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Policy orientation effects on performance with licensing to start-ups and small companies

Joshua B. Powers [a,*], Patricia McDougall [b]

[a] *Indiana State University, ELAF 1215, College of Education, Terre Haute, IN 47809, USA*
[b] *Indiana University, USA*

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Abstract

This study empirically tests a model of a university's selectivity and support policy orientation for technology licensing and its interaction with the external environment for entrepreneurship. Using a sample of 134 US research universities, we investigate main, two-way and three-way interaction effects for two measures of technology transfer performance—licenses with companies that subsequently go public and product royalties. Results indicate both main and moderating effects for both measures of performance. Implications for practice and policy are offered, with special attention to public universities.

Keywords: US universities; University start-ups; Technology transfer

1. Introduction

In recent years, a growing number of research universities have been aggressively advancing a technology commercialization agenda. Stimulated in part by the Bayh-Dole Act of 1980, the opportunities presented through biotechnology (Argyres and Liebeskind, 1998), and the need by public institutions to offset state appropriation reductions (Slaughter and Leslie, 1997), universities have rapidly escalated their involvement in technology transfer. A growing body of literature has explored this phenomenon and made clear that such practices contribute positively to economic development (e.g., Bozeman, 2000; Rosenberg and Nelson, 1994; Zucker et al., 2002).

Technology transfer is the process by which university-developed technologies are transformed into marketable products. Universities have traditionally sought to license their technologies to established private and public firms, usually in exchange for the reimbursement of patent costs, an up-front licensing fee, and a percentage of product sales. As universities have become more involved in technology transfer, an increasingly common transfer mechanism is to license

* Corresponding author. Tel.: +1 812 237 3862;
fax: +1 812 237 8041.
E-mail address: jopowers@indstate.edu (J.B. Powers).

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a technology to a start-up company rather than to a larger, established firm. Given the firm's limited cash position, a university licensing deal with a start-up or small private company often involves taking equity in lieu of any immediate or near term cash payments (Bray and Lee, 2000; Feldman et al., 2002).

A few universities have been well rewarded for taking this risk when the firm is purchased by a larger company or reaches the point of a public offering. Yet, for every success story, there are clearly many company failures or at least many that languish for a number of years, a fact affirmed by research on business formations (Dennis, 1999) and indirectly by recent data from the Association of University Technology Managers (AUTM, 2003).

Despite the risks of technology transfer in general and the practice of licensing to start-ups and other small private firms in particular, university enthusiasm for its practice continues to grow. Fortunately, a growing body of literature is beginning to focus on the phenomenon by investigating factors that may explain performance differences among universities (e.g., Feldman et al., 2002; Siegel et al., 2003; Thursby and Thursby, 2002). This work has been helpful for informing policy, practice, and follow-on research. To date, however, empirical investigations of how university and external environmental factors may interact in impacting noted downstream measures of performance is largely unexplored. Exploring performance contingencies is useful for developing more complex models of technology transfer.

The purpose of this study is to develop a university technology transfer policy framework in terms of a university's orientation toward patenting and licensing technologies to start-ups or small companies versus large, established firms. Specifically, we adapt and build upon Roberts and Malone's (1996) selectivity and support model for spinning off small companies from R&D organizations such as universities and then empirically test it on a sample of US research universities. Utilizing previous research on technology transfer practice, combined with contingency theory, we investigate the direct and interactive effects among a university's policy orientation and a new composite measure of the external entrepreneurial environment in which a university is embedded, entrepreneurial density, on downstream performance. We measure performance in two ways, one in terms of the number of licensee firms that subsequently go public and the other via product sale royalties. The former measure of performance represents a coveted milestone for a university and the firm and is certainly a high profile example of economic development. The latter measure is another important outcome, since it reflects a degree of product success—customers are actually purchasing the outcome of a licensed technology.

In the following sections, the theoretical background and hypotheses are presented. The hypotheses include the direct effect of selectivity, and the three-way interaction between selectivity, support, and entrepreneurial density on the two performance variables, the number of licenses to companies that go public and product sale royalties. The sample, sources of data, and variable measures are then presented in Section 3, followed by the results of the validity and reliability analyses of the derived variables and the moderated regression procedures testing the hypotheses. Finally, the study presents a discussion of the findings, implications for practice, study limitations, opportunities for future research, and a policy discussion in the conclusion.

2. Theoretical background and hypotheses

Much attention has been focused on the emergent entrepreneurial orientation of research universities (Etzkowitz et al., 2000). Etzowitz (1998) refers to this current environment as a second academic revolution. Whereas the first academic revolution ushered in the rise of the research university model, the second one emphasizes the translation of research into bona fide products and new enterprises for the practical benefit of society. As is often true with industries confronting rapid change, there has been much experimentation in universities with various structural configurations (Dill, 1995) and policy and practice mechanisms (e.g., Clarysse et al., 2005; Feldman et al., 2002; Friedman and Silberman, 2003) designed to increase the quantity and speed at which university-sourced innovations get successfully transferred to the marketplace.

One theme that has received some attention within this growing literature is the degree to which universities may be digging deep into their potential patent pools such that the overall quality of these technologies may be declining. Thursby and Thursby (2002), for instance, note that in their survey of 64 US research universities between the years 1994 and 1998, the growth rate in technology disclosures and patent applications has been higher than the growth rate in licenses executed. They infer this to mean that the "marginal university innovation offered to the market has declined in commercial appeal" (p. 102). Henderson et al. (1998) noted that the Bayh-Dole Act of 1980 stimulated a substantial increase in patenting by academic institutions but not an increase in commercially important university inventions. Patented technologies with questionable appeal to industry are less likely to be licensed and developed into a viable product for sale. Furthermore, in related research, Thursby and Kemp (2002) found evidence that public universities may suffer from larger productive inefficiencies with technology transfer than private universities, perhaps as a function of higher social contract for science expectations and/or their relative newness to its practice.

