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S Y M P O S I U M

THE PSYCHOLOGICAL FOUNDATIONS OF UNIVERSITY SCIENCE COMMERCIALIZATION: A REVIEW OF THE LITERATURE AND DIRECTIONS FOR FUTURE RESEARCH

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As interest in university science commercialization has expanded, researchers have increasingly acknowledged the elemental role of individual academic scientists in associated activities—from scientific discovery and invention to licensing and new venture development. In this article, we review recent literature focused on psychological aspects of academic scientists' involvement in such activities, which has concentrated primarily on topics that we have categorized as human capital, social capital, heterogeneous objectives, and demographic characteristics. In addition, we offer suggestions for potential theoretical and methodological advances to this literature. Finally, we discuss emerging trends in university science commercialization and the important role that individual academic scientists will likely need to play to ensure the future viability of universities' efforts to both generate and appropriate value from such activities.

An increasing number of universities have developed policies, systems, and processes to identify the scientific discoveries of their faculty members and cultivate them into tangible technologies that can be commercialized via licensing agreements and/or the development of spin-out companies (e.g., technology transfer offices, start-up incubators) (Huyghe, Knockaert, Piva, & Wright, 2016; Rothaermel & Thursby, 2005). This trend was partly initiated in the United States by the Bayh-Dole Act of 1980, which allowed for the commercialization of government-funded research (Grimaldi, Kenney, Siegel, & Wright, 2011), along with similar legislation in several other countries (Abreu & Grinevich, 2013). Since the passage of the act, a number of prestigious university researchers have become involved in science commercialization activities, which helped to gradually alter professional norms of the academic scientific community toward acceptance of engaging in research for financial profit—opening the door for a broader range of academic scientists of different rank and standing to become involved in such activities (Etzkowitz, 1998; Stuart & Ding, 2006).

A primary benefit of science commercialization by universities is the opportunity to create new streams of revenue that can offset the rising cost of research and support operations that, in many cases, used to be more heavily funded by state and federal agencies (Bray & Lee, 2000). More distal, but no less important, outcomes of universities' commercialization of science include regional development in the form of new businesses and jobs (Fini, Grimaldi, Santoni, & Sobrero, 2011) and societal advances made through the introduction of innovative products and services (Colyvas, 2007). In addition, universities that are successful at commercializing the scientific discoveries and inventions of their faculty gain other benefits, such as prestige and improved placement opportunities for their students (Abreu & Grinevich, 2013). For these reasons, technology transfer has become a third mission for many universities, in addition to teaching and research (Lockett, Wright, & Wild, 2013).

Even though the *promise* of science commercialization has been alluring, with the exception of universities that both have elite science and engineering programs and are located in geographic regions with well-developed entrepreneurial ecosystems (e.g., Stanford, MIT; Breznitz, O'Shea, & Allen, 2008; Leih & Teece, 2016), the degree to which university technology transfer programs have been able to demonstrate clear value has been somewhat inconsistent (Geuna & Nesta, 2006; Harrison & Leitch, 2010; Siegel & Wessner, 2012). One reason such efforts have not produced greater success may be that a top-down approach has typically been taken by university administrators toward technology transfer activities (Philpott, Dooley, O'Reilly, & Lupton, 2011), with a lack of consideration for nuanced differences in the goals, motives, and experience of academic scientists (Jain, George, & Maltarich, 2009). Moreover, managing multiple identities and transitions between roles relating to science and business can create complex demands on the limited time and energy of university faculty members who participate in technology transfer activities (Ashforth, 2001; Stryker, 1980; Tajfel & Turner, 1979). Taken together, these present a considerable hurdle for universities that want faculty to engage, to some degree, in multiple occupational roles.

Researchers examining the phenomenon of university science commercialization have gradually begun to recognize the unique and complex part the individual academic scientist plays as the active element in the process of technology transfer. This paper first summarizes the most recent literature on this topic, focusing specifically on what we know and don't know about (1) why some academic scientists, but not others, engage in science commercialization activities, and (2) why some academic scientists who engage in commercialization activities are more or less successful in such efforts than other academic scientists. We use this summary to inform suggestions regarding theoretical and methodological advancements that could be made with future research in this area. Overall, we hope that a better understanding of the psychological foundations of university science commercialization (i.e., the individual characteristics, motives, cognition, and behaviors of academic scientists) will help to provide a more complete picture with which to inform universities regarding how they can better realize the promise of science commercialization.

SCOPE OF THE LITERATURE REVIEW

Our review includes articles focusing on academic scientists' engagement in university science commercialization activities that have been published in mainstream general management (*Academy of Management Journal*, *Journal of Management*, *Journal of Management Studies*, *Management Science*, *Strategic Management Journal*, and *Organization Science*), entrepreneurship (*Journal of Business Venturing*, *Strategic Entrepreneurship Journal*, *Entrepreneurship Theory and Practice*, *Small Business Economics*, *Entrepreneurship and Regional Development*, *and International Small Business Journal*), and technology and innovation management (*Research Policy*, *IEEE Transactions on Engineering Management*, *Journal of Technology Transfer*, *Journal of Product Innovation Management*, and *Technovation*) journals. The first step in our article-selection process was to search these journals over the most recent 10-year period (2006–2015) for the following terms: *technology transfer*, *technology commercialization*, *science commercialization*, *university spin-off*, and *academic entrepreneurship*. A total of 817 articles met this initial search criterion.[1]

The second step involved closely reviewing each article to determine whether it focused on empirical research that informs the psychological foundations of technology transfer and positions the academic scientist as the focal actor. This process resulted in the identification of 56 target articles that formed the foundation of our review (see Table 1 for a summary of these studies). It is worth noting that we excluded articles focused on teams of academic scientists because that is the focus of a different review article in this symposium (see Nikiforou, Zabara, Clarysse, & Gruber, in this issue). Moreover, we restricted the coverage of our review to academic scientists engaged in university science commercialization due to differences in motivational and contextual factors as compared to other groups, such as scientists working to commercialize technology in corporate settings (Sauermann & Stephan, 2013).

PRINCIPAL TOPIC AREAS

We have organized our review of the identified target articles into the following principal topic areas: human capital, social capital, heterogeneous objectives, and demographic characteristics. Before moving forward, there are two points of clarification

[1] Due to the use of *technology transfer* as a search term, every article published in the *Journal of Technology Transfer* for the time period reviewed met the initial search criterion. Without this journal included, a total of 415 articles met the initial search criterion.

TABLE 1
Psychological Foundations of Science Commercialization Target Studies

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
Abreu and Grinevich (2013)	22,556 academics based in U.K. higher education institutions	Determinants, likelihood of academic engagement	*Primary theoretical framework:* Unspecified *HC:* Entrepreneurial experience and having an applied research focus are positively related to engagement in science commercialization activities that fall outside of regular university channels. *SC:* Universities that place greater weight on business or commercial activities have fewer research faculty and staff engaged in informal, noncommercial activities that take place outside of formal university channels. *DC:* Males are more likely to be involved in informal, noncommercial activities that occur outside of formal university channels than are females.
Agrawal (2006)	124 MIT faculty inventors in the Departments of Mechanical Engineering and Electrical Engineering and Computer Science	Licensing commercialization success with inventor engagement	*Primary theoretical framework:* Unspecified *SC:* Licensing strategies that directly involve the inventor increase the likelihood that the invention will be commercialized and generate greater royalties than those that do not involve the inventor.
Aldridge and Audretsch (2010)	392 scientists who patented technology created as part of research funded by the National Cancer Institute (NCI)	Modes and routes to commercialization	*Primary theoretical framework:* Unspecified *SC:* University scientists who select a backdoor route to science commercialization that does not involve assigning patents to their institutions tend to start a new firm as a means of technology transfer, whereas those who decide to assign patents to their institutions more often select licensing as a form of technology transfer.
Aldridge and Audretsch (2011)	1,693 scientists, 392 scientists with patent, and 140 scientists with patent who were interviewed having research funded by the National Cancer Institute (NCI)	Factors that inhibit or are conducive for scientists becoming entrepreneurs	*Primary theoretical framework:* Unspecified *HC:* There is no significant relationship between the number of citations per publication and the propensity of scientists to become entrepreneurs. *SC:* Linkages with private industry and having industry copublications are positively related to scientists' propensity to become entrepreneurs. There is no significant relationship between resource availability from TTOs (in terms of number of TTO employees and number of TTO employees dedicated to licensing divided by the number of administrative employees) with scientists' propensity to become entrepreneurs. *DC:* There is no significant relationship between the gender of scientists and their propensity to become entrepreneurs. There is no relationship between the age of scientists and their propensity to become entrepreneurs.
Aldridge, Audretsch, Desai, and Nadella (2014)	1,899 university scientists (drawn from Association of University Technology Managers [AUTM] database)	Factors driving likelihood of scientists starting companies	*Primary theoretical framework:* Unspecified *SC:* Being a member of a corporate scientific advisory board is positively associated with the likelihood of starting a new business. *DC:* Found a negative relationship between years in tenure and academic rank with the likelihood of starting a business.
Alshumaimri, Aldridge, and Audretsch (2012)	272 academic scientists employed by universities in Saudi Arabia	Factors influencing commercialization activities	*Primary theoretical framework:* Unspecified *HC:* Number of publications is positively related to intentions to start a new firm. *SC:* Belonging to a corporate board is not related to the likelihood of becoming involved in entrepreneurial activities. *DC:* Gender is not related to intentions to start a new firm. Scientists who have recently completed their doctoral degrees are more entrepreneurial than their more senior counterparts.

Note: HC: human capital; SC: social capital; HO: heterogeneous objectives; DC: demographic characteristics.

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
Bercovitz and Feldman (2008)	1,780 academic scientists (primary study) and interviews with 50 persons who were technology transfer officials, university administrators, and faculty members (background for the study)	Probability of disclosure activity	*Primary theoretical framework:* Social learning theory *HC:* Scientists with graduate training that included learning about science commercialization processes are more likely to disclose inventions to their university's technology transfer office than those without such training. *DC:* Years since last degree was granted is negatively related to patent disclosures filed.
Calderini, Franzoni, and Vezzulli (2007)	131 Italian academic scientists	Length of elapsed time before failure event	*Primary theoretical framework:* Unspecified *HC:* Scientists working on applied research are significantly more likely to become inventors than their colleagues who mainly conduct basic research.
Casper (2013)	19,441 biotechnology patents filed in the state of California	Number of patents	*Primary theoretical framework*: Spillover theory *SC:* Linkages between industry and academic scientists are associated with increased university science commercialization.
Clarysse, Tartari, and Salter (2011)	2,194 academic scientists based in the United Kingdom	Researcher's decision to get involved as cofounder or venture board of directors	*Primary theoretical framework:* Unspecified *HC:* Entrepreneurial experience is positively related to involvement in a new venture as either a director or cofounder. *DC:* Females view science commercialization through new venture creation as being less appealing than do their male counterparts.
Colyvas, Snellman, Bercovitz, and Feldman (2012)	1,088 academic scientists	Likelihood of reporting an invention, number of inventions reported, number of inventions licensed, and proportion of inventions converting to licenses	*Primary theoretical framework:* Unspecified *DC:* Females are significantly less likely to disclose inventions, but this relationship goes away after controlling for academic rank, publication record, and history of research funding. Similarly, no gender differences exist with respect to the success of science commercialization (i.e., the extent to which patent disclosures lead to licensing agreements) once these same controls are included.
Criaco, Minola, Migliorini, and Serarols-Tarres (2014)	Founders of 80 Spanish university-based companies	University start-up survival or failure	*Primary theoretical frameworks:* Human capital theory, threshold model of entrepreneurial exit *HC:* The entrepreneurial education (i.e., a degree in entrepreneurship or business) and university work experience as a professor or researcher of founders is positively related to firm survival, but prior start-up experience of founders is negatively related to firm survival.
D'Este, Mahdi, Neely, and Rentocchini (2012)	1,528 academic scientists based in the United Kingdom	Opportunity discovery (patents) and opportunity exploitation (business founding)	*Primary theoretical framework:* Unspecified *HC:* Scientific excellence (defined by the number of citations per publication) is more positively related to the discovery of entrepreneurial opportunities than to the exploitation of such opportunities. In addition, breadth of scientific research (i.e., the degree to which research is conducted across multiple disciplines) is positively related to the exploitation of entrepreneurial opportunities, but is not a significant factor in the discovery of such opportunities.
Ding and Choi (2011)	6,138 university life scientists	Determinants, timing, and rate of scientific advisory board membership versus founding activities	*Primary theoretical frameworks:* Demand side theory, supply side theory *HC:* Numbers of publications and citations are positively related to business founding and advising activities. In addition, patent counts are also positively related to these activities.

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
			SC: Network ties with a coauthor who has founded a business significantly increase the odds of founding a new firm. *DC:* Female scientists are less likely than male scientists to have started a business. Scientists who started businesses to commercialize their discoveries are younger, with the peak time for engaging in such activities being about 12 years after earning their doctoral degrees.
Edler, Fier, and Grimpe (2011)	958 German academic scientists	Technology transfer activities	*Primary theoretical frameworks:* Resource-based theory of the firm, scientific and technical human capital approach, organization environment perspective *SC:* Scientists who spend more time at institutions abroad are more likely to engage in technology transfer back in their home countries.
Fini, Grimaldi, and Sobrero (2009)	88 Italian academic scientists	Factors fostering academics to start new ventures	*Primary theoretical framework:* Unspecified *HO:* The decision to start a business is positively associated with the expectation of identifying new research projects, building an enhanced reputation and status as a prominent academic, generating grant (or other funding) opportunities for research assistants and doctoral students, or acquiring new facilities or other types of infrastructure for conducting academic research.
Forti, Franzoni, and Sobrero (2013)	59 inventors and 85 non-inventors who were academic scientists at Italian universities	Networks based on patenting activity	*Primary theoretical framework:* Theory of socially constructed knowledge *SC:* Inventors hold denser network ties and have more redundant links than do non-inventors.
Fox and Xiao (2013)	100 female associate professors who were affiliated with Canadian institutions	Chances of promotion	*Primary theoretical framework:* Unspecified *DC:* Reward structures perceived by female scientists as supporting entrepreneurial activity negatively predict their perceived odds of being promoted.
Fritsch and Krabel (2012)	2,604 scientists associated with the Max Planck Society	Entrepreneurial attractiveness and attractiveness of work in the private sector	*Primary theoretical framework:* Unspecified *HC:* The pursuit of entrepreneurial business opportunities is considered to be more attractive to scientists working on applied research, as compared to those who are focused on basic research. No relationship was observed between patenting experience and interest in entrepreneurial endeavors. *SC:* Scientists who partner with corporations on research are more likely to perceive starting a new business to be attractive as compared to those without such partnerships. *DC:* Females view science commercialization through new venture creation as less appealing than do their male counterparts. Scientists with tenure perceive engagement in entrepreneurial activities as being less attractive than those without tenure.
Glenna, Welsh, Ervin, Lacy, and Biscotti (2011)	912 plant and animal biotechnology (academic) scientists at 60 research universities	Proprietary index, percentage of basic research in a scientist's research portfolio, and percentage of the scientist's total research funding from industry	*Primary theoretical frameworks:* Mertonian theory of science, institutional theory of action *HC:* Industry funding is positively associated with applied, as opposed to basic, research.
Goel and Goktepe-Hulten (2013)	2,577 academic scientists associated with the Max Planck Society	Filing a patent application, disclosing an invention	*Primary theoretical framework:* Theory of intellectual property

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
			DC: Female scientists file fewer invention disclosures and gain fewer patents than male scientists. The age of a scientist is positively related to invention disclosures and patents.
Goktepe-Hulten and Mahagaonkar (2010)	Over 2,500 scientists associated with the Max Planck Society	Likelihood of scientists' patenting activities and expectations for commercialization	*Primary theoretical frameworks:* Mertonian theory of science, signaling theory *HO:* The expectation of financial gain is not associated with the patenting activity of academic scientists working without industry partners. Instead, the desire to enhance one's academic reputation is more strongly associated with the patenting activity of such academic scientists.
Grimm and Jaenicke (2012)	60 academic scientists who are patentees	Personal attributes and institutional environmental contributions to academic entrepreneurship	*Primary theoretical framework:* Unspecified *DC:* The age of scientists who are patentees is positively related to holding an entrepreneurial attitude.
Grimpe and Fier (2010)	Ranges between 745 and 948 academic scientists associated with German universities	Alternative mechanisms of informal technology transfer	*Primary theoretical framework:* Unspecified *HC:* Scientists who spend more time at institutions abroad are more likely to engage in technology transfer back in their home countries as compared to those who spend less time abroad. *DC:* Male scientists are more likely to engage in informal technology transfer, specifically the commercialization of technology and consulting activities, than are female scientists.
Guerrero and Urbano (2014)	207 academics associated with Spanish universities	Factors contributing to academics' start-up intentions	*Primary theoretical framework:* Knowledge spillover theory *HO:* Perceived behavioral control is positively related to entrepreneurial intentions.
Haeussler and Colyvas (2011)	2,294 German and United Kingdom life scientists	Commercial Activity Index (consulting, patenting, and founding activities)	*Primary theoretical framework:* Unspecified *SC:* Having a parent who was an entrepreneur is positively associated with founding a business. *DC:* Female scientists are less likely to found companies than are male scientists. Being a tenured professor is positively associated with founding a business.
Hoye and Pries (2009)	172 science faculty members from a major Canadian university	Repeat commercializing activity	*Primary theoretical framework:* Unspecified *HC:* The 12% of faculty scientists who are repeat commercializers are responsible for 80% of innovations that are commercialized.
Huyghe and Knockaert (2015)	437 research scientists associated with Swedish and German universities	Scientists' entrepreneurial intentions in terms of a) spin-off creation, b) intellectual property rights (patenting or licensing), and c) industry–science interaction (contract research or consulting)	*Primary theoretical framework:* Institutional theory *HO:* Entrepreneurial self-efficacy is positively related to scientists' intentions to engage in spin-off creation and patenting or licensing, but not to industry–science interactions.
Jain, George, and Maltarich (2009)	20 tenured academic scientists at a research university located in the Midwest region of the United States	Role identity modification	*Primary theoretical framework:* Identity theory *HO:* Academic scientists develop hybrid professional identities that center primarily on the role of being a traditional academic involved in research and teaching and secondarily on the role of being a businessperson involved in commercialization. Moreover, scientists employ two different mechanisms for maintaining a desired balanced between their primary and secondary role

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
			identities: delegating and buffering. Delegating involves identifying and creating relationships with persons (located in the university or beyond) who possess skills that can help them to commercialize their scientific discoveries or inventions. Buffering involves actively taking steps to clarify and maintain the scientists' primary role of an academic, and preventing their secondary role as being involved in science commercialization from interfering with their primary role as an academic.
Kalar and Antoncic (2015)	1,266 academic scientists associated with universities in the Netherlands, Belgium, Slovenia, and the United Kingdom	Academics' perception of an entrepreneurial university	*Primary theoretical framework:* Unspecified *HO:* Perception of whether one's department is high in entrepreneurial orientation predicts the degree to which he or she will engage in entrepreneurial pursuits as well as the likelihood of believing that technology transfer activities are not detrimental to academic science.
Karlsson and Wigren (2012)	7,260 university employees in Sweden	Business start-up	*Primary theoretical frameworks:* Institutional theory, human capital theory, knowledge spillover theory *HC:* Individuals with previous experience helping a colleague to start a firm are more likely to start a firm in the future than those without such experience. *SC:* Persons who have relationships with new product development teams, involvement in contract research, and participation in research with individuals employed outside of the university are more likely to start a new business than those who do not. *DC:* Females were less likely to have started a firm than males. Older individuals are less likely to start firms than are younger persons.
Karnani (2013)	148 founders of spin-offs from German universities	Types of start-ups and knowledge base	*Primary theoretical framework:* Theory of tacit knowledge *SC:* The majority of academic spin-offs (55%) develop their businesses by drawing from university knowledge that is not directly related to the research findings of scientists. Therefore, science commercialization accounts for only a portion of the spin-outs that come from universities.
Knockaert, Foo, Erikson, and Cools (2015)	251 doctoral and postdoctoral researchers based at a university in Norway	Growth intentions	*Primary theoretical framework:* Social cognitive theory *HO:* Having a planning cognitive style (i.e., holding a preference for structure, control, and routines) is positively related to entrepreneurial growth intentions, whereas having a knowing cognitive style (i.e., holding a preference for logic, objectivity, and precision) is negatively related to such intentions. *DC:* Female scientists have lower entrepreneurial intentions than male scientists.
Krabel and Mueller (2009)	2,604 scientists associated with the Max Planck Society	Engagement in starting a business (are they nascent entrepreneurs?)	*Primary theoretical framework:* Unspecified *HC:* Prior entrepreneurial experience and having previously filed for a patent are positively related to nascent entrepreneurial activity (i.e., involvement in applying for financing, seeking venture capital, writing a business plan, searching for office space, or building a new venture team). *DC:* The gender of scientists in not related to being a nascent entrepreneur. The age of scientists is negatively related to being a nascent entrepreneur.
Krabel, Siegel, and Slavtchev (2012)	2,604 scientists associated with the Max Planck Society	Engagement in starting a business (are they nascent entrepreneurs?)	*Primary theoretical framework:* Unspecified *SC:* Foreign-born and foreign-educated scientists are more likely to be engaged in the process of starting a new business than are their native-born and native-educated counterparts.

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
Lam (2011)	36 scientists were interviewed and 734 scientists completed an online survey. Participants were from five major research universities located in the United Kingdom.	Source of motivation for involvement in science commercialization	*Primary theoretical framework:* Self-determination theory *HO:* Academic scientists were categorized into three general categories: traditional scientists, hybrid scientists, and entrepreneurial scientists. Traditional scientists were reluctantly involved in science commercialization and primarily motivated by the opportunity to obtain research funding that could be used to further their academic reputations. Hybrid scientists were more willingly involved in science commercialization, had a greater level of intrinsic interest for such activities, and perceived such engagement as an opportunity to widen their scientific contributions. Entrepreneurial scientists were primarily motivated by the potential economic gains that they could personally derive from science commercialization.
Landry, Amara, and Saihi (2007)	479 researchers in engineering and 449 researchers in life sciences funded by the Natural Sciences and Engineering Research Council of Canada (NSERC)	Number of patents	*Primary theoretical framework:* Resource-based theory of the firm *SC:* Academic researchers in the life sciences who have linkages with market participants are more likely to be engaged in patenting and the creation of a new venture than are those who do not; however, the same relationships are not found for academic researchers in engineering. *DC:* Males in both life sciences and engineering are more likely to be involved with the creation of a spin-off than are females in these fields.
Link and Ruhm (2013)	63 high-potential young international inventors (under age the age of 35) from universities, large and small businesses, and government laboratories	Patenting behavior	*Primary theoretical framework:* Life course perspective *SC:* The patenting behavior of "high-potential" inventors is similar to that of their fathers.
Lissoni (2010)	185 Italian academic inventors	Network ties among academic inventors	*Primary theoretical framework:* Social network theory *SC:* Only a few academic inventors hold key brokerage positions in which they have strong records of publication and an above-average percentage of their patents held by companies, rather than by their universities. More commonly, academic inventors hold positions as either gatekeeper (i.e., standing between a researcher from industry and a researcher from academia) or a liaison (i.e., standing between a researcher from industry and a student).
Lockett, Kerr, and Robinson (2008)	14 academics, 18 small business owner–managers, and 21 non-academics who included intermediaries, brokers situated within and outside university structures, and large companies who were based in the communities near Lancaster University	Barriers to knowledge transfer between higher education institutions and universities and individual motives for engaging in such activities	*Primary theoretical framework:* Unspecified *HO:* Barriers to knowledge transfer between universities and industry included a lack of time, differences in the perception of time (e.g., how long it should take for a research project to be completed), uncertainty as to who will own the right to any intellectual property generated by such interactions, the fear that academics are viewed by industry as weird and disconnected, and perceptions that technology transfer is not state of the art. Academics feel there is a lack of incentives (e.g., publications tend to be rewarded more than anything else) to engage in knowledge transfer between universities and industry, and there is a perception of knowledge transfer being a third mission that rates below the other missions of teaching and research, which diminishes motivation to engage in such activities.

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
Lowe and Gonzalez-Brambila (2007)	150 faculty entrepreneurs who founded firms between 1990 and 1999. Only full-time university faculty; excludes firms founded by students, postdoctorates, and university staff	Research productivity	*Primary theoretical framework:* Unspecified *HO:* Faculty members who found firms are, on average, more productive researchers than their nonentrepreneurial peers.
Moog, Werner, Houweling, and Backes-Gellner (2015)	480 life sciences researchers in Switzerland and Germany	Propensity to become self-employed	*Primary theoretical framework:* Lazear's jack-of-all-trades theory *HC:* Academic scientists with more balanced and diverse skill sets have greater intentions to start a new venture, but only when their time is balanced across a wide range of work-related activities (i.e., teaching, academic administration, research, noncommercial use of research, commercial use of research, development of new research projects, and other type of work activity) and if they work regularly with peers who have entrepreneurial experience. *SC:* Having personal connections with entrepreneurial peers is a positive moderator of the relationship of academic scientists' human capital (i.e., having a diverse and balanced skill set) with their entrepreneurial intentions. *DC:* Female academic scientists view science commercialization through new venture creation as being less appealing than do their male counterparts. The age of academic scientists is negatively related to their entrepreneurial intentions.
Mosey and Wright (2007)	24 academic scientists	Social capital development	*Primary theoretical frameworks:* Human capital theory, social capital theory *HC:* Entrepreneurial experience is an important factor for helping academic scientists to build relationships with experienced managers and potential investors who can help them to better perform critical activities related to developing their products/services and launching a new business.
Nelson (2014)	17 individuals with 11 individuals involved with science commercialization at Stanford University	Organizational context influence on decision to become an entrepreneur	*Primary theoretical framework:* Unspecified *HO:* Engagement in entrepreneurial activities is more likely for scientists working among archetypal researchers who are involved in such activities as compared to those who do not work with such persons.
O'Gorman, Byrne, and Pandya (2008)	Two case studies of scientists at a university in Ireland, seeking assistance from the university's TTO to commercialize new knowledge they had created	Role of TTO and of incubation in firm emergence	*Primary theoretical framework:* Knowledge spillover theory of entrepreneurship *SC:* Having contact with individuals possessing market knowledge is essential for scientists' ability to recognize opportunities for engaging in science commercialization. *HO:* The potential to gain research funding and academic promotion is the primary motive for academic scientists to engage in entrepreneurial activities. When academic scientists seek external market information, they communicate new knowledge externally that enables market participants and potential resource providers to learn from them (i.e., they open up channels for reciprocal learning to take place).
O'Kane, Mangematin, Geoghegan, and Fitzgerald (2015)	63 TTO management personnel	TTO legitimacy building	*Primary theoretical framework:* Identity theory *HO:* TTO officials attempt to shape the identities of their office to align with two different agents that may have conflicting expectations of their roles, academics (i.e., faculty scientists) and management (academic administration). In so doing, such persons attempt to build the legitimacy of their office by emphasizing the sameness (e.g., demonstrating similarity regarding how their mission aligns with

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
			the goals of faculty and norms of science) and uniqueness (e.g., demonstrating how they add differentiated value to university stakeholders) of these dual identities. Efforts by TTO officers to build legitimacy and shape the identity of their office can, however, become muddied by the competing logics of university science commercialization (e.g., advance the creation of new knowledge versus appropriate economic value) and, therefore, make it difficult to establish legitimacy with any one group.
Padilla-Meléndez, Del Aguila-Obra, and Lockett (2013)	18 individuals in Spain who were involved in knowledge transfer between universities and academic spin-offs	Challenges to knowledge transfer between universities and industry partners	*Primary theoretical framework:* Social capital theory *SC:* Recognition, timescale, and intellectual property contracts are key challenges to knowledge transfer between universities and industry partners.
Patzelt and Shepherd (2009)	98 academic entrepreneurs	Academic entrepreneurs' assessment of the usefulness of the policy programs for firm development	*Primary theoretical framework:* Goal-setting theory *HO:* Access to funding is a critical factor in the decision of academic scientists to pursue entrepreneurial activities, but mainly so as to provide resources (e.g., hiring other people to help to run the business) that can be used to offset the risk of being pulled away from their regular academic roles as scientists and to reduce the professional cost of engaging in science commercialization.
Rasmussen (2011)	49 participants located in Norway who were in various positions, including company founders and entrepreneurial team members, researchers, university managers, people involved in commercialization support, and industrial partners	Differences in social capital and motivation for academic scientists across different stages of the entrepreneurial process	*Primary theoretical framework:* Process theory *SC:* Industry contacts and interactions with potential users were crucial to developing the experience, networks, and competence of founders. *HO:* Motivations to start a venture were varied and influenced by the focus of the firm's development. The academic entrepreneurs altered their strategy and focus as the firm developed. At first, such persons identified themselves more as professors than as entrepreneurs, but as they became more committed to their role as founders their identity shifted toward being more entrepreneurs.
Rasmussen, Mosey, and Wright (2015)	54 individuals in the United Kingdom and Norway who were company founders and entrepreneurial team members, researchers, university managers, and people involved in the support of commercialization	Types of social capital that contribute to the attainment of various entrepreneurial competencies	*Primary theoretical framework:* Network theory *SC:* Weak ties with industry actors are useful for academic entrepreneurs to develop opportunity refinement competencies, while subsequently developing these weak ties into strong ties. Strong ties with industry actors are useful for academic entrepreneurs to develop resource acquisition and championing competencies, while developing new weak ties to further develop these competencies into the future.
Renault (2006)	98 professors at 12 Southeastern U.S. universities	Entrepreneurial actions by faculty	*Primary theoretical frameworks:* Mertonian theory of science, evolutionary model of university transformation, institutional policy perspective *SC:* Financial incentives and institutional support are positively associated with university researchers' intentions to create a spin-off firm.
Rizzo (2015)	Eight case studies of Italian start-ups (or academic spin-offs) with academic entrepreneurs involved in the founding team	Contextual factors of academic spin-offs	*Primary theoretical framework:* Unspecified *HO:* New-venture development can act as an alternative pathway for young scientists to advance in their fields without having to deal with the challenges associated with career progress within a bottlenecked university system.

TABLE 1
(Continued)

Study	Sample	Outcomes	Primary Theoretical Framework(s), Topics, and Key Findings
Rosa and Dawson (2006)	173 academic (co)founders of university spin-outs (study part 1), 4 academic scientists and 14 respondents identified in study 1 (study part 2); all participants based in the United Kingdom	Representation of female academic scientists founding university spin-outs, gender differences in motivation for starting a university spin-out, gender differences in challenges faced when launching a university spin-out	*Primary theoretical framework:* Human capital theory *DC:* Only 10.6% of academic scientists who found university spin-outs are female. The main problem relating to the underrepresentation of women appears to be a lack of females heading research teams based in leading science and engineering departments. Once starting a university spin-out, female academic scientists report difficulties balancing work and family life, as well as a lack of commercial skills. Both males and females reported difficulties acquiring funding and challenges dealing with their universities regarding technology transfer.
Shane, Dolmans, Jankowski, Reymen, and Romme (2015)	239 TTO officers	What dissuades inventors from starting a company, recommendation for university venture capital fund	*Primary theoretical framework:* Representativeness heuristic *HC:* TTO officers apply a representativeness heuristic to select academic inventors who they feel have high potential for science commercialization based on having “typical” entrepreneurial characteristics—such as being a male, having an Asian name, and possessing industry work experience.
Toole and Czarnitzki (2009)	213 academic entrepreneurs in the population of NIH SBIR PIs	Research success (winning Phase II SBIR funding) and invention success (patenting) at the firms	*Primary theoretical framework:* Human capital theory *HC:* Academic scientists’ contributions to the patent productivity of firms decreases with the depth of their scientifically related human capital.
Wu, Welch, and Huang (2015)	675 inventors. 2010 National Survey on Intellectual Property in Academic Science and Engineering	Likelihood that a patent will be licensed	*Primary theoretical framework:* Unspecified *SC:* The degree to which inventors collaborate with industry researchers is a positive predictor of such persons holding a favorable attitude toward science commercialization.

that should be made regarding the outcomes covered in our review. First, we define participation in science commercialization as engagement in one or more of a broad range of activities relating to the development and exploitation of intellectual property (e.g., patenting, licensing, new venture creation). Second, the performance (or success) of science commercialization is considered for the purposes of our review to include the extent to which such activity results in productive outcomes for one or more principal stakeholders. Productive outcomes are considered to be economic (e.g., licensing revenue) and/or noneconomic (e.g., enhanced work satisfaction of academic scientists). Principal stakeholders are defined as including academic scientists and their universities.

We now review and integrate findings within each of these topic areas, highlighting patterns of consistency and divergence. In so doing, we begin our review of each topic area with a focus on our first research question regarding participation in science commercialization, and then—to the extent to which relevant findings are available, and denoted with "(RQ2)"—we consider our second research question regarding associated performance outcomes.

Human Capital

Human capital comprises the personal knowledge, habits, personality attributes, skills, and abilities that are developed through investments in education, training, and other kinds of experience that can aid in creating social and economic value (Becker, 1964; Wright, Hmieleski, Siegel, & Ensley, 2007). The human capital of academic scientists has been one of the most commonly examined topics in recent studies aimed at predicting the involvement and performance of such persons in science commercialization. Our review of this literature found that the most common sources of human capital examined were entrepreneurial experience, having an applied versus basic research focus, and number of publications and citations.

Entrepreneurial experience. Prior entrepreneurial experience has been one of the most widely studied predictors of engagement in entrepreneurial activity within the mainstream entrepreneurship literature, as such experience tends to increase individuals' confidence in their ability to perform the roles and tasks of entrepreneurship (Hao, Seibert, & Hills, 2005). It is therefore not surprising that this variable has also received considerable attention within the literature focused on the entrepreneurial behavior of academic scientists. Generally, the findings of such studies have identified a positive relationship between entrepreneurial experience and science commercialization. For example, results of a qualitative study by Mosey and Wright (2007) found that having prior entrepreneurial experience is important for helping academic scientists build relationships with experienced managers and potential investors who can help them perform critical activities related to developing their products/services and launching a new business. Another study (Clarysse, Tartari, & Salter, 2011) found that previous entrepreneurial experience was positively related to the involvement of academic scientists in a new venture as either a director or cofounder. Similarly, Krabel and Mueller (2009) found both prior entrepreneurial experience and having previously filed for a patent to be positively related to the nascent entrepreneurial activity of university researchers (e.g., involvement in applying for financing, seeking venture capital, writing a business plan, searching for office space, or building a new venture team). Still further, academic scientists who have had previous experience helping a colleague start a firm are more likely to themselves start a firm in the future (Karlsson & Wigren, 2012). Finally, a study by Hoye and Pries (2009) found 12% of science faculty members to be "repeat commercializers" (i.e., they demonstrate a similar pattern of behavior to habitual entrepreneurs) and that these individuals were responsible for 80% of innovations commercialized at their universities. Overall, these findings suggest that prior experience in entrepreneurial endeavors is of particular importance for predicting participation in science commercialization.

Research findings regarding the relationship between the entrepreneurial experience and entrepreneurial performance of academic scientists have proven to be more precarious. For example, research by Criaco, Minola, Migliorini, and Serarols-Tarres (2014) found that university-based start-ups tend to survive longer when their founders have an entrepreneurial education (i.e., a degree in entrepreneurship or business) and university work experience as a professor or researcher, but that prior start-up experience is negatively related to firm survival (RQ2). The authors explained that start-up experience may not be advantageous for survival if the entrepreneur is repeating the same mistakes. Overall, it appears that entrepreneurial experience is associated with academic scientists' involvement in entrepreneurial endeavors, yet the relationship of such experience to performance is less certain and perhaps not directly linked (e.g., it may be curvilinear or depend on contextual moderating variables).

Applied research experience. Another aspect of human capital that has garnered recent research attention is whether having a primary focus on applied versus basic research relates to academic scientists' level of engagement in commercialization activities. For example, one study found academic scientists working on applied research to be significantly more likely to become inventors than their colleagues who mainly conduct basic research (Calderini, Franzoni, & Vezzulli, 2007). Similarly, research by Glenna, Welsh, Ervin, Lacy, and Biscotti (2011) found the acquisition of industry funding by scientists to be positively associated with applied, as opposed to basic, research. Even though such funding may prove beneficial to scientists conducting applied research, these authors argue that this relationship may represent a bias against industry funding for basic research and potentially skew research agendas.

More recent research found that scientists who are engaged in applied research and those with prior entrepreneurial experience are more likely to engage in science commercialization activities that fall outside of regular university channels (Abreu & Grinevich, 2013). Thus, academic scientists who focus on applied research (particularly those with prior entrepreneurial experience) may be more likely to engage in forms of science commercialization that their universities are less easily able to appropriate value from as compared to their counterparts who are focused on basic research. Training in technology transfer may, however, help to overcome such issues. In support of this point, a study (Bercovitz & Feldman, 2008) found that scientists whose graduate training included learning about science commercialization processes were more likely to disclose inventions to their university's technology transfer office (TTO).

In addition to the propensity for patenting and engaging in licensing activities, a focus on applied research also appears to be related to the likelihood of being involved in a start-up. For example, a study by Fritsch and Krabel (2012) found the pursuit of entrepreneurial business opportunities to be more attractive to academic scientists working in applied research areas in which commercialization is common, as opposed to those who are focused on basic research in which commercialization is less frequent. The authors failed to observe a relationship between patenting experience and interest in entrepreneurial endeavors. In sum, there appears to be accumulating evidence that having a focus on applied, rather than basic, research is associated with engagement in patenting and licensing activities (even if outside of university channels). Furthermore, a positive association between having an applied research focus and being involved in entrepreneurial start-up activity is also empirically supported in the literature, albeit with few studies from which to draw conclusions.

Experience publishing and gaining citations. The final area in which we identified a number of studies on the human capital of academic scientists has to do with research examining the relationship of publications and citations to science commercialization. For example, Alshumaimri, Aldridge, and Audretsch (2012) found the number of publications to be positively related to academic scientists' intentions to start a new firm. Similarly, research has shown that academic scientists with greater numbers of publications and citations are more likely to be involved in business founding and business advising activities; these authors also found patent count to be positively related to such activities (Ding & Choi, 2011).

Other studies considering publications and citations have, however, led to different (or even contradictory) results. One example is a study by Aldridge and Audretsch (2011). Their results found no significant relationship between the number of citations per publication and the propensity of scientists to become entrepreneurs. In addition, a study by D'Este, Mahdi, Neely, and Rentocchini (2012) found scientific excellence (defined by the number of citations per publication) to be more positively related to the discovery of technological entrepreneurial opportunities than to the exploitation of such opportunities. Moreover, these authors found the breadth of scientific research (i.e., the degree to which the individual conducted research across multiple disciplines) to be positively related to the exploitation of entrepreneurial opportunities but unrelated to the discovery of such opportunities. Therefore, in sum, even though the relationship of publications and citations might not be clearly (or directly) linked with entrepreneurial activity, such forms of human capital do appear to be related to the discovery of opportunities that hold the potential for commercialization.

Other human capital research. Recent literature on academic scientists has also examined some additional forms of human capital, but there are fewer studies from which to draw patterned conclusions. One example is breadth of human capital. For example, one recent study found academic scientists with more balanced and diverse skill sets to have greater intentions to start a new venture, but only when their time was balanced across a wide range of work-related activities (i.e., teaching, academic administration, research, noncommercial use of research, commercial use of research, development of new research projects, and other types of work activity) and when they worked with peers who had entrepreneurial experience (Moog, Werner, Houweling, & Backes-Gellner (2015). Research has also explored the depth of academic scientists' human capital with respect to science commercialization. For instance, a study by Toole and Czarnitzki (2009) found that academic scientists' contributions to the patent productivity of firms decreased with the depth of their science-related human capital.

Other research has investigated what is considered to be prototypical human capital for academic scientists who engage in entrepreneurial activities. As an example, research by Shane, Dolmans, Jankowski, Reymen, and Romme (2015) found that TTO officers tend to apply a representativeness heuristic to select academic inventors they feel have high potential for science commercialization based on having "typical" entrepreneurial characteristics—such as being male, having an Asian name, and possessing industry work experience. Presumably, such characteristics are viewed as markers of useful human capital for science commercialization.

Finally, a study by Grimpe and Fier (2010) found that scientists who spend more time at institutions abroad are able to expand their human capital in ways that make them more likely to engage in technology transfer back in their home country as compared to those who spend less time abroad. Further research is needed to determine more precisely how such variations in context shape the human capital of academic scientists in ways that may increase their participation (and effectiveness) in science commercialization.

Social Capital

Social capital consists of the benefits that individuals are able to gain from their networks, social structures, and memberships to be marshaled toward the creation of social and economic value (Hmieleski, Carr, & Baron, 2015; Lin, Cook, & Burt, 2001). The social capital of academic scientists has been another frequently examined topic in research attempting to predict the involvement of such persons in technology transfer activities. Our review of this literature found industry linkages, entrepreneurial connections, relationships with TTOs, international ties, network structures, institutional support, and social barriers to be the most commonly studied issues related to social capital.

Industry linkages. Having industry contacts has been one of the most consistently identified sources of social capital to be associated with academic scientists' involvement in technology commercialization activities, and in particular with founding a new business. For example, a study by Wu, Welch, and Huang (2015) identified collaboration with industry researchers as being a positive predictor of academic scientists having a favorable attitude toward science commercialization. Similarly, research by Fritsch and Krabel (2012) found partnering with corporations on research to be positively related to the perceived attractiveness of starting a new business for academic scientists. In addition, a study by Rasmussen (2011) found that having contacts and interactions with industry was crucial for developing the personal competencies, networks, and experience levels of academic scientists who were attempting to create new ventures. A study by Rasmussen, Mosey, and Wright (2015) identified the importance of industry linkages for academic scientists who are engaged in the start-up process. Specifically, the findings of their research suggest that having weak ties with industry actors is useful for academic scientists to develop opportunity refinement competencies, whereas having strong ties with industry actors is useful for developing resource acquisition and championing competencies. Further, a qualitative study by O'Gorman, Byrne, and Pandya (2008) found that having contact with those possessing market knowledge was essential for academic scientists to recognize opportunities for engaging in science commercialization.

As previously noted, industry connections have also been linked to the propensity to engage in business founding. For example, research by Landry, Amara, and Saihi (2007) found having linkages with market participants to be positively related to patenting and the creation of new ventures for university researchers in life science, but not for those in engineering. Presumably, because engineering is an applied discipline, industry linkages may provide more redundant information for researchers in this field than for those in the life sciences. Additional support for this pattern of findings is provided by Aldridge and Audretsch (2011), whose research found scientists' linkages with corporations and industry copublications to be positively related to their propensity for becoming entrepreneurs. Similarly, a study by Aldridge, Audretsch, Desai, and Nadella (2014) found membership on a corporate scientific advisory board to be positively associated with the likelihood that academic scientists will start a new business. This finding, however, is in contrast to research by Alshumaimri and colleagues (2012) that found that belonging to a corporate board is not related to the likelihood that academic scientists will become involved in entrepreneurial activities. Finally, a study by Karlsson and Wigren (2012) found relationships with new-product development teams, involvement in contract research, and participation in research with persons employed outside of the university to be related to the likelihood that academic scientists will start a new business.

Entrepreneurial connections. The degree to which academic scientists have connections with entrepreneurs is another source of social capital that has been identified in recent research as being associated with commercialization activities. For example, research by Moog and colleagues (2015) found having personal connections with entrepreneurial peers to positively moderate the relationship of human capital (i.e., having a diverse and balanced skill set) with entrepreneurial intentions for academic scientists. Moreover, a study by Ding and Choi (2011) found that having network ties with a coauthor who has founded a business significantly increases the odds of an academic scientist founding a new firm. Similarly, research has shown that academic scientists who have a parent who was an entrepreneur are more likely to found a business (Haeussler & Colyvas, 2011), and that academic scientists' patenting behaviors are similar to those of their fathers (Link & Ruhm, 2013).[2] Overall, the results of these studies suggest the presence of a consistent positive association between entrepreneurial social capital and the engagement of academic scientists in a broad range of science commercialization activities.

Relationships with TTOs. As TTOs are increasingly becoming the main conduit through which science commercialization occurs at most universities, the relationships between such units and academic researchers have been the focus of recent studies regarding individual patenting and start-up behavior. For example, a study by Aldridge and Audretsch (2010) found that university scientists who failed to utilize TTOs and instead selected a backdoor route to science commercialization that did not involve assigning patents to their institutions tended to start new firms as a means of technology transfer. In contrast, those who decided to work with TTOs and assign patents to their institutions more often selected licensing as a form of technology transfer. A later study by Aldridge and Audretsch (2011) found no significant relationship between resource availability from TTOs (in terms of number of TTO employees and number of TTO employees dedicated to licensing divided by the number of administrative employees) and scientists' propensity to become entrepreneurs. Based on these findings, it appears that social capital derived through relationships with TTOs may be more useful to academic scientists with respect to the licensing of technology rather than the creation of new firms. Nonetheless, much work remains to be done to develop a more complete understanding of the variety of relationships and behavioral patterns among scientists, TTOs, and industry partners.

Importantly, research has found that many university spin-outs do not draw from knowledge based in the empirical findings of academic scientists. For example, a study by Karnani (2013) found that the majority of academic spin-outs[3] (55%) develop their businesses using university knowledge that is not directly related to the research of scientists (RQ2). Thus, science commercialization accounts for only a portion of university spin-outs. This finding suggests that there are other forms of knowledge, beyond that which results from scientific discovery, within universities that TTOs and other university entities (e.g., incubators, accelerators) might work to codify to create more spin-outs.

International ties. There is also some evidence that international ties serve as a source of social capital that may be related to science commercialization by university researchers. For example, a study by Krabel, Siegel, and Slavtchev (2012) found that foreign-born and foreign-educated scientists are more likely to be engaged in the process of starting a new business than their native-born and native-educated counterparts. The authors propose that such relationships are likely due, in part, to broader social capital that such persons have built through their international experiences. Somewhat similarly, academic scientists who spent more time at institutions abroad were more likely to engage in technology transfer back in their home countries (Edler, Fier, & Grimpe, 2011). These authors argue

[2] None of the mothers of the inventors held a patent, which is why only fathers' patent behavior was relevant to the study's findings.

[3] The authors refer to them as "spin-offs" in the article.

that this finding is evidence of "brain circulation," in that the diversity of the knowledge academic scientists gain from their experiences abroad and through the development of diverse social connections provides valuable insights to help such persons to engage in technology transfer activities.

Network structures. The structures from which academic scientists draw their social capital has also been a topic of research in the recent literature on science commercialization. For example, a study by Lissoni (2010) found that only a few academic inventors hold key brokerage positions. Such persons possess strong records of publication, and an above-average percentage of their patents are held by companies rather than by their universities. Further, Lissoni (2010) found that, more commonly, academic inventors hold positions as either gatekeeper (i.e., standing between a researcher from industry and a researcher from academia) or a liaison (i.e., standing between a researcher from industry and a student). Other research has found that inventors tend to hold denser network ties and have more redundant links than noninventors (Forti, Franzoni, & Sobrero, 2013). Taken together, the findings of these studies suggest that the nature (or structure) of university scientists' connections to others, in addition to their overall amount of certain sources of social capital, may be important factors to consider with respect to science commercialization.

With respect to science commercialization outcomes, one study (Agrawal, 2006) found that licensing strategies directly involving the inventor enhanced the likelihood that the invention would be commercialized and increased the amount of royalties generated (RQ2). In addition, a qualitative study (O'Gorman et al., 2008) found that when academic scientists seek external market information, they open up channels for reciprocal learning by communicating new knowledge externally and enabling market participants and potential resource providers to learn from them (RQ2). Finally, a network study (Casper, 2013) found connections linking industry and academic scientists to be associated with increased university science commercialization (RQ2). Moreover, the characteristics of the regional environment influenced the degree to which industry networks were available for university scientists to make such linkages.

Institutional support. Institutions vary in terms of support provided for commercialization activities. Evidence of the need for universities to provide aid to academic scientists in order for them to engage in science commercialization can be found in a study by Renault (2006), which identified financial incentives and institutional support as being associated with the intentions of academic scientists to create a spin-off firm. In addition, research by Abreu and Grinevich (2013) found that universities that place greater weight on business or commercial activities have fewer research faculty and staff engaged in informal, noncommercial activities that take place outside of formal university channels. Therefore, support for science commercialization can help to encourage engagement in technology transfer activities and build conformance with university expectations regarding norms for science commercialization. This point is particularly important in light of other research (Lockett, Kerr, & Robinson, 2008) that investigated barriers to engagement in collaborative technology transfer arrangements between universities and industry partners. Their findings indicate that academic scientists frequently perceive publications to be more highly rewarded than technology transfer engagement, and feel that the notion of science commercialization as being a "third mission" of the university suggests that it rates below the other more primary missions of teaching and research—thus diminishing interest in engaging in such lesser valued activities.

Social barriers. Research has identified several potential barriers that may inhibit activities, particularly learning and knowledge transfer, from occurring between academic scientists and industry partners who are engaged in science commercialization activities. For example, a qualitative study found such barriers to include a lack of available time, differences regarding the perceived amount of time needed to complete a research project in an academic versus corporate setting (e.g., how long it should take for a research project to be completed), and uncertainty as to who will own the rights to any intellectual property generated by such partnerships (Lockett et al., 2008). Another study similarly found that key challenges hampering active science commercialization partnerships between academic scientists and industry partners include lack of recognition, timescale differences between academia and industry, and concerns over ownership of intellectual property (Padilla-Meléndez, Del Aguila-Obra, & Lockett, 2013) (RQ2).

Heterogeneous Objectives

An increasing amount of research within the mainstream entrepreneurship literature has found aspiring business founders to be motivated by a broad range of objectives beyond purely financial gain (Baker & Pollock, 2007; Hmieleski & Lerner, 2016; Powell & Baker, 2014). Similarly, recent research on academic scientists has observed that such persons also tend to possess a broad array of objectives relating to their interest in engaging in commercialization activities. Our review of this literature found that the most commonly studied sources of heterogeneous objectives are academic advancement, professional identity, and social cognitive mechanisms.

Academic advancement. One of the more widely studied topics in recent literature on science commercialization involves myriad attempts to incentivize academic scientists to engage in university technology transfer. Within this stream of research, the most frequently investigated topic involves whether academic scientists are primarily driven by academic accolades or financial gain. For example, research by Fini, Grimaldi, and Sobrero (2009) found that the decision by academic scientists to start a business is most positively related to expectations that they will identify new research projects, gain an enhanced reputation and status as a prominent academic, generate grant (or other funding) opportunities for research assistants and doctoral students, or acquire new facilities or other types of infrastructure for conducting academic research. Similarly, a study found the desire to enhance one's academic reputation to be more strongly associated than expectations for personal financial gain with the patenting activity of academic scientists (Goktepe-Hulten & Mahagaonkar, 2010). Additional evidence supporting this pattern of findings can be found in a qualitative study by O'Gorman and colleagues (2008); the results of this research identified the potential to gain research funding and academic promotion to be the main reasons for wanting to engage in entrepreneurial activities.

Therefore, financial outcomes do appear to be of importance to academic scientists, but generally as a secondary factor that is viewed as useful for the purpose of supporting their research agendas. Additional evidence for this point is demonstrated by the research findings of Patzelt and Shepherd (2009), who identified access to funding as a critical factor in the decision of academic scientists to pursue entrepreneurial activities, but mainly to provide resources (e.g., hiring other people to help to run the business) that could be used to offset the risk of being pulled away from their regular academic roles as scientists and reduce the professional cost of engaging in science commercialization. Lam (2011) undertook a slightly more nuanced investigation of this issue; the findings of her mixed-methods study suggest that academic scientists fall into three general categories—traditional scientists, hybrid scientists, and entrepreneurial scientists—and that each type has a different set of reasons for participating in technology transfer activities.

A study by Lowe and Gonzalez-Brambila (2007) identified faculty members who founded firms as being, on average, more productive researchers than their nonentrepreneurial peers (RQ2). The findings of this study suggest that the "third mission" of universities with respect to science commercialization may actually help to advance their primary objectives with regard to conducting scientific research and disseminating knowledge.

Finally, in countries in which there may be few opportunities for the advancement of young university researchers, science commercialization may provide an additional way for such persons to maintain progress toward achieving their academic-related goals outside of a traditional university setting. For example, a study by Rizzo (2015) observed that new venture development can act as an alternative pathway for young scientists to advance in their fields without having to deal with the challenges associated with career progress in a university system. The findings of this study provide yet further evidence that scientists primarily wish to obtain academic-related achievements, even if making progress toward such outcomes takes them outside of the traditional university setting.

Professional identity. The findings noted in the previous section allude to the desire of scientists to maintain their professional identity—the beliefs, conceptions, expressions, and qualities that classify a person as being a member of a particular occupational group (Tajfel, 1978)—as a traditional academic rather than as a businessperson. Qualitative research by Jain and colleagues (2009) provides evidence supporting this point. The findings of their study indicate that scientists develop hybrid professional identities centering primarily on the role of being a traditional academic involved in research and teaching, and secondarily on the role of being a businessperson involved in commercialization.

Additional research has considered how the professional identity of TTO personnel may influence their ability to successfully engage faculty in the science commercialization process. For example, recent research has found that TTO management personnel attempt to shape the identities of their office to align with two different agents who may have conflicting expectations of their roles: academics (i.e., faculty scientists) and management (academic administration) (O'Kane, Mangematin, Geoghegan, & Fitzgerald, 2015). In so doing, such persons attempt to build the legitimacy of their office by emphasizing the sameness (e.g., demonstrating similarity regarding how their mission aligns with the goals of faculty and norms of science) and uniqueness (e.g., demonstrating how they add differentiated value to university stakeholders) of these dual identities. The authors found, however, that efforts by TTO officers to build legitimacy and shape the identity of their office can become muddied by the competing logics of university science commercialization (e.g., advancing the development of new knowledge versus creating appropriate economic value) and, therefore, make it difficult to establish legitimacy with any one group. As an alternative approach the authors suggest that TTO officers should aim to create a single shared or collective identity within the university that is broader and more coherently builds legitimacy with all stakeholders through a unified set of expectations regarding their role. This would presumably give university scientists greater motivation to work with them on commercialization activities because doing so would be viewed as less of a threat to their ability to uphold their professional identity as academics.

Finally, a study by Rasmussen (2011) found that the identities of academic scientists tend to evolve over time. As the academic scientists in the study initially became involved in launching firms, they maintained professional identities aligned with their academic roles. Yet over time, as they became more involved in the ventures, their professional identities shifted toward that of an entrepreneur. Thus, through involvement in entrepreneurial activities, the professional identities of academic scientists appear to evolve naturally without necessarily needing to be shaped by TTO officers.

Social cognitive mechanisms. Social cognitive aspects of motivation involve the degree to which individuals learn new behaviors either through education or personal experience or from modeling the actions of others, and, in so doing, develop the confidence that they can successfully control and direct their energies toward performing those behaviors on their own or with others (Bandura, 1986). Recent studies on science commercialization have highlighted several aspects of social cognition. For example, a study by Nelson (2014) found engagement in entrepreneurial activities to be more likely for academic scientists working among archetypal researchers who are involved in such activities. In other words, scientists appear to model the behavior of their most prominent colleagues. Somewhat similarly, research by Kalar and Antoncic (2015) found that perceptions of whether one's department was high in entrepreneurial orientation predicted whether an academic scientist engaged in entrepreneurial pursuits as well as the likelihood of believing that technology transfer activities are not detrimental to academic science.

Other research has focused on the confidence of academic scientists to direct their efforts toward performing roles and tasks relating to the pursuit of entrepreneurial outcomes. For example, one study found perceived behavioral control of academic scientists to be positively related to their intentions to engage in entrepreneurial activities (Guerrero & Urbano, 2014). Moreover, a study looking at cognitive style found having a planning cognitive style (i.e., holding a preference for structure, control, and routines) to be positively related to the entrepreneurial growth intentions of academic scientists, whereas having a knowing cognitive style (i.e., holding a preference for logic, objectivity, and precision) was negatively related to such intentions (Knockaert, Foo, Erikson, & Cools, 2015). Finally, research by Huyghe and Knockaert (2015) found the entrepreneurial self-efficacy of academic scientists to be positively associated with their entrepreneurial intentions as well as their engagement in patenting or licensing activities. Taken together, these findings highlight the importance to academic scientists of perceiving that they can exert control over the achievement of their goals regarding science commercialization.

Demographic Characteristics

There has been a considerable amount of research in the mainstream entrepreneurship literature on gender differences, with findings generally indicating that males are more likely to engage in entrepreneurial activities than females (Haus, Steinmetz, Isidor, & Kabst, 2009). This overall finding has been expressed as resulting from males being higher, on average, than females in entrepreneurial self-efficacy (Hao, Seibert, & Hills, 2005), risk propensity (Tan, 2008), diversity of personal networks (Renzulli, Aldrich, & Moody, 2000), and access to financial capital (Alsos, Isaksen, & Ljunggren, 2006). In addition to gender differences, several other demographic characteristics have been examined in recent studies on the propensity of academic scientists to engage in science commercialization. These characteristics include age, time since earning a doctoral degree, and tenure and academic rank.

Gender differences. In the recent literature on science commercialization, research on gender differences in academic researchers' engagement in technology transfer activities has received relatively little attention as a focal topic (for exceptions, see Colyvas, Snellman, Bercovitz, & Feldman, 2012; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007). Many studies in this literature have, however, considered gender as a control variable and therefore provide a number of data points from which to extrapolate general patterns of relationships. In general, results dovetail with those from the mainstream entrepreneurship literature. For example, numerous studies have found that female university researchers view science commercialization through new venture creation to be less appealing than their male counterparts do (Clarysse et al., 2011; Fritsch & Krabel, 2012; Knockaert et al., 2015; Moog et al., 2015). Relatedly, research has found academic scientists who are female to be less likely than those who are male to have actually started a business (Ding & Choi, 2011; Haeussler & Colyvas, 2011; Karlsson & Wigren, 2012; Landry, Amara, & Saihi, 2007). A study by Rosa and Dawson (2006) similarly found academic scientists who are female to be underrepresented—with only 10.6% of university spin-outs being led by women. Follow-up surveys with 14 academic scientists (eight females and six males) leading spin-outs indicated that the underrepresentation of females as entrepreneurs may be partly due to the lack of representation of women among heads of research teams in leading departments of science and engineering.

A parallel pattern regