

# High-Technology and Regions in an Era of Open Innovation

Darrene Hackler<sup>1</sup>  
Associate Professor  
Department of Public and International Affairs  
George Mason University, VA, USA  
dhackler@gmu.edu

## Abstract

*The U.S. economy benefits greatly from the production of knowledge into economically useful innovations. However, a dramatic shift has occurred in how ideas are commercialized. Closed innovation, where internal research and development (R&D) labs of large companies control future discoveries, has faded. Today, it is more common that innovations evolve externally of the commercializing firm because of open innovation activities like licensing agreements. The changes in dynamics of innovation can create large opportunities for small business and entrepreneurs, yet the research on how nascent entrepreneurs utilize open innovation and how the regional social and economic environment affects this process is understudied in our time of global and regional competition. The paper examines open innovation strategy in nascent firms to explain how it varies in different technology industries, by a firm's R&D capacity, an entrepreneur's human capital and gender, and regional characteristics. The paper utilizes the largest longitudinal study of new businesses, the Kauffman Firm Survey (KFS). The results suggest that high-technology firms differ in terms of how firm and regional characteristics affect their likelihood of utilizing more open innovation strategies, and regional effects are consequential to all firms, but especially to high-technology firms. The paper informs the body of entrepreneurship research addressing innovation and high-technology economic development and furthers regional policy development to support nascent open innovation dynamics.*

**Keywords:** innovation, knowledge, licensing agreements, patents, R&D, human capital, gender, high-technology, regional economy, technology, entrepreneurship

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## Changing dynamics of innovation

A fundamental shift has occurred in the ways that ideas become marketable goods and services and it has great implications for new businesses. Chesbrough describes how internal R&D is not the strategic asset it once was, and that in an *open innovation* model, firms seek to commercialize both internal and external ideas “by deploying outside (as well as in-house) pathways to the market” (Chesbrough 2003, pp.36-37). Although some of the literature examining Chesbrough’s concept of open innovation focuses on how firms include customers and outside ideas in their innovation strategy, this paper focuses on how an open innovation strategy suggests that the firm incorporates innovation from a variety of sources.<sup>2</sup> The strategy of *closed innovation* requires control and self-reliance in order to internally generate ideas and solely be responsible for developing, manufacturing, marketing, and distributing the new product or service. In contrast, an open innovation strategy utilizes technology alliances, joint development, and technology licensing agreements that may alter traditional internal research and development (R&D) activities.

The interplay of traditional measures of innovation, like patents, and these open innovation measures are of consequence. The paper focuses on licensing agreements as an open innovation strategy, examining two in particular, the *licensing in* and *licensing out* of ideas. In the former, an idea can originate outside of a company but be purchased by another company that pursues the commercialization of the idea. Microsoft, Cisco and other large companies have made *licensing in* a common business development practice. Some research has referred to this as inward technology licenses (Kuen-Hung Tsai & Hui-Chen Chang 2008). A company may also choose to profit from an idea that seems to lack value from an internal investment perspective, but through *licensing out* the intellectual property becomes valuable.

The types of firms that are more likely to utilize a more open innovation strategy are an important focus given that the role of new business formation is in itself an innovation. According to Schumpeter, it is the entrepreneur that initiates great change in the economic system whether it results in a new product and its resulting markets or a new production method and process (Schumpeter 1934; Swedberg 2000). Understanding what types of firms are likely to engage in an open innovation strategy convey how the change in the paradigm of firm innovation will filter through entrepreneurship. In addition, the changing paradigm is not isolated from the regional environment. Regional economic, social, and cultural dynamics also provide a foundation for supporting entrepreneurs and their processes. In fact, the innovation capacity of the region itself may have an effect on a firm’s innovation strategy.

## Open innovation in nascent firms

Although the examples of open innovation often describe the changes from a large company’s perspective, new entrepreneurs and small businesses can also leverage both types of licensing agreements. From a new firm’s perspective, licensing out can enable the firm to maintain a focus on further innovation or free the firm from the investment required to commercialize the idea, while licensing in allows a new business to take

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<sup>2</sup> The idea of innovation strategy refers to the processes a firm utilizes to direct the decisions and activities around the use and development of its ideas into useful innovations and forms of technology (Eisenhardt & Schoonhoven 1990; Acs *et al.* 2002).

advantage of an innovation to improve the firm's own good or service production. Yoshikawa suggested that a new firm is more likely to engage in inward licensing agreements for mature technologies that have established patents (Yoshikawa 2003). The agreements are somewhat less strategic in terms of developing a competitive advantage, but the time pressure that a new firm feels to push a product or service to market tends to increase usage of inward licenses. In addition, the firm can then focus time and expenditures on other issues and not 'reinvent the wheel'. Innovation strategies of nascent firms could be considered much more absorbing of this form of open innovation.

The lack of appropriate measures of open innovation activity in nascent firms has slowed our understanding of how open innovation affects new business formation. However, the open innovation paradigm is of great economic consequence, as exhibited in Schumpeter's ideas about creative destruction and findings that suggest small businesses are more likely to generate major innovations than large businesses (Scherer & Ross 1990; Small Business Administration 1996). A U.S. Small Business Administration study found that "small patenting firms produce 13–14 times more patents per employee as large patenting firms" and that "small firm patents are twice as likely as large firm patents to be among the 1% most cited patents" (CHI Research Inc. 2002, p.3). However, some suggest that "it would appear that increasingly those who invent are dissuaded from seeking patents by the costs involved, the time delays, and the prospect in many new industries that patents will provide very little protection" (Miner *et al.* 1992, p.103), making external technologies even more appealing.