Universities that are selective about what they patent and who they license a technology to may increase their chances for a successful transfer. Roberts and Malone (1996) apply this notion of selectivity to the decision process associated with when to transfer a technology via a start-up company route versus other paths such as licensing to large, established companies. As a matter of practice, universities that are very strict about when to license a technology to a start-up or small company take an active role in seeking out these types of firms and likely do a substantial amount of advance work to hopefully better ensure its success in the marketplace. Universities that take a more passive attitude toward the evaluation of a technology and its fit with these types of licensee firms may be more likely to under evaluate and hence heighten the chances that the technology will not be appropriately transferred and developed. Universities that approach the process more passively may rely on rubrics of convenience (i.e., which firms have already expressed interest in the technology and/or are conveniently available to contact) and faculty inventor desires (i.e., what they prefer), even when such an approach may be sub-optimum. Hence:

Hypothesis 1. Universities that are more selective in deciding which technologies to patent and license to start-ups and small companies will exhibit higher levels of technology transfer performance (i.e., IPO licensees and product royalties) than universities that are less selective.

Although it is hypothesized that selectivity may have a direct and positive effect on university success at transferring technologies to industry and ultimately seeing those technologies lead to firm and/or product achievements, there are likely contingencies that effect that relationship. Contingency theory at its core argues that there is no one best way to solve all organizational problems but that they are situationally useful and appropriate. As such, there is no "best" way of organizing—instead, the optimum organization structure depends on a number of factors such as the complexity of the environment, the strategic positioning of the organization, and/or the technology that the organization is using (Galbraith, 1973, p. 2).

In the context of university technology transfer, there has been little research on the possible contingency effects of particular institutional structures or processes. Yet, one likely candidate for such an investigation focuses on the degree of technology transfer office attention or effort brought to bear on the identification, evaluation, and selection of technologies for patenting as well as the ongoing relationship management necessary to assist a licensing firm, especially a start-up or small company, to actually commercialize a technology. In Roberts and Malone's (1996) case study of policies and structures for spinning off new companies from universities and non-profit research organizations, they found that the R&D organizations had varying degrees of support for the start-ups that they created. They defined support to mean the level of managerial and financial assistance given to a start-up by the university from the time of the first disclosure through the time when the university relinquishes all interests in the new venture. Highly supportive universities were likely to devote considerable staff time and effort to preparing and executing licensing deals with start-ups and then taking an active interest in their nurture in ways such as providing managerial leads, helping to keep the faculty inventor involved when necessary, and in general, keeping in regular contact with the firm for the purpose of troubleshooting issues that might arise.

Although a selective patenting and licensing orientation associated with transferring technologies to start-ups and small firms may be enhanced via strong support for such a program, that relationship may also be contingent on the nature of the external environment for entrepreneurship. Specifically, not only do universities need to consider their selectivity and support policy orientations, they need to consider how well those orientations match what they confront in their external environment. Roberts and Malone (1996) suggest that various selectivity and support configurations will likely have differential benefits depending on the strength of the external environment for entrepreneurship. Universities attempting to spin-off companies in a weak entrepreneurial environment, for instance, may benefit most by being both highly selective in deciding what technologies to license via a start-up or small company route and highly supportive of the companies with whom they license. The reason that this is an important policy orientation is because the external environment is largely incapable of meeting these needs. If the licensee company is going to have the best chance of being successful, it needs to have in its possession a technology that was carefully evaluated and targeted toward such a firm and then provided the necessary advisory, managerial, financial, and/or liaison connection with the faculty inventor types of support. Because these kinds of resources are not available in the external environment and there are likely few geographically like firms with whom to network, the university itself needs to assume this role. In a recent study that used Roberts and Malone's (1996) selectivity and support framework, Degroof and Roberts' (2004) case studies of eight universities and 47 spin-off firms found suggestive evidence in support of this particular contingency. Namely, universities in entrepreneurially weak regions that pursued a high selectivity, high support approach to licensing via the start-up route seemed to experience greater success in generating new ventures capable of exploiting new market opportunities than universities that pursued some other selectivity – support configuration.

In the case of universities located in a strong external environment for entrepreneurship, the need to provide a high degree of support for start-ups and small firms is lessened because the external environment can ostensibly take care of them. Research has pointed to the consistent success of technology transfer programs in northern California or the greater Boston area, for instance, places where the external environment for entrepreneurial activity is strong (Kenney, 2000; Roberts, 1991). This allows a university to assume a more passive orientation to support and, in essence, lets the external environment sort things out. Furthermore, universities are often not especially adept at the nimble and multifaceted decisions necessary for managing or advising a young company and may be better off having outsiders do it anyway (Lockett et al., 2003; Radosevich, 1995). Although in their case studies of eight R&D organizations, Roberts and Malone (1996) did not investigate whether or not a policy orientation–environment match in entrepreneurially strong external environments led some institutions to outperform others similarly situated, it did suggest that over investment in time and resource intensive support mechanisms that are not needed may lead such universities to under perform. Clarysee et al.'s (2005) study of new venture incubation strategies among research institutions also suggests differences in performance based on internal organizational and external environmental factors.

