two types of knowledge available to a firm, namely the internal knowledge which is 'embedded' within the company and the external one resulting from spillovers 'outside' of the firm itself. Knowledge internal to an establishment is measured by the total number of successful patent applications filed by each firm to date (*FirmApplications*)[10]. The date of the application, not the date of a patent, which can be granted years from the application date, determines when an application enters the dataset. For example, an application filed in year 1992 with patent granted in year 1994 is counted toward the value of knowledge variable in 1992. Such an approach allows us to capture the effects of knowledge, not of property rights or increased business value associated with patents and makes the discussion of internal and external effects of *knowledge* possible. In addition to this measure, a dummy equal to one if a company filed at least one successful patent application during the study period (*AppsDummy*) is included in the models (in the models with a dummy, the number of patent applications – an additional measure of internal knowledge – is total number of applications minus one). Using these two variables allows factoring out the effects of knowledge *per se* vs. the amount of knowledge on firm size and survival likelihood. The data come from the U.S. Patent and Trademark Office (PTO). A variable that approximates external knowledge in a MSA (*ExtKnowledge*) is the total number of successful patent applications filed by all inventors residing in a metropolitan area in a given year, standardized by metropolitan population. This measure can be potentially superior to commonly used patent counts as patents, in a sense, protect knowledge from spilling over, whilst patent applications reflect the level of research activities that may be more conducive to spill-overs.

The number of employees in a given year in logarithmic form (*Employment*) controls for the effects of firm size on survival. Extensive literature documents a positive relationship between these variables (Esteve-Perez et al., 2010; Jensen, Webster, & Buddelmeyer, 2008).

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[10] Some scholars argue that composite measures of innovation and knowledge should be used in order to capture the elusive nature of this phenomenon (Hagedoorn & Cloodt, 2003; Nelson, 2009). In the case of high-technology sectors, like NAICS334, however, the correlation among alternative measures such as R&D inputs, patent counts, patent citations and new product announcements is very high. This makes using just one approximation an appropriate strategy (Hagedoorn & Cloodt, 2003).

Following Tsvetkova et al. (2014b), we add an interaction term between *Employment* and *ExtKnowledge* in order to capture possible intervening role played by firm size in the effect of outside knowledge on business survival, as well as a measure of expansion from the previous year (*Expand*). The latter variable is calculated as the difference between the current number of employees and the number of employees in the previous year from the NETS Database.

A set of controls includes various firm-, industry-, and metropolitan characteristics that the literature finds important for business performance. *Age* is the number of years a company has been in business. The existing research suggests that this variable is crucial for firm life-cycle dynamics (Kueng, Yang, & Hong, 2014; Sorensen & Stuart, 2000), although it may be less relevant in a dataset where all establishments are of the same age. Another firm characteristic is productivity measured by the sales per worker (*Productivity*). This variable is calculated as the ratio of total sales to employment for each establishment based on data from NETS. Employment includes both payroll employees and the owners themselves.

Agglomeration and urbanization are essential conditions for knowledge spillovers (Koo, 2005b). Industrial concentration may signal the availability of necessary resources, qualified labor pool, and other favorable conditions. At the same time, higher density is likely to increase the costs of doing business and to heighten competition. The models in this paper include population density in logarithmic form (*PopDensity*) and the number of NAICS334 establishments per square mile in a MSA (*BusDensity334*) to control for these potential effects. The NETS Database and the U.S. Census Bureau provide the data for the variables.

An unemployment rate approximates economic conditions in a metropolitan area. The rate of unemployment in logarithmic form (*Unemployment*) is a parsimonious measure of possible economic hardships in an MSA. The data come from the U.S. Bureau of Labor Statistics. The population-adjusted number of graduates with a bachelor's degree or higher (*Graduates*) controls for the quality of the labor pool available to firms. The data are aggregated into a metropolitan-level variable from individual college data in the Integrated Postsecondary Education Data System (IPEDS). Beside variables described above, all models include a set of industry dummies that distinguish between six NAICS 4-digit categories used in this research.

4. *Econometric approach*

To estimate the survival models in this paper we use a parametric technique. A more flexible semi-parametric approach (e.g. Cox model) is inappropriate because the proportionality assumption, necessary for the semi-parametric estimates to be valid, is violated in our sample. Parametric models assume a specific distribution of failure times. If the choice of a distribution is correct, parametric estimators are more efficient compared to the semi-parametric ones.

Analysis of the literature and inspection of our data suggest an increasing and then decreasing hazard faced by firms in computer and electronic product manufacturing. Two distributions are able to accommodate the non-monotonic hazard functions, log-normal and log-logistic[11]. We use the latter to model the effect of internal and external knowledge on firm survival in NAICS334.