The paper examines open innovation among nascent firms from the perspective that innovations are largely the work of smaller firms. The analysis will also explore the differences among high-technology nascent firms given that they face even greater changes in their innovation model, spending only a fraction of what large firms spend on total R&D but producing more than half of the innovations (Small Business Administration 1996). The analysis examines open innovation and develops testable hypotheses about the measures of innovation with respect to firm characteristics as well as owner characteristics, such as human capital. It explores differences with respect to gender to provide fuller context to our understanding of entrepreneurs and open innovation. Although women have traditionally founded businesses in the retail and service sector (Loscocco & Robinson 1991; Moore & Buttner 1997; Anna & Chandler 1999), they are increasingly represented in non-traditional industries such as high-technology, construction, transportation, public utilities, business consulting and other types of services (Langowitz 2003; Center for Women's Business Research 2003; Center for Women's Business Research 2004).

The discussion of innovation dynamics occurs across a considerable literature from a variety of disciplines. Although Schumpeter focused on creative destruction, others link innovation's economic impact to geographic space and how the agglomeration of innovations in one area can have large implications on a locale's economic well-being. Past studies suggest that knowledge is not distributed evenly across space (Feldman & Audretsch 1999; Jaffe *et al.* 1993), resulting in spatial disparities of innovation activities. Actually, "cited patents originate with a high degree of statistical likelihood from the same geographic locality" (Scott 2006, p.9). In addition, there is large heterogeneity in self-employment across space (Glaeser 2007). Thus, the paper examines what types of regions are more likely to have firms that are pursuing a more open innovation strategy. In total, the paper seeks to examine open innovation at the firm level as well as address the lack of general understanding of the role of location in entrepreneurship.

## **Innovation and the firm**

Chesbrough's concept of open innovation suggests that innovation potential is broadened, opening an internal process to the influence of other firms. A likely result of this is that a greater number of firms can influence a single firm's innovation strategy through its application of external technologies. The exposure to external ideas and technologies, or what some have called "knowledge networks," should enable the firm to also enhance their own innovativeness (Zahra *et al.* 2005). If this is true, the firms will most likely be more successful and their contribution to the region in which they are in should enable the region to also be more successful. "New ventures, companies 6 years or younger, [are] a group of firms that need to use both internal R&D and external sources to assemble the knowledge necessary to survive and even prosper" (Zahra *et al.* 2005, p.154). This paper attempts to understand these relationships, by identifying what characteristics of nascent firms are more likely to create a more open innovation strategy as well as propose what types of regions are more likely to have firms that are pursuing a more open innovation strategy.

A firm's innovation strategy relies on its innovation capacity. From a knowledge-based or resource view of the firm, innovation capacity can be tangible measures like R&D expenditures, but also less tangible measures like practical skills and knowledge (Tödtling *et al.* 2006; Acs *et al.* 2002; VanPraag & Versloot 2007; Teirlinck & Andre 2008; Doloreux 2004; D'este 2005; Cooper *et al.* 1994). The tangible and intangible side of the analysis allows for both the examination of the results of business decisions as well as the entrepreneurs' qualities.

The tangible nature of R&D expenditures serves as the primary measure of innovation quantity (VanPraag & Versloot 2007), and more specifically, a firm's investment in R&D and its number of employees committed to R&D activities. The nature of nascent firms suggests they would be more open to a variety of innovation sources, even with the presence of R&D investment and employees. This is particularly so for high-technology firms. "As competition intensifies and the pace of technological change accelerates, many high-technology firms adopt different strategies to acquire external technologies, such as technology alliances, joint development, and technology licensing to complement or even substitute for their internal research and development (R&D) activities" (Kuen-Hung Tsai & Hui-Chen Chang 2008, p.88). High-technology firms also utilize inward licensing to lower the trial and error of internal R&D that is relatively more costly in this industry (Zahra *et al.* 2005). Consequently, the first two hypotheses suggest these expectations.

*Hypothesis 1: R&D investment and employees increase a nascent firm's or high-technology firm's likelihood of utilizing a more open innovation strategy.*

*Hypothesis 2: High-technology industry firms are more likely to utilize a more open innovation strategy.*

## **Innovation and entrepreneurship**

The intangible measures of a firm's innovation capacity that influence its strategy are related to entrepreneurship given the likely smallness of nascent firms. Knowledge and skills are often combined into a concept of human capital. Education level relates to

knowledge and skills (Cooper *et al.* 1994), and as this increases, the entrepreneur is likely more open to accepting external ideas. In addition, work experience in the same industry suggests in-depth knowledge of processes, markets, and networks that should convey to better technology selections and choices (Cooper *et al.* 1994). However, too much familiarity with old strategies and processes, may lead an entrepreneur to resist open innovation. This can be similarly said for the age of an entrepreneur, where age conveys experience but may make one resistant to change. For the human capital characteristics, the following hypotheses emerge:

*Hypothesis 3: Education level of the entrepreneur increases a nascent firm's or high-technology firm's likelihood of utilizing a more open innovation strategy.*

*Hypothesis 4: Years of work experience of the entrepreneur increases a nascent firm's or high-technology firm's likelihood of utilizing a more open innovation strategy.*

*Hypothesis 5: The age of the entrepreneur increases a nascent firm's or high-technology firm's likelihood of utilizing a more open innovation strategy.*

Female ownership of nascent firms and high-technology firms is growing. Between 1997 and 2004, the growth in the number of women-owned businesses (51 percent or more) was nearly two and half times the rate of all U.S. privately held firms (22.9 percent versus 9 percent), and employment in these firms grew more than three times faster (39 versus 11.6 percent) (Center for Women's Business Research 2004). In addition, there is a “new generation of women entrepreneurs” emerging who see business ownership as a viable career option (Brush *et al.* 2004). How they embrace open innovation strategy is not understood.

*Hypothesis 6: A female owner of a nascent or high-technology firm will exhibit a different tendency than a male owner in terms of open innovation strategy.*

If as suggested, “Young start-ups do not have the resources or capabilities to develop their products internally, possibly encouraging them to engage in licensing” (Zahra *et al.* 2005, pp.160-161), the entrepreneur's decisions and the entrepreneur's human capital should influence how open the firm is in the innovation strategy. Yet, beyond the firm's capabilities, a supportive region is likely to provide necessary nourishment and influence its decision making.

## **Innovation and the region**

Open innovation suggests that the firm can seek external innovation from anywhere, within the region and outside. Examining alliances indicates that inter-regional linkages are important, and this would easily translate to licensing agreements (McNaughton 2001). Yet, the effect of knowledge and how it produces innovations in the economy is also the basis for new growth theory, which proposes that endogenous factors like technological change, R&D, and human capital (education) drive economies and predict economic progress and stability (Lucas 1988; Romer 1986; Glaeser 2000). Firms in the region rely on these dynamics and benefit from regional agglomeration economies and cluster formation. The heart of economic development is therefore a dynamic process

that is the result of change in internal economic conditions. Yet, the age-old analysis of the flow of knowledge through individuals into economically useful innovation (Acs *et al.* 2002) is still not perfectly understood.

From the 1970s, one of the predominant methods—beyond research and development (R&D) expenditures—for examining innovation has been through the lens of patent activity. This measure of economic output indicates the creation of economically useful knowledge. However, patents have sometimes been viewed skeptically; “patents are a flawed measure of innovative output particularly since not all new innovations are patented and since patents differ greatly in their economic impact” (Pakes & Griliches 1980, p.378). Recent research has shown that patents are just as good of an indicator of innovative activity as a literature-based innovation count database, like the Small Business Administration developed for only 1982 (Acs *et al.* 2002). Although, patents and product innovation are concentrated in larger agglomerations (Tödtling & Trippl 2005), the effects of innovation and knowledge spillover, in general, do not diffuse beyond a certain geographic distance and remain constrained to industrial clusters and agglomerations (Feldman & Audretsch 1999). The relevance of patents to innovation and what it symbolizes in terms of a region’s R&D capacity implies that a region with higher patenting activity will create an environment that is different from a region with lower patenting activity. How this environment is transferred to a firm’s innovation strategy is of interest even if a firm can go outside of the region for open innovation activities. Regional patent measures are capturing this effect in the analysis.

*Hypothesis 7: Patent counts and growth of patents in a region increase a nascent firm’s or high-technology firm’s likelihood of utilizing a more open innovation strategy.*

Human capital is critical to economic growth, as it is to entrepreneurship, and new growth theory stresses the connection between human capital and economic growth (Romer 1986; Glaeser 1998; Glaeser 2000; Glaeser 2007; Lucas 1988) Most studies proxy human capital with educational attainment, either through the level of education/degree attained or the number of years of school. As the educational component of any economy, the region’s knowledge base will influence the firm through the labor pool and may transform in some manner the firm’s innovation strategy. Education has been found to positively influence innovation, and high-technology industry has been found to be attracted to regions with high levels of education attainment (Hackler & Mayer 2008; Hackler 2003; Lee *et al.* 2004; Audretsch *et al.* 2008; Mayer *et al.* 2007; Florida 2002).

*Hypothesis 8: Educational attainment in the region increases a nascent firm’s or high-technology firm’s likelihood of utilizing a more open innovation strategy.*

Regional prosperity, the result of new growth theory’s successful application, implies that regions are more able to provide a sound foundation for an entrepreneurial economy. Prosperity measures, like disposable income, influence a region’s firm formation (Lee *et al.* 2004). Regions with more nascent firms are likely to foster a market in which the need to establish a technology advantage is essential.

*Hypothesis 9: Regional income increases a nascent firm’s or high-technology firm’s likelihood of utilizing a more open innovation strategy.*

## Data and sample

The data utilized for this paper are from the Kauffman Firm Survey (KFS) conducted by the Ewing Marion Kauffman Foundation over the period 2005-2008. The following description of the sample comes from the KFS documentation (Robb *et al.* 2009). A random sample of 32,469 firms was chosen from Dun and Bradstreet's database of all new businesses started in 2004 in the United States, excluding nonprofit firms, those owned by an existing business, or firms inherited from someone else; the KFS research team interviewed principals of 4,928 new firms between July 2005 and July 2006 (43% response rate with sampling weights) and respondents were paid \$50 to participate. In regard to high-technology firms, the KFS includes a variable depicting a firm as high, medium or low technology based on established criteria (Hadlock *et al.* 1991) that accounts for an industry's percentage of R&D employment in science and technology occupations. There were 2,034 firms in the KFS labeled as high- or medium- technology firms. The firm level data are from the Baseline Survey for 2004 consisting of 4,928 new firms.

In addition, the analysis examines the effect of regional level characteristics on the firm's innovation strategy. These regional data come from a variety of sources and are available at the metropolitan level. The data were merged with the firm level data utilizing the geographic identifier for each firm, the metropolitan area statistical FIPS code.<sup>3</sup> The sources of these data are described in following the discussion of measures.

## Measures

### Dependent variable

*Level of Open Innovation.* The level of open innovation is a constructed variable that attempts to measure a firm's willingness to incorporate other firms' ideas into their innovation strategy. Open innovation activity includes all binomial categorical variables on whether or not the firm possesses a patent(s), has licensed out (LO) patent(s) owned by the firm to another business, or licensed in (LI) patent(s) from another business. The multinomial categorical dependent variable created used the following coding:

- **Closed Innovation:** The firm is completely closed to innovation; 0 = no patents, LO or LI.
- **Less Closed Innovation:** The firm has a patent and is somewhat innovative; it may commercialize it and/or license a patent to another business; the firm remains fairly closed to outside innovations; 1 = firm has patent and LO, but no LI.
- **Semi-Open:** The firm licenses in a patent, conveying it is more open to external ideas to generate commercialized innovations; 2 = LI, but no patent or LO.
- **Most Open:** The firm does all three, generating ideas, selling ideas, and accepting external ideas for innovation; 3 = firm has patent, LI and LO.

The construction of this variable has no spatial dimension. Firms in one region can enter into licensing agreements with firms from anywhere. However, certain firm level and

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<sup>3</sup>FIPS stands for Federal Information Processing Standard which serves as the United States' standards for encoding geographical data.

regional level characteristics may make it more likely for a firm to become more open to all sources of innovation for their own innovation strategy and commercialization.

## **Independent variables**

*Research and Development.* Given that the KFS firms are nascent, small firms, greater R&D infrastructure is important to open innovation strategy; this adjusts Chesbrough's (2003) thoughts that those firms with large R&D infrastructure are more likely to be closed innovators to the size factor for nascent firms. For firm level R&D infrastructure, the KFS includes two variables of interest, R&D investment and number of R&D employees. R&D investment is a dichotomous variable for whether or not the firm invested in R&D in year one. Respondents were asked, "Did your business spend any money on research and development for new products or services?" Responses were coded as "yes" = 1 and "no" = 0. Prior research (Cassiman & Veugelers 2006) also utilizes a similar dummy variable for R&D investment as an indicator of the firm's internal innovation. In addition, respondents provided the number of employees responsible for R&D, another indicator of innovation capacity of the firm.

*Primary Owners' Human Capital and Gender.* The analysis examines the human capital of only the primary owner. In the case of multiple owners for a single firm, owner characteristics are for the owner with the largest equity share, including gender. In the baseline KFS for 2004 data, 65% of the firms had just one owner, with 26% reporting two owners, and only 9% reporting 3 or more owners. The first component of human capital the research examines is the primary owner's level of education. Respondents reported the highest level of education the each owner had completed, ranging from 1 (less than 9<sup>th</sup> grade) to 10 (professional school or doctorate); the analysis utilizes the response of the primary owner. The primary owner's industry knowledge is also important in terms of years of work experience in the industry in which the firm competes. Respondents were asked, "how many years of working experience have you had in this industry—the one in which the business competes?" and their responses ranged from 1 to 40+ (more than 40 years). The final component of human capital is the age of the primary owner. The three components together assess how a new firm's intangible human capital can influence the innovation nature of the firm.

The final primary owner characteristic is gender to determine if firms with female primary owners differ from male counterparts. Of the baseline KFS respondents, 31.5 percent were women owners. Less attention has been paid to the environment in which women business owners operate, and Brush suggests taking a so-called "integrated perspective" of women's business ownership into account when studying regional and social environmental aspects of entrepreneurship. The variable is a dichotomous dummy, with the reference category of male = 0.

*Technology Industry.* The nature of the industry in which a firm operates should also affect its innovation nature. The analysis examines the effect of both high-technology and medium-technology industries on innovation, 14.3 and 26.9 percent of baseline KFS respondents. Each measure is a dichotomous dummy variable with the reference category of the null.

*Metropolitan Characteristics.* Although firm characteristics are necessarily the primary component of firm innovation strategy and its openness, much research addresses the



importance of the region or metropolitan area in this process (Audretsch *et al.* 2008; Audretsch 1998; Doloreux 2004; Doloreux *et al.* 2007; Acs & Armington 2003; Tödttling *et al.* 2006). Doloreux, Dionne, and Lapointe go as far to point out that metropolitan regions are “where innovation is most likely to occur” (Doloreux *et al.* 2007, p.407). Most of the literature has focused on specific characteristics that either promote or slow entrepreneurial opportunities and entrepreneurship. However, this analysis alters the focus to the firm’s innovation strategy and not its success, merging the KFS firm level data on innovation strategy and owner characteristics with metropolitan characteristics previously found to influence innovation.

The purpose of the metropolitan analysis is to understand what types of regions are more likely to have firms that are pursuing a more open innovation strategy. Thus, the analysis includes measures of the endogenous effect of a region’s R&D capacity, the number and growth in the number of patents in a firm’s metropolitan area. The measures convey how metropolitan areas that are more successful on these indicators may influence a new firm’s patent innovation and level of open innovation. Although the number of utility patents is considered a more traditional measure of innovation, it remains one of the most available measures of innovation. The patents were collected from the 2000 and 2004 United States Patent and Trademark Office’s release of utility patents issued and assigned to the metropolitan statistical areas definition used in the KFS.<sup>4</sup>

To encompass the influence of the metropolitan knowledge base on a firm’s innovation strategy, the analysis includes a measure of metropolitan educational attainment. Under new growth theory assumptions, the effect of knowledge and how it produces innovations in the economy is correlated with educational attainment of the population (Hackler & Mayer 2008; Hackler 2003; Lee *et al.* 2004; Audretsch *et al.* 2008; Mayer *et al.* 2007; Florida 2002; Glaeser 2000). Educational attainment accounts for the percent of the metropolitan population with a Bachelors degree.<sup>5</sup>

Measures of disposable income are also highly relevant to defining regional supportive of innovation. The income data are measured in two ways, as per capita income for the base year of the KFS data, 2004, and as per capita income growth from 2000-2004. Regions with higher per capita income may indicate more funds availability for nascent firms.<sup>6</sup>

In order to arrive at robust results regarding the impact of different firm and metropolitan measures affecting firm innovation, the analysis includes another factor considered important in the empirical literature. The analysis utilizes population growth in the metropolitan area under consideration between the years of 2000 and 2004 as a *control variable*.<sup>7</sup>

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<sup>4</sup> We merged utility patents with the address information provided for the U.S. inventor(s) associated with each patent. We limit the inventors assigned in this step to those with U.S. (50 States plus D.C.) locations as our objective is to fully re-apportion the U.S. patents to U.S. metro areas. Each U.S. patent has at least one inventor with a U.S. location, yielding 1,579,124 patent-inventor pairs. We are able to assign 98.9% of these addresses to U.S. counties. The remaining 1.1% of patent-inventor addresses contain errors or misspellings that are not resolved. Each patent is then assigned proportionally to the counties of inventors with recognized addresses. We are able to apportion 99.62% of the patents to counties in this manner.

<sup>5</sup> Educational attainment is for 2004 from the American Community Survey and is calculated from table B15002, Sex by educational attainment for the population 25 years and over.

<sup>6</sup> The data for per capita income in 2000 is from the 2000 U.S. Census summary file three (SF3), table P82.

<sup>7</sup> Population growth was calculated using population estimates reported at <http://www.census.gov/popest/datasets.html>. The 2004 data are from the American Community Survey, with per capita income from table B19301.

## Data analysis

The analysis utilizes multinomial logit (MNL) regressions given the nature of the dependent variable, a firm's level of open innovation. The MNL regressions examine the direct or interaction effects of the independent variables on level of open innovation (coded as 0 = closed, 1 = less closed, 2 = semi-open, and 3 = most open, see details above). MNL works well with a dependent variable that has more than two categories. Given that the categories display a ranking, an ordinal logistic regression is preferred to multinomial logistic regression. However, the application of ordinal regression must satisfy the assumptions of parallel lines among the results for each category of the dependent variable and have adequate cell count. The data violated these assumptions, thus the use of ordinal regression is inappropriate. MNL is then best to test the model, and MNL has been used in prior research (Cooper *et al.* 1994). In addition, logistic regression remains more robust to violation of the normality assumption for categorical explanatory variables, and MNL represents an extension of the common binary logit model when the dependent variable has more than two categories (Cooper *et al.* 1994).

The reference category of the dependent variable is closed, and the models estimate parameters of the explanatory variables for the propensity of the level of open innovation: 1) less closed innovation versus closed innovation; 2) semi-open innovation versus closed innovation; and 3) most open innovation versus closed innovation. The coefficients do not represent any absolute effect on the probability of that outcome (Cooper *et al.* 1994). An important parameter in MNL is the odds ratio,  $\text{Exp}(\beta)$ , that shows the factor by which the odds of a given outcome (levels of open innovation) change for a one-unit change in a continuous independent variable; when using a categorical or dichotomous independent variable, the odds ratio is interpreted compared to the reference category. For example, no R&D investment, male, not high-technology, and not medium-technology are the reference categories for the categorical independent variables in the model, so the odds ratio indicates the odds for having R&D investment, being a female primary owner, and being a high-technology or medium-technology firm.

The KFS Baseline Survey oversampled businesses in high-technology industries so we weighted our data prior to the analysis using the weighting factor provided by MPR statisticians (included in the KFS dataset); this ensures that estimates reflect the true population based on the full sample frame. The analysis uses STATA survey (svy) commands to ensure the stratified sampling and proper weighting. However, with this command, some estimation and post-estimation statistics and commands are not appropriate like the log likelihood ratio (LR).<sup>8</sup> The tables reporting the MNL models display all that is available using the survey commands. Also, with the use of the survey commands for the MNL models,  $\text{Exp}(\beta)$  reported is actually the relative risk ratio, thus the coefficients are giving the probability rather than the odds. Although these probabilities cannot be negative, presence of a negative sign in front of the  $\text{Exp}(\beta)$  denotes a decrease in probability of the outcome.

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<sup>8</sup> Stata survey commands use probability weights (pweights), rendering the standard likelihood-ratio test inappropriate because the "likelihood" for pweighted maximum likelihood estimations (MLEs), like MNL used here, is not a true likelihood or the distribution of the sample. With pweights, the "likelihood" does not fully account for the "randomness" of the weighted sampling. The "likelihood" for pweighted MLEs is for point estimates and not for variance estimation using standard formulas. The model chi-squared test is a Wald test, reported as F-test in tables. See <http://www.stata.com/support/faqs/stat/lrtest.html> and <http://www.stata.com/support/faqs/stat/chi2.html> for further information.

## **Examining open innovation in nascent firms**

The analysis uses the 2004 baseline of the KFS. Table 1 reports the summary statistics for the independent variables in the analysis; four of the variables are dichotomous variables, so only the mode is reported. Correlation among of the independent variables was analyzed, and the models were tested for multicollinearity, with results within acceptable ranges. The remainder of this section discusses the results of the regression models.

**Table 1: Summary statistics of firm and Metropolitan characteristics**

	<b>Mean/Mode</b>	<b>Linearized Standard Error</b>	<b>Mean/Mode</b>	<b>Linearized Standard Error</b>
	Obs. = 4860, firm characteristics only		Obs. = 1412, firm and metropolitan characteristics	
R&D Employees	0.6139265	0.0149281	0.6448577	0.0280038
R&D Investment	0		0	
Owner Age	44.4873	0.1780715	44.62038	0.3210515
Owner Education	6.13097	0.0349859	6.074153	0.0652493
Owner Work Experience	11.87981	0.1703661	12.0025	0.308341
Female	0		0	
High-Tech	0		0	
Medium-Tech	0		0	
Patents 2004			412.4088	15.41692
Metro Patent Growth 2000-2004			-2.779369	0.6989336
Metro Per capita income, 2004			23586.19	92.64596
Metro Growth Per Capita Income, 1999-2004			10.67008	0.1453097
Educational Attainment, 2004			17.99119	0.1181374
Metro Percent Population Growth, 2000-04			5.870936	0.1364171

The MNL models examine the effect of firm and metropolitan level characteristics on the level of open innovation. These relationships are reported for all firms in the KFS in 2004 in Table 2 and for the high-technology industry subpopulation in Table 3. In Table 2, the MNL regressions for all firms test separate models, with results on firm level variables reported in column 1a-c for each level of open innovation, and results for the full model with firm and metropolitan level variables reported in columns 2a-c. As discussed earlier, using the survey commands in STATA to ensure proper probability weighting, estimation statistics for MNL are limited to the Wald test (F-test) for the chi-square (see note 7); however, post-estimation testing revealed the model was significant, indicating the models of firm and metropolitan characteristics significantly predict the level of open innovation for all firms and the subpopulation of high-technology firms.

The results indicate that R&D employees and investment have significant effects on the probability of a firm's innovation strategy being more open. The relative risk ratio for R&D employees is  $\text{Exp}(\beta) = 1.34$  (column 1c), which means that a firm's probability of having the most open level of open innovation (having patents and agreements to license in and out patents) is 1.34 times greater with one more R&D employee, adjusting for all other firm-level independent variables in the model. When taking into account firm and metropolitan independent variables, the probability that a firm utilizes the most open innovation strategy rather a closed strategy is 1.29 (column 2c) times greater with one more R&D employee. Both R&D measures have positive effects; however, R&D investment has the greatest effect of the two in either the firm level model ( $\text{Exp}(\beta) = 5.38$ ) or the firm and metropolitan level characteristics model ( $\text{Exp}(\beta) = 9.52$ ). In addition, R&D investment increases the probability of being semi-open (licensing in) by 1.83 (column 1b) times in the firm level model. For nascent firms, internal firm R&D influences a firm's likelihood of taking up outside innovations as well as selling them off. The results provide support for the first hypothesis for all firms.

Of the entrepreneur's human capital measures, only the owner's age and education have significantly positive effects on the probability of a firm's innovation strategy being more open (columns 1c and 2c), indicating older and more educated primary owners are most active at this level of open innovation. These results provide support for hypotheses three and five in terms of all firms.

In terms of female entrepreneurs, the probability that a firm is most open or semi-open rather than being closed is decreased if the primary owner is a female, supporting hypothesis six. The reasons for this gender difference, however, are not examined but indicate the need for further examination of open innovation strategy and female entrepreneurs.

In regard to type of industry, the probability that a firm is most open rather than being closed is 8.76 (column 1c) and 6.51 (column 2c) times greater for a high-technology firm. This is also true for a firm's probability of being semi-open instead of closed, but the probabilities are lower. However, medium-technology firms exhibit no evidence of being more likely to have open innovation strategies. The combination of these results provide evidence for hypothesis two and suggest that further examination of these relationships within the high-technology subpopulation is useful.

**Table 2: Multinomial logistic regressions, dependent variable: level of open innovation, 2004, total firms**

Independent Variables	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Less Closed	Semi-Open	Most Open	Less Closed	Semi-Open	Most Open
R&D Employees	1.285*** (0.0909)	1.121 (0.116)	1.340*** (0.0815)	1.390** (0.187)	1.195 (0.206)	1.285* (0.182)
R&D Investment	5.440*** (1.347)	1.825** (0.516)	5.384*** (2.962)	3.922*** (1.961)	1.775 (0.897)	9.519*** (8.060)
Owner Age	-0.990 (0.0126)	-0.988 (0.0123)	1.045** (0.0219)	-0.972** (0.0137)	-0.992 (0.0223)	1.074* (0.0402)
Owner Education	1.060 (0.0670)	1.010 (0.0565)	1.445*** (0.147)	1.135 (0.101)	1.125 (0.118)	1.427** (0.198)
Owner Work Experience	-0.982 (0.0132)	-0.994 (0.0149)	-0.994 (0.0266)	1.016 (0.0248)	-0.980 (0.0235)	-0.983 (0.0274)
Female	-0.519* (0.178)	-0.307*** (0.128)	-0.467 (0.335)	1.228 (0.703)	-0.212* (0.170)	-0.174* (0.164)
High-Tech	5.134*** (1.120)	2.280*** (0.619)	8.759*** (4.402)	6.468*** (2.995)	4.085*** (1.956)	6.508*** (4.415)
Medium-Tech	1.481* (0.348)	1.070 (0.289)	2.114 (1.086)	1.421 (0.625)	1.146 (0.613)	2.149 (1.190)
Patents 2004				-1.000 (0.000588)	-1.000 (0.000454)	-1.000 (0.000572)
Metro Patent Growth 2000-2004				1.011 (0.00819)	-0.992 (0.00911)	1.007 (0.0135)
Metro Per capita income, 2004				1.000 (0.0000681)	-1.000 (0.0000792)	-1.000 (0.000110)
Metro Growth Per Capita Income, 1999-2004				1.053 (0.0429)	-0.950 (0.0638)	-0.983 (0.109)
Educational Attainment, 2004				1.007 (0.0627)	1.197** (0.0945)	1.120 (0.320)
Metro Percent Population Growth, 2000-04				-0.999 (0.0439)	-0.883* (0.0617)	-0.862 (0.192)

**Table 2 Continued**

	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Less Closed	Semi-Open	Most Open	Less Closed	Semi-Open	Most Open
Constant	0.0116*** (0.00743)	0.0277*** (0.0185)	0.0000129*** (0.0000194)	0.00121*** (0.00217)	0.0207** (0.0373)	0.00000361** (0.0000180)
<i>Observations</i>	4857	4857	4857	1412	1412	1412
<i>F Test</i>	13.04			7.182		
<i>F Test, Wald (24, 4851), (42,1406)</i>	13.10			7.40		
<i>Prob &gt; F</i>	0			0		

NOTE: Closed (no patents or licensing) is reference category. Coefficients are  $\text{Exp}(\beta)$  with negative signs where needed. Standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. STATA survey commands do not report some estimation statistics (see note 8).

Moving to the metropolitan characteristics' effects on all firms, the full model doesn't suggest either of the measures of metropolitan patents having an effect. These results do not support the expectations in hypothesis seven for these measures of the new growth economy. Of the other regional innovation measures, only educational attainment exhibits a significant effect. A firm's probability of having a semi-open level of open innovation (licensing in a patent) is 1.20 (column 2b) times greater with one percent more of the population having Bachelors degree. Metropolitan educational attainment may have an absorptive innovation effect on nascent firms—they are more likely to license in patents, taking advantage of others good ideas. The result provides evidence for hypothesis eight. For growing regions, a firm's probability of utilizing a semi-open innovation strategy is minimally decreased; thus, for all nascent KFS firms, the effect of regional supportiveness of innovation seems muted.

### **High-Technology firms**

With the dummy variable for high-technology firms indicating greater probabilities of a more open innovation strategy, Table 3 displays the MNL regressions for the subpopulation of high-technology firms. Again, separate models are reported, with results on firm level variables reported in column 1a-c for each level of open innovation, and results for the full model with firm and metropolitan level variables reported in columns 2a-c.

The high-technology subpopulation exhibits several variations from the regression results for total firms. In terms of the firm level characteristics, R&D investment has a very consistent and large effect. This is particularly so in the full model where the probability of a firm utilizing the most open innovation strategy rather than closed is 288.7 (column 2c) times greater for a high-technology firm that invests in R&D, when controlling for both firm and metropolitan characteristics. The number of R&D employees varies in the full model, such that it decreases the probability of a high-technology firm being the most open by 0.21 times (column 2c) with one more R&D employee, but increases the probability of being semi-open by 1.60 times (column 2b). There is partial support for hypothesis one in terms of high-technology firms. The results also suggest that R&D investment may be more important to a firm having a more open innovation strategy, creating innovations as well as accepting them from a variety of places. Those that “do” are more able to better utilize inward licensing, suggesting that innovation is in the ideas rather than the numbers.



**Table 3: Multinomial logistic regressions, dependent variable: level of open innovation, 2004, High-Tech firms**

Independent Variables	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	Less Closed	Semi- Open	Most Open	Less Closed	Semi- Open	Most Open
R&D Employees	1.013 (0.0865)	1.128 (0.113)	1.151* (0.0977)	-0.553* (0.183)	1.596* (0.415)	-0.206** (0.161)
R&D Investment	7.300*** (2.336)	4.690*** (2.134)	3.960*** (2.022)	16.23*** (11.19)	8.749** (8.915)	288.7*** (453.7)
Owner Age	1.021 (0.0150)	1.035 (0.0220)	1.024 (0.0266)	1.043* (0.0227)	1.072** (0.0293)	1.001 (0.126)
Owner Education	1.147* (0.0874)	-0.911 (0.0880)	1.576*** (0.206)	1.070 (0.232)	1.071 (0.222)	2.860** (1.425)
Owner Work Experience	-0.989 (0.0146)	-0.970 (0.0201)	-0.970 (0.0242)	-0.976 (0.0284)	-0.902** (0.0402)	1.030 (0.123)
Female	-0.808 (0.360)	-0.164* (0.170)	1.200 (0.706)	-0.318 (0.406)	8.67e-18*** (0)	13.82 (25.40)
Patents 2004				-0.999** (0.000672)	-1.000 (0.000989)	-0.999 (0.00131)
Metro Patent Growth 2000-2004				-0.999 (0.0126)	1.042** (0.0171)	1.023 (0.0407)
Metro Per capita income, 2004				-1.000 (0.000129)	-1.000 (0.000209)	-0.999** (0.000277)
Metro Growth Per Capita Income, 1999-2004				1.122 (0.0824)	1.193 (0.129)	1.952*** (0.371)
Educational Attainment, 2004				1.245** (0.124)	-0.920 (0.0992)	3.520*** (1.253)
Metro Percent Population Growth, 2000-04				1.088 (0.115)	1.006 (0.0981)	-0.462*** (0.0955)
Constant	0.00713*** (0.00624)	0.0116*** (0.0149)	0.000310*** (0.000437)	0.0000617** (0.000237)	0.0209 (0.138)	0*** (1.52e-10)
<i>Observations</i>	690	690	690	184	184	184
<i>F Test</i>	6.083			70.62		
<i>F Test, Wald (18, 688), (36,182)</i>	6.24			87.43		
<i>Prob &gt; F</i>	0			0		

NOTE: Closed Innovation (no patents or licensing) is reference category. Coefficients are  $\text{Exp}(\beta)$  with negative signs where needed. Standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. STATA survey commands do not report some estimation statistics (see note 8).

The effects of the three human capital measures also differ within the high-technology results, with each having an effect. The primary owner's age is only significant in the full model, and then, it only increases the probability of a high-technology firm when comparing closed to less closed (having a patent and licensing out) or semi-open (licensing in). This provides partial support for hypothesis five. In terms of work experience, an owner in a high-technology firm with more experience in the industry has a negative effect. The probability of the firm being semi-open versus closed is smaller ( $\text{Exp}(\beta) = -0.90$ , column 2b) when an owner has one additional year of work experience. This does not support the expectation in hypothesis four. Finally, an owner's education has a significant effect on the probability of a high-technology firm being more open ( $\text{Exp}(\beta) = 2.86$ , column 2c) and is supportive of hypothesis three. Thus, of all the human capital variables, education has the most positive effect on a firm's openness to a variety of innovation strategies, with the age of the owner also affecting the likelihood of the firm's semi-open innovation strategy.

Gender of the primary owner has a somewhat dampened effect among high-technology firms. Instead of the significantly negative effect found for all firms, female ownership has a negligible effect, and only for the semi-open category of open innovation. Gender in high-technology industry presents less of an impact on the likelihood of an open innovation strategy, limiting the support for hypothesis six, but insinuating that women entering new industries, like high-tech, are less likely to be different from their male counterparts.

In comparison to the results for the sample of all KFS firms, the effects of the metropolitan characteristics have more predictive power within high-technology subpopulation. Educational attainment now has a positive effect on being most open; a high-technology firm's probability of having a most open level of open innovation is 3.52 (column 2c) times greater with one percent more of the population having a Bachelors degree. Among high-technology firms, the results provide support for hypothesis eight.

In terms of patents, although the total number in the metropolitan area decreases the probability of being less closed ( $\text{Exp}(\beta) = -0.99$ , column 2a) than closed, the growth of patents in the region actually has a positive effect. A high-technology firm's probability of utilizing a semi-open in comparison to closed innovation strategy is 1.04 times greater with a one percent increase in the growth of patents. The level of dynamism and technological change in high-technology industry suggest that nascent firms would be more likely to license in the technology to get the process started more quickly (Zahra et al. 2005). The finding suggests that in regions that are experiencing patent growth, nascent high-technology firms may be more able to rely on other's innovations, even though there is no way to determine whether a firm utilizes patents created in the same region. Regardless, the results provide partial support to hypothesis seven.

In terms of income's effect on innovation strategy, the measures exhibit different signs. The growth of per capita income significantly increases the probability of being most open by 1.95 times with every one percent growth in income. As found with metropolitan patent growth, perhaps regions with growth in per capita income provide more cushion to nascent firms in terms of start-up. However, higher regional per capita income decreases the probability of high-technology firms utilizing the most open innovation strategy (column 2c). Thus, although growth indicates support, if it grows to too high of a level, it may be a barrier and present a problem to the firm wanting to explore a full range of innovation sources for its innovation process. Hypothesis nine garners only partial support.

Population growth serves as a metropolitan control variable, and a growing population has an interesting effect for high-technology firms. Regions with population growth decrease the probability of high-technology firms utilizing the most open innovation strategy, but this is somewhat similar to the finding for all KFS firms.

## **Open innovation: a region's role and high-technology variation**

The ideas emerging from Chesbrough's concept of open innovation and the role of innovation in the economy provide fertile ground for exploration of how these ideas affect entrepreneurship and the nascent firm. If certain regions are more innovative, does this contribute to a distinctive firm innovation strategy for all firms as well as high-technology industry? This paper attempts to unravel these relationships with the identification of nascent firm and regional characteristics that are likely to create a more open innovation strategy in firms.

The results suggest two primary conclusions. First, high-technology firms differ in terms of how firm and metropolitan characteristics affect their likelihood of utilizing more open innovation strategies. High-technology's distinction in regard to open innovation strategy is even more interesting since only about 4-5% of high-technology firms have patents or licensing agreements in the KFS 2004 baseline data. In terms of firm characteristics, each human capital variable had an effect on innovation strategy among high-technology firms, unlike for all firms. R&D measures in high-technology firms behaved differently, as the results implied that R&D investment may be more important to a more open innovation strategy. Those that "do", may be more able to better utilize inward licensing. The final firm characteristic with variation among all firms versus high-technology firms was that of gender. The differential effect of female ownership on innovation strategy found within all firms almost disappeared within the high-technology analysis. The reasons for this difference implore further examination on the dynamics of open innovation strategy and female entrepreneurship.

The second primary conclusion from the paper's results amplifies the importance of documenting regional effects. This is particularly so in terms of high-technology industry. Regional factors had even greater relevance on a high-technology firm's likelihood of utilizing more open innovation strategies with educational attainment and at least one measure of those for patents and income increasing the probability of more open innovation. The regional population control variable also provided insight. A comparison of the negative effect of population growth on the probabilities of open innovation indicates that growing regions are less likely to support and promote open innovation strategies among firms.

The results of the regression models and conclusions drawn from these findings offer a contribution to the literature on innovation and high-technology economic development, particularly as it relates to public policies that facilitate location-based innovation and the leveraging of internal growth opportunities like entrepreneurship. Further understanding of these regional factors' effects on open innovation dynamics will assist local, state, and federal public policymakers in crafting economic development policies. The findings suggest greater attention to higher education policies and creating a suitable environment for those that create and those that buy ideas and innovation. How the exposure to external ideas and technologies create beneficial regional knowledge networks warrants further analysis. In addition, it remains essential to utilize data from

nascent firms, like the KFS, to understand whether open innovation enables the firm to also enhance its own innovativeness and how regional policy can assist and support this dynamic.

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