In light of the research discussed, then, contingency theory would suggest that not only might support for technology transfer moderate the selectivity–performance relationship, but that impact would depend on a third factor, the strength of the external environment for entrepreneurial firm establishment and growth. Hence, the following hypotheses are offered:

Hypothesis 2a. For universities located in entrepreneurially weak external environments, high selectivity in deciding which technologies to patent and license to start-ups and small companies will be more positively related to technology transfer performance (i.e., IPO licensees and product royalties) under conditions of high rather than low university support for technology transfer.

Hypothesis 2b. For universities located in entrepreneurially strong external environments, high selectivity in deciding which technologies to patent and license to start-ups and small companies will be more positively related to technology transfer performance (i.e., IPO licensees and product royalties) under conditions of low rather than high university support for technology transfer.

3. Methodology

3.1. Sample and data sources

Our sample included 134 US research extensive and research intensive universities as defined by the Carnegie Classifications of US collegiate institutions and that were geographically spread across the contiguous United States. The universities included 92 public and 42 private institutions. The sample was identified based on data reported in the annual licensing surveys of the Association of University Technology Managers (AUTM, 2003) that were used primarily to derive the support and selectivity measures for this study. A second source of data was IPO prospectus filings with the Securities and Exchange Commission. These filings were used to identify companies that went public based in full or in part on a university licensed technology. The third source of data involved collecting various external environment measures relevant to building a measure of external support for entrepreneurial ventures or what we label entrepreneurial density. These sources were obtained from the *Venture Capital Yearbook*, the US Patent Office database, the National Science Foundation's database of science and engineering employment, the US Census Bureau, and the Small Business Administration's database of SBIR and STTR grants. Finally, data on faculty quality, one of the control measures in the study, was obtained from the *Gourman Report's* rankings of graduate programs.

3.2. Dependent variable measures

3.2.1. IPO companies

Two dependent variables were investigated for this study. The first one was the number of licenses with private companies that subsequently went public. In an environment where institutions enhance their reputations as engines of economic development by actively engaging in technology transfer, there are perhaps fewer more visible manifestations of this than being involved with a company that goes public. Even though a company having an initial public offering of stock may not mean that a product is available for sale, it does represent a significant milestone of performance since enough value has been created in the company that the sale of stock to the general public becomes viable. Not only does being associated with firms that go public have potential reputational benefits for universities, it may also have financial benefits should the university own stock in the company.

The 4-year period between May 1996 and June of 2000 was chosen for the investigation. The May 1996 date was selected, since this was the first time that the SEC required online filings for all initial offerings. The June 2000 date was chosen to provide a full 4 years of data, an important consideration in order to generate enough data variation. We utilized a specialized search engine, 10kwizard.com, to assist with the data mining given that it is especially useful for conducting Boolean searches of filings and surfacing university licensing deals. Once we had tallies for each institution, we triangulated the results with Recombinant Capital's database of biotechnology, pharmaceutical, medical device, and IT companies, the kinds of firms most likely to emerge from universities. The results of this secondary analysis affirmed the accuracy of our database since Recombinant Capital tracks licensing agreements with universities as well.

An average annual IPO performance value over the 4-year period of study was generated for all 126 institutions in the data set. We felt that this was a reasonable proxy for an institution's performance over time, but that was not necessarily characteristic of its performance at a specific point in time, the latter of which would require greater attention to temporal issues. The variable was log transformed because of skewness in the data.

3.2.2. Product sale royalties

The second dependent variable investigated was royalties received on product sales for a university. Whereas an IPO has symbolic and sometimes financial importance to a university, a royalty stream from product sales represents a key measure of achievement as well. Specifically, the technology has moved from a proof of concept through the various stages of development to a commercialized product. In this sense, then, royalty revenues represent the crowning achievement of success given that consumers are actually purchasing what was produced.

Data for this variable was obtained from the AUTM Licenses surveys. An average figure was calculated for the years 1999 and 2000 so as to smooth potential year to year fluctuations and derive a more reasonable measure of royalty performance. Skewness in the data required that the variable be log transformed.

3.3. Independent variable measures

3.3.1. Selectivity

Selectivity in this study was defined as the degree of strictness used by the technology transfer office in choosing which technologies to patent and license via the start-up or small company route. We operationalized selectivity as the factor score associated with four ratio measures—the number of licenses to start-ups and small companies[1] per the number of faculty invention disclosures, the number of new patent applications, the number of patent issues, and the total number of licenses executed, respectively. Given the degree of annual variation in our chosen technology transfer activity measures, we used a 2-year average from the years 1996 to 1997 for each of the numerator and denominator values. Because lower ratios infer higher selectivity, we reverse coded the data to make the interpretation of regression results easier to understand.

3.3.2. Support

Support was defined as the professional staff resources available through the technology licensing office to support technology transfer both before and after the licensing of a technology to industry. We operationalized support as the factor score associated with four ratio measures of support—the number of full-time equivalent (FTE) professional licensing staff per the number of faculty invention disclosures, the number of new patent applications, the number of patent issues, and the number of licenses to start-ups and small companies, respectively. These four ratios, we theorized, represented reasonable proxies for how much attention and effort could be devoted to the identification, evaluation, and selection of technologies for patenting as well as to the ongoing relationship management necessary to assist a licensing firm to actually commercialize a technology. We again used 2-year averages from 1996 and 1997 to create these measures. Higher ratios in these areas indicate greater support for one's technology transfer program.

[1] We used the AUTM definitions for start-ups (company founded specifically to develop a university technology), small companies (less than 500 employees), and large companies (more than 500 employees).

3.3.3. Entrepreneurial density

Previous research on regional entrepreneurial activity suggests that R&D activity (Caloghirou et al., 2004), patenting (Malerba and Orsenigo, 1999), venture capital accessibility (Powell et al., 2002; Shane and Stuart, 2002), and the presence of highly educated expert scientists and engineers (Porter, 2001) may be reasonable proxies for the kind of external environmental entrepreneurship support needed by university affiliated start-ups or small private companies. As such, these measures were used along with the number of SBIR and STTR grants received in a given state to develop a set of ratio measures that we labeled as entrepreneurial density. Not only do SBIR and STTR grants provide financial support for a company for early stage product development, they may also serve as a valuable marketplace signal that the company recipient has a potentially valuable technology under development, something attractive to later stage venture capital investment (Audretsch et al., 2002).

Four of the measures, the level of R&D activity, the number of patents, the amount of venture capital commitments in a given state, and the number of SBIR and STTR grants, were each expressed as a proportion of the size of a given state in square miles. The fifth measure, the number of scientists and engineers with Ph.D. degrees in a given state, was expressed as a proportion of the overall labor force in that state. A 1997 measure was used in all five cases, although a 2-year average from 1996 and 1997 was used in the case of venture capital commitments given its greater annual variability. Higher ratios infer a more entrepreneurially dense external environment.

3.4. Control variables

Consistent with prior research on technology performance, we included three control variables in our study. The first of these was the age of the technology transfer office as a proxy for experience. Previous research has shown that older technology transfer offices often outperform younger ones (Friedman and Silberman, 2003) and thus might be predictive of our measures of performance. Due to skewness in the data, this variable was log transformed. This information was obtained from the 2000 AUTM licensing survey and represents the age in years of the technology transfer office at that time. A second control variable included was the quality of the faculty. Previous research has also shown that universities with more eminent faculty often have the higher performing technology transfer programs (Powers and McDougall, 2005). Rating information on the graduate programs from each of our 134 universities was obtained from the 1997 *Gourman Report*, consistent with prior research (DiGregorio and Shane, 2003). Given that at times having a professional school, especially a medical school, is positively predictive of technology transfer performance (Thursby and Thursby, 2002), a dummy variable for the presence of a medical school was also included in our study. This final control variable was coded a one if the institution had a medical school and a zero if it did not.

4. Results

Phase one of this study focused on construct development for the support, selectivity, and entrepreneurial density variables. In each circumstance, we factor analyzed the variables to establish construct validity followed by tests of reliability using coefficient alpha. A Kaiser–Meyer–Olkin test of sampling adequacy revealed that we had an acceptable sample size for each of the three factor analyses (all were above 0.58). Bartlett's test of sphericity was also highly significant in each case, indicating further support for the factor analysis procedure.

4.1. Validity and reliability analyses for selectivity and support constructs

Because the data used to construct our selectivity ratios were measured on different scales, it was necessary to first standardize the variables (mean = 0; standard deviation = 1) prior to conducting the factor analysis. The KMO statistic was within the acceptable range (0.58) and Bartlett's test was highly significant (0.000), suggesting that the data were suitable for factor analysis (Mertler and Vannatta, 2002). The results of the principal components extraction with a varimax rotation for the support and selectivity items are shown in Table 1.

The factor analysis resulted in the extraction of two factors supportive of our theory. Specifically, the support measures loaded highly on one factor (loadings ranging from 0.71 to 0.82) and selectivity measures loaded highly on the other factor (0.71 to 0.89). There were no substantive cross-loadings. Subsequent reliability analyses of the variables within each factor provided further evidence of their utility as separate constructs. Coefficient alphas were 0.77 for the support factor variables and 0.84 for the selectivity factor variables, solidly within the acceptable range (Nunnally, 1967). Once it was clear that our two latent factors of support and selectivity existed in the data, we then used their factor scores in the regression analysis.

4.2. Validity and reliability analyses for entrepreneurial density construct

As we had done with selectivity and support, we first standardized the individual entrepreneurial density variables because they too were measured on different scales. The KMO statistic was once again within the acceptable range (0.56) and Bartlett's test was also highly significant (0.000), suggesting that the data were suitable for factor analysis (Mertler and Vannatta, 2002). The results of the principal components extraction with a varimax rotation for the entrepreneurial density items are shown in Table 2.

Table 1
Results of factor analysis of support and selectivity measures

Variable	Communalities	Factor 1 (selectivity)	Factor 2 (support)
Licensing FTE/invention disclosures	0.77	0.17	0.82
Licensing FTE/new patent applications	0.81	0.07	0.81
Licensing FTE/patent issues	0.64	0.10	0.74
Licensing FTE/start-up and small company licenses	0.60	−0.35	0.71
Start-up and small company licenses/invention disclosures	0.66	0.89	0.01
Start-up and small company licenses/new patent applications	0.77	0.88	−0.05
Start-up and small company licenses/patent issues	0.60	0.78	0.05
Start-up and small company licenses/total licenses	0.64	0.71	0.08

Table 2
Results of factor analysis of entrepreneurial density

Variable	Communalities	Factor loadings
Total R&D expenditures in state/square miles of the state	0.86	0.95
Total number of patents in state/square miles of the state	0.80	0.92
Total number of SBIR and STTR grants in state/square miles of the state	0.83	0.89
Average venture capital commitment in state/square miles of the state	0.81	0.88
Number of scientists and engineers with Ph.D.'s in a state/size of the state labor force	0.60	0.68

The factor extraction was strong (three loadings above 0.9, two above 0.88, and one at 0.68), all well within acceptable limits for factor analysis. Subsequent reliability analyses were also robust (0.92 alpha). Considering these results, we then used their factor scores in the regression analysis.

4.3. Hierarchical moderated regression analyses

Phase two of the study involved the inferential analysis necessary to investigate our hypotheses. Specifically, the data were analyzed using hierarchical moderated regression, the appropriate statistical tool given our testing of two- and three-way interactions. The means, standard deviations, and correlation matrix for our research variables are shown in Table 3.

The average university in our dataset had 1.9 IPO companies in its portfolio and product sale royalties of $4 million. In addition, they had an average quality rating on a five-point scale of 3.64 and a technology transfer office that was 14 years old. As seen in the correlation matrix, all independent variable correlations were below rules of thumb for likely collinearity concerns. However, variance inflation factors (VIFs) were also calculated (not shown). VIFs ranged between 1.0 and 1.7, well below the rule of thumb threshold of 10.0 for collinearity concerns (Mertler and Vannatta, 2002).

Consistent with the procedural approach associated with testing lower and higher order interactions (Allison, 1977), the variables were entered into the model in a series of four steps. The three control variables were entered in step one followed by the main effects (selectivity, support, and entrepreneurial density) in step two. In step three, we entered the two-way interactions, and, in step four we entered the three-way interaction term. In order to demonstrate support for the Hypotheses 2a and 2b, the three-way interaction term in the regression model would need to have a negative and significant β. Such a finding would imply that a negative relationship between selectivity and support promotes performance in entrepreneurially dense (strong) external environments, while a positive relationship between selectivity and support promotes performance in entrepreneurially sparse (weak) external environments.

4.3.1. Regression analyses: IPOs

Table 4 shows the results of the regression analyses involving IPOs as the dependent variable measure of performance.

Table 3
Summary statistics and correlation matrix ($N = 134$)

Variable	M	S.D.	1	2	3	4	5	6	7
1. Log (IPO)	0.32	0.33							
2. Log (royalties)	5.37	1.54	0.37**						
3. Selectivity	0.00	1.00	0.18*	−0.03					
4. Support	0.00	1.00	0.17*	0.27**	0.00				
5. Entrepreneurial density	0.00	1.00	0.30*	0.09	−0.01	−0.01			
6. Log (TTO age)	1.03	0.34	0.41**	0.40**	−0.04	0.20*	0.15		
7. Faculty quality	3.64	0.77	0.66**	0.39**	0.16	0.22*	0.27**	0.46**	
8. Medical school	0.57	0.50	0.36**	0.20*	−0.00	0.05	−0.06	0.21*	0.41**

* $p < 0.05$.
** $p < 0.01$.

Table 4
Hierarchical moderated regression results with IPOs as dependent variable ($N = 134$)

Independent variables	Model 1		Model 2		Model 3		Model 4	
	β^a	S.E.	β^a	S.E.	β^a	S.E.	β^a	S.E.
Constant	−0.73	0.11	−.060	0.12	−0.64	0.12	−0.64	0.12
Log (TTO age)	0.14^{+}	0.07	0.15^{*}	0.07	0.18^{*}	0.08	0.18^{*}	0.08
Faculty quality	0.24^{***}	0.04	0.19^{***}	0.04	0.20^{***}	0.04	0.20^{***}	0.04
Medical school	0.07	0.05	0.10^{*}	0.05	0.09^{+}	0.05	0.09^{+}	0.05
Selectivity			0.04^{*}	0.02	0.04^{+}	0.02	0.04^{+}	0.02
Support			0.01	0.02	0.01	0.02	0.01	0.02
Entrepreneurial density			0.05^{*}	0.02	0.05^{*}	0.02	0.05^{*}	0.02
Selectivity × Entrepreneurship					-0.04^{+}	0.03	−0.04	0.03
Selectivity × Support					−0.01	0.02	−0.01	0.03
Entrepreneurship × Support					0.00	0.03	0.00	0.03
Entrepreneurship × Selectivity × Support							0.00	0.04
F-value	33.56^{***}		19.19^{***}		13.18^{***}		11.76^{***}	
R^2	0.45		0.49		0.50		0.51	

[a] Unstandardized regression coefficients are reported because unlike standardized regression coefficients, they are not affected by the points of origin of the independent variables (Southwood, 1978).
* $p < 0.05$.
*** $p < 0.001$.
\+ $p < 0.10$.

As can be seen in Table 4, the *F*-value for each model was highly significant ($p < 0.001$) with the full model explaining approximately half of the variance in the dependent variable. In order to answer Hypothesis 1 involving IPOs as the dependent variable, though, it is necessary to examine Model 2 since main effects become uninterpretable in the presence of interactions (Southwood, 1978). Model 2 indicates that both selectivity and entrepreneurial density are significant positive predictors of the number of licenses held with private companies that subsequently went public ($p < 0.05$). In the case of selectivity, this finding infers that universities with a selective policy orientation toward licensing with start-ups and small companies appear to have more IPO companies than universities with less selective policies. Thus, Hypothesis 1 was supported. Furthermore, universities located in entrepreneurially dense external environments appear to have larger portfolios of IPO companies than universities located in more entrepreneurially sparse external environments. However, the level of support for one's technology transfer program does not appear to provide performance benefits in terms of IPOs.

Model 4 provides the results associated with Hypotheses 2a and 2b. Specifically, the three-way interaction was not significant and hence Hypotheses 2a and 2b were not supported. This result infers that a university's selectivity and support orientation is not significantly influenced by the density or sparseness of the external entrepreneurial environment. Furthermore, the selectivity × support interaction was also not significant, collectively suggesting that university technology transfer performance measured in terms of IPO firms does not appear to depend on the policy orientation, nor is that policy orientation significantly influenced by the external environment for entrepreneurship.

In order to parse out these relationships for public universities only, an identical supplemental hierarchical moderated regression analysis was performed (not shown). In this case ($N = 92$), all models were also highly significant ($F < 0.001$) with an R^2 in the full model of 0.41. In Model 2, entrepreneurial density was the only one of the three main effects that was significant ($p < 0.05$). In Model 4, the three-way interaction was not significant, although this time the selectivity × entrepreneurial density interaction was negative and significant ($p < 0.05$). This result suggests that for public universities, entrepreneurial density negatively moderates the relationship between selectivity and performance. Specifically, public universities located in entrepreneurially strong regions accrue fewer IPO performance benefits from a selective policy orientation than do public universities located in entrepreneurially weak regions that employ high selectivity. To more finely understand the nature of the interaction, we performed sub-group correlation analysis using the bottom third and the top third of the sample on the measure of entrepreneurial density. The selectivity – IPO relationship for those public universities in the entrepreneurially sparse environments had a 0.24 correlation ($p < 0.05$) while those in the entrepreneurially dense environments had a −.189 selectivity–IPO correlation ($p < 0.05$). This result affirms that public universities in entrepreneurially weak environments are advantaged by pursuing a more selective policy orientation while public universities in entrepreneurially strong environments are likely advantaged by pursuing a less selective policy orientation.

4.3.2. *Regression analyses: product royalties*

Table 5 shows the results of the regression analyses involving product royalties as the dependent variable measure of performance.

As can be seen in Table 5, the *F*-value for each model was highly significant ($p < 0.001$) with the full model explaining approximately 40% of the variance in the dependent variable. In order to answer Hypothesis 1 involving product royalties, though, it is once again necessary to examine Model 2 because of the higher order terms involved in Models 3 and 4. The results of the analysis in Model 2 revealed only marginal support ($p < 0.1$) for the hypothesis that a more highly selective policy orientation is associated with higher levels of technology transfer performance, at least in terms of product royalty flows. The other two main effects were not significant, indicating that neither the external entrepreneurial environment in which a university is embedded nor the level of support offered through their technology transfer program provides significant royalty flow benefits.

In the case of the full model (Model 4), the three-way interaction was once again not significant, rendering Hypotheses 2a and 2b not supported in the model involving royalties. However, the two-way interaction between selectivity and support was significant and negative ($p < 0.05$). This finding infers that universities that are more selective about their choices for what to patent and license via the start-up and small company route appear to be especially disadvantaged in terms of royalty flows when they provide a high degree of support for their technology transfer program. Conversely, universities that are less selective appear to be advantaged by a stronger support orientation. A further sub-group correlation analysis was once again

Table 5
Hierarchical moderated regression results with product royalties as dependent variable ($N = 114$)

Independent variables	Model 1		Model 2		Model 3		Model 4	
	β^a	S.E.	β^a	S.E.	β^a	S.E.	β^a	S.E.
Constant	2.64	0.44	2.99	0.48	2.73	0.48	2.75	0.48
Log (TTO age)	0.70*	0.29	0.73*	0.29	0.90*	0.30	0.91*	0.30
Faculty quality	0.63***	0.14	0.53***	0.15	0.56***	0.15	0.55***	0.15
Medical school	−0.16	0.19	−0.01	0.19	−0.14	0.19	−0.13	0.19
Selectivity			0.17+	0.09	0.13	0.09	0.13	0.09
Support			0.12	0.09	0.01	0.09	0.01	0.10
Entrepreneurial density			0.00	0.09	0.00	0.08	0.00	0.10
Selectivity × Entrepreneurship					−0.01	0.11	−0.01	0.12
Selectivity × Support					−0.19*	0.09	−0.22*	0.10
Entrepreneurship × Support					−0.15	0.13	−0.19	0.15
Entrepreneurship × Selectivity × Support							0.01	0.17
F-value	16.49***		9.34***		7.29***		6.54***	
R^2	0.31		0.34		0.38		0.39	

[a] Unstandardized regression coefficients are reported because unlike standardized regression coefficients, they are not affected by the points of origin of the independent variables (Southwood, 1978).
* $p < 0.05$.
*** $p < 0.001$.
+ $p < 0.10$.

employed to analyze the bottom third and the top third of the sample, this time on the measure of support. In this case, the correlations between selectivity and royalties at either end were weak and not significant. However, for the middle third, the correlations were −0.27 and significant ($p < 0.05$). Thus, it appears that the negative moderator relationship is characteristic of universities that pursue a middle ground selectivity and support orientation. Specifically, for those universities in the middle third of the support range, an increase in selectivity results in a decreasing royalty benefit up to a point.

Once again, in order to parse out these relationships for public universities only, an identical supplemental hierarchical moderated regression analysis was performed (not shown), this time using the product royalty dependent variable. All models were highly significant ($F < 0.001$) with an R^2 in the full model of 0.41 ($N = 83$). In this circumstance, both selectivity and support as a main effect were positively significant in Model 2 ($p < 0.05$). None of the higher order interactions were significant in either Model 3 or Model 4.

5. Discussion and implications for practice

This study was the first to empirically test a model of a university's selectivity and support policy orientation for technology licensing and its interaction with the external environment for entrepreneurship. The results confirmed the utility of operationalizing support and selectivity as two distinct policy orientations associated with the technology transfer process. Specifically, universities can be placed into positions given their degree of support for the commercialization process and selectivity in picking technologies to advance via the start-up and small private company route for licensing. Furthermore, our measure of entrepreneurial density proved valid, reliable, and useful as an important additional measure of context for the conduct of university technology transfer within a state.

In terms of how selectivity, support, and the external entrepreneurial environment impact performance, three themes emerged from our findings. First, from a theory perspective, our findings do support a contingency perspective on technology transfer practice. Whereas most research to date has investigated the direct effects of various institutional and environmental factors and resources, this quantitative study suggests that the relationships are likely more complex, findings that others are surfacing via qualitative study (Clarysse et al., 2005). For example, for public universities, a policy of selectivity appears to have differential benefits depending on the nature of their external environment for entrepreneurship. When they are located in external environments that are supportive of the development and growth of small businesses such as is true in states like Massachusetts and California, selectivity does not necessarily provide the advantages that it does in states with a less robust entrepreneurial environment. This finding aligns well with Roberts and Malone's (1996) research in which they found that institutions such as the University of Chicago and at that time its technology transfer arm, ARCH Development Corporation, were able to be successful in their less than ideal external environment for entrepreneurship in part by emphasizing a selective approach to the licensing of technologies to start-ups. Conversely, they found that universities like MIT and Stanford did not need nor should be so strict about what to pursue via new ventures, since external expertise and resources for making those kinds of choices were readily available in the area. Choice, in those circumstances, should be left to the venture capitalists and local entrepreneurs to "pick winners." Furthermore, the external environment could better absorb a higher number of spin-offs even if the quality of patented and licensed technologies was not as strong.

A related contingency issue and the subject of the second theme emerging from this study is the interaction between selectivity and support. As discussed earlier, there was a negative and significant interaction effect of support on the selectivity–royalties relationship. Roberts and Malone's (1996) and later Degroof and Roberts' (2004) research support the idea of contingencies in technology transfer. Specifically, they tended to find that in strong entrepreneurial circumstances, it was sub-optimum for a university to be both highly selective and highly supportive because it represented an inefficient and unnecessary investment of scare institutional resources. Similarly, a low selectivity, low support policy position was found to be sub-optimum for a university trying to establish itself in a weak entrepreneurial region. Our finding that as support increases, the benefits of high selectivity diminish (and vice versa) also suggests a contingency at work, but that it revolves around universities who pursue a middle position in terms of support. The combined fact that selectivity has no effect on royalty flows and support at either extreme does not change that relationship, implies a useful revision of the Roberts and Malone (1996) model, at least in terms of raising revenues and demonstrating product success. Namely, that extreme levels of either support or selectivity may not be the optimum policy orientation. The "better" position may be a middle ground one, depending on the outcome of interest. Selectivity and entrepreneurial density, for instance, were both positively related to IPO performance, suggesting that the middle position may not hold true for all measures of performance. Nevertheless, Fig. 1 below in which the selectivity and support positions of our sample universities can be found along with overlays of the top performers in noted technology transfer categories offers support for the middle and balanced policy orientation proposition.

As seen in the data, it appears that the high performers are generally found near the mean lines of the chart on selectivity and support. This graphical depiction, then, appears to align with what we found in our data with royalty income. Furthermore, it suggests that a balanced approach to one's policy orientation may work best, rather than one at the extremes.

The third theme of note from the data focuses on public universities. As discussed in Section 4, some unique issues were discovered for public institutions. These include a direct positive effect of selectivity and support, respectively, on royalty revenues and a negative selectivity–IPO performance contingency involving entrepreneurial density. As it regards the former, there appears to be evidence that public institutions in particular may benefit from emphasizing a high selectivity, high support policy orientation for technology transfer, one of the high performance positions suggested by Roberts and Malone (1996). The support finding, at least, is in general alignment with what others have reported in the literature (Rogers et al., 2000; Siegel et al., 2003). A possible explanation for this finding is that the public universities in our sample disproportionately confronted weaker external environments for entrepreneurship. Hence, to be successful, they felt that they needed to be both selective about what they patent and license via the start-up and small

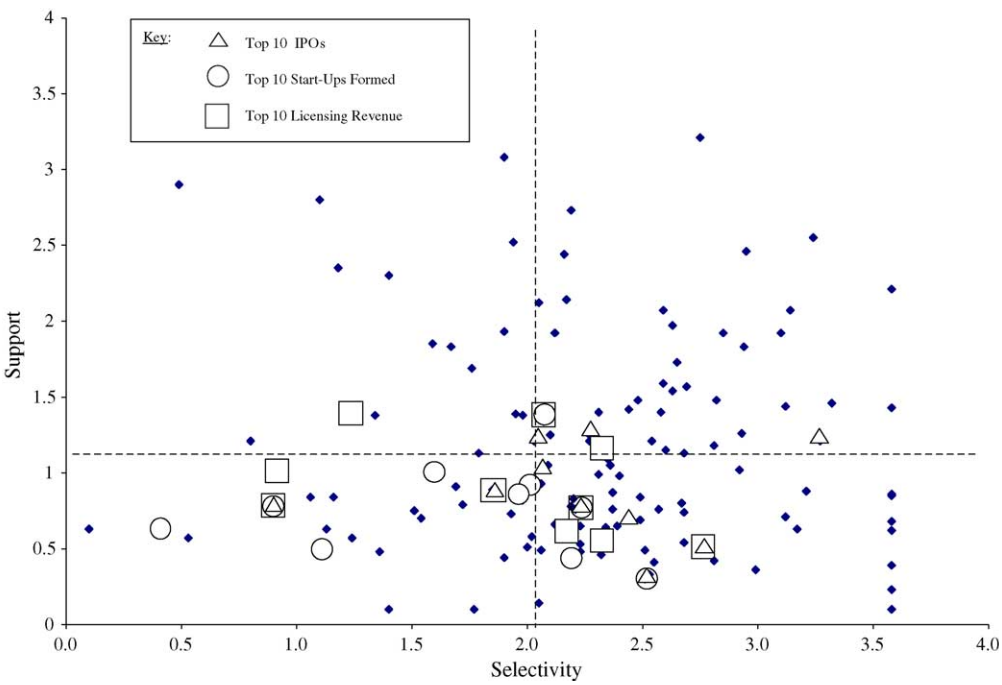

Fig. 1. Policy orientation positions with top ten performers superimposed.

company route and devote sufficient staff resources to supporting those entrepreneurial firms with whom they license technologies. Previous research, however, suggests that public universities are somewhat more likely than private universities to have a low support, low selectivity policy orientation (Powers and McDougall, 2003). This suggests either their inability to devote the resources needed to be successful or their comparably recent entry to technology transfer practice (private universities on average have older technology licensing programs than do public universities). Thus, public universities may be less likely to have the requisite expertise and infrastructure to be more supportive of technology transfer such as through business incubation, seed funding programs, and other kinds of internal support mechanisms oriented toward start-ups and small companies.

In regards to the significant negative impact of entrepreneurial density on the selectivity–IPO performance relationship, this too has considerable implications for public universities. This relationship suggests that public universities in weak external environments benefit most by a highly selective approach to technology transfer. For public institutions in strong external entrepreneurial environments, they are advantaged by pursuing a less selective policy orientation. Unfortunately, previous research suggests that public universities may be seeking to emulate successful private institutions like MIT and Stanford in ways that are not especially helpful (Powers and McDougall, 2003). These two institutions have a low selectivity, low support policy orientation, appropriate perhaps given their strong external environment, but not necessarily for a public institution facing a weak external environment for entrepreneurship. Given Thursby and Thursby's (2002) work on patent quality, if a growing number of institutions are patenting and seeking to license increasingly marginal technologies (a possible proxy measure of declining selectivity), those public universities trying to do so in a weak external entrepreneurial environment will likely have an especially difficult time being successful.

5.1. Limitations and opportunities for future research

The findings of this study and implications should be considered in light of its limitations. First, as mentioned earlier, while the constructs of selectivity and support are both valid and reliable, they are really proxy measures that roughly capture how a university pursues technology transfer on two distinct dimensions. They do not necessarily represent intentional strategies nor are they necessarily continuum choices that universities can choose to pursue even if they desired to do so. Nevertheless, they do have implications as have been shown by this study. As such, future research using other operationalizations of support and selectivity would be useful, especially via scale development through surveys of technology transfer professionals. Relatedly, our selectivity and support measures do not inherently consider the issue of technology–market fit as has been discussed in the literature (Markman et al., 2004). Specifically, it may be that a technology emerging from a university is incongruent with the needs of either industry or consumers. Hence, future investigations might consider the use of a technology–market fit variable, both as a direct and a moderating effect on any university–technology transfer performance relationship.

Second, operationalizing entrepreneurial density by state, while helpful and appropriate for informing state policies, may not adequately capture regional differences that transcend state boundaries. Future research using a university's metropolitan statistical area (MSA), for example, would be useful to investigate.

Lastly, our research focused on two measures of performance. Future research might focus on different outcomes of importance. For example, given increasing university interest in taking equity positions in their licensee companies, measures of post-IPO stock price performance would be a valuable new route for investigation.

6. Conclusion and implications for policy

The implications of the findings for public policy, especially as it affects public research universities, are considerable. State and federal policymakers who desire to advance the cause of regional economic development, for instance, would be wise to examine their own polices and practices as it relates to the support of small high-technology companies and public universities attempting to move university-developed technologies to the marketplace. Thus, for example, environmental audits of a state to determine the infrastructure needs supportive of small company growth would be wise given its importance for stimulating economic growth (Tornatzky, 2000). State legislators might also consider incentive mechanisms to stimulate their public higher education sector to become more intentionally engaged in activities that support an economic development agenda (Schmidt, 2002; State Science and Technology Institute, 1997) and to carefully assess the interface between choices that are made about technology transfer and the external environment. Public research universities might be provided seed funding to develop their technology transfer programs, for example, and other types of institutions such as community colleges could be given resources to expand their workforce development initiatives. Given the condition of most state economies, however, new monies will be hard to come by so partnering with the federal government will be critical. Using state funds to match or leverage federal resources from programs such as EPSCoR,[2] SBIR, and/or STTR are three very applicable examples. However, given higher education's predictable resource dependence response to the state appropriation reductions of recent years (Slaughter and Leslie, 1997), we would caution policy makers to recognize that not all public universities are set up to adequately manage a technology transfer mission. Yet, given the opportunity to go after new state funding sources, all or most would likely do so, a situation where the potential impact of state investment could be diluted. Thus, we would advise careful planning and investment made strategically based upon institutional capabilities.

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[2] EPSCoR is a federal program designed to expand and enhance the research capability of scientists in states that traditionally have lacked strong university-based research efforts with the intent of helping those states to compete more successfully for federal academic R&D resources.

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