The hazard function in log-logistic regression is assumed to be of the form[12]

$$h(t|x_j) = -\frac{d}{dt}S(t|x_j)/S(t|x_j) \tag{2}$$

where $S(t|x_j)$ is the survival function that depends on time t and covariates x, which in our case include measures of internal and external knowledge and controls described in Section 3. The log-logistic model is an accelerated failure time (AFT) model. Covariates accelerate time to failure by an acceleration parameter $exp(-x_j\beta_x)$, thus,

$$S(t_j|x_j) = S_0\left\{\exp(-\boldsymbol{x}_j\boldsymbol{\beta}_x)t_j\right\} \tag{3}$$

A function of failure time t_j, $\tau_j = exp(-x_j\beta_x)t_j$ is assumed to be distributed as log-logistic with mean β_0 and variance γ.

To keep the estimation strategy consistent with the employment equations, we first estimate a log-logistic survival model using the whole sample. To factor out the effects of internal knowledge vs. the effects of additional internal knowledge, we include *AppsDummy* and *FirmsApplication* one by one and then together; this approach generates three distinct models. We then repeat estimation using two subsets of the data, one with only patenting firms, and one with only non-patenting firms.

5. *Estimation results*

[11] They are practically indistinguishable for the purpose of estimation.
[12] Discussion in this subsection is based on Cleves et al. (2010).

Table 2 presents the results for the log-logistic survival models. The estimates for the whole sample in columns [1]-[3] suggest that internal and external knowledge have opposite effects on survival likelihood. Companies that possess innovative knowledge measured by the presence of successful patent applications tend to live longer. It appears, however, that this result is driven by the *a priori* superior qualities of the companies analyzed. A simple dummy variable (*AppsDummy*) has a larger and stronger coefficient (column [1]); the effect of the application count is approximately eight times smaller in magnitude (column [2]). In addition, the inclusion of both measures of internal knowledge reveals no additional explanatory power of *FirmApplications* above and beyond the dummy variable. To filly make sense of this result, we further analyzed the sample and found that companies that start with a patent or file a patent early in their life are likely to keep patenting throughout the duration of the study. Although this result is rather preliminary and requires further analysis, it may cast some doubt on the intuitive notion that additional knowledge creation is the force behind improved business performance of companies. It could be that initial superior qualities of management and of the labor force cause both innovative activities and better market outcomes. Unlike internal knowledge and in line with the Schumpeterian view of creative destruction, external knowledge hampers survival chances in the whole sample as evidenced by the negative coefficient on the variable *ExtKnowledge*. This result is significant at the 10% only.

Somewhat unexpectedly, given the substantial evidence of positive relationship between firm size and survival (Kaniovski & Peneder, 2008; Segarra & Callejón, 2002; Strotmann, 2007), this characteristic turns out to be insignificant in our models. Researchers note that in many instances the effect of company size on hazard depends on the sector, industry and technology (Agarwal & Audretsch, 2001; Fritsch, Brixy, & Falck, 2006); stages of industry life cycle (Agarwal, Sarkar, & Echambadi, 2002); time horizon of a study (Audretsch, 1995; Audretsch, Houweling, & Thurik, 2000; Fritsch et al., 2006); and the degree of engagement in innovative activities (Cefis & Marsili, 2006). A few studies, like ours, find insignificant effect (Audretsch et al., 1999; Saridakis, Mole, & Storey, 2008).

The importance of size comes through another channel, via its moderating effect on the relationship between external knowledge and survival. As Table 2 suggests, survival of larger companies is less sensitive to the negative effects of knowledge-rich environments. If the negative effect comes from increased competition and the creative destruction regime inherent in the innovative milieu, larger firms may be better suited to compete successfully due to greater resources at their disposal.

Table 2. Estimation results for firm survival (the log-logistic model)

Variable	**Whole sample**			**Firms with applications**	**Firms without applications**
	[1]	**[2]**	**[3]**	**[4]**	**[5]**
AppsDummy	0.110***		0.101***		
	(0.028)		0.029		
FirmApplications		0.013**	0.003	0.003	
		(0.006)	0.003	(0.003	
ExtKnowledge	-0.027*	-0.027*	-0.026*	0.042	-0.032**
	(0.016)	(0.016)	0.016	(0.054)	(0.016)
Employment	0.001	0.003	0.001	0.011	-0.000
	(0.009)	(0.009)	0.009	(0.032)	(0.009)
ExtKnowledge Employment*	0.019**	0.019**	0.019**	0.009	0.019**
	(0.008)	(0.008)	0.008	(0.020)	(0.008)
Expand	-0.001***	-0.001***	-0.001***	-0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.117***	0.117***	0.117***	0.094***	0.119***
	(0.003)	(0.003)	(0.003)	(0.008)	(0.003)
Productivity	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	0.000
PopDens	0.000	0.000	0.000	0.000*	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
BusDensity334	-0.015	-0.016	-0.014	-0.324	0.018
	(0.053)	(0.053)	0.053	(0.225)	(0.054)
Unemployment	-0.238***	-0.240***	-0.238***	-0.048	-0.251***
	(0.027)	(0.027)	0.027	(0.074)	(0.028)
Graduates	0.022***	0.021***	0.021***	0.053	0.019
	(0.007)	(0.007)	(0.007)	(0.041)	(0.007)
Constant	1.647	1.654	1.649	1.352	1.667
	(0.060)	(0.060)	(0.061)	(0.153)	(0.064)
Industry dummies	Yes	Yes	Yes	Yes	Yes
Gamma	0.185	0.185	0.185	0.128	0.185
Observations	19,249	19,249	19,249	1,711	17,538
Wald $\chi2$	2,710.79	2,716.08	2,720.12	276.15	2,602.94
Prob > $\chi2$	0.000	0.000	0.000	0.000	0.000

*** - significant at the 0.01 level; ** - significant at the 0.05 level; * - significant at the 0.1 level

Robust standard errors reported in parentheses are allowed to be correlated within each establishment

Four control variables in models [1] – [3] are statistically significant. In line with extensive literature (e.g. Agarwal & Gort, 2002; Esteve-Perez et al., 2010; Fontana & Nesta, 2010) the establishments that survived longer are likely to continue operations, as the coefficient on the variable *Age* shows. A negative and statistically significant coefficient on *Expand* implies that in our sample companies that add employees in one year are likely to exit in the following year. The evidence may be suggestive of the limited ability of the firms to manage their growth or a choice to go out of business in order to start a new venture as new opportunities arise. The level of unemployment in an MSA and educational level have expected signs, with economic hardship increasing hazard and labor pool of higher quality promoting survival.

The survival dynamics remarkably differs between companies that create knowledge, as approximated by successful patent applications, and those that do not. In general, innovative companies in the sense of our study are not sensitive to several factors important for longevity of the other subset of firms and in the whole sample. Confirming the results reported in columns [1]-[3], additional patent applications do not extend the expected life span of knowledge-creating companies. Such companies are also immune to the negative effects of knowledge-rich regional environment. Age still plays an important role in this sub-sample. Metropolitan business density is related not only to the size of innovative firms in our sample; it also promotes survival, although this coefficient is significant at 10% in both models. As follows from the last column of Table 2, in the subset of establishments that do not create knowledge in the terminology of this research, the patterns of the relationship between survival and independent variables are identical to those in the whole sample, which is dominated by non-innovative companies.

6. Conclusions

This paper studies the effects of knowledge internal and external to a firm on business survival. It uses parametric survival analysis and focuses on a cohort of computer and electronic product manufacturing start-ups that were established in the continental U.S. MSAs in 1991.

The estimation shows divergent results for the two types of knowledge. A company' own knowledge that is captured by the presence and by the number of successful patent applications boosts its survival chances but is not related to the size of NAICS334 firms. This could be welcome news to policy-makers who promote innovative efforts among firms and seek to create conditions that stimulate private innovation. The results, however, appear to suggest that innovative activities of establishments tend to be very path-dependent with highly innovative companies applying for patents throughout the study period. The lack of additional explanatory power of the variable that counts successful patent applications points to the fact that greater innovative efforts do not translate into increased survival chances. This could be an indication of more favorable initial conditions the knowledge-creating firms seem to enjoy, most likely due to the expertise and talent of their employees. From the public policy point of view, these conclusions may indirectly imply the importance of programs aimed at enhancing human capital.

On the other hand, innovative environment commended in the literature as promoting a vast variety of economic and social benefits (Cassia et al., 2009; Feser, 2002; Kirchhoff, Newbert, Hasan, & Armington, 2007; Koo, 2005a, 2005b; Zachariadis, 2003) decreases survival chances in the whole sample and among non-patenting firms. The negative effect of innovative milieu on the longevity of MAICS334 firms is moderated by company size with larger firms less affected.

To expand on the differences between companies that create knowledge and those that do not, being an innovator hedges against the negative influence of several factors. On average, companies with successful patent applications seem to be less sensitive to the environment when it comes to their likelihood to stay in business. The age and industrial affiliation plays an essential role, while metropolitan innovation, potentially signaling intense competition regime, has no effect. Likewise, the hazard faced by such companies is not related to the measures of unemployment, which reflect the level of economic hardships in a metropolitan economy. Overall, this paper offers a more nuanced picture of the influence of innovation, in its two incarnations, on high-tech business survival. It highlights the need for further research that can distinguish between the effects of innovation efforts *per se* from the effects of the initial firm characteristics relevant to its performance.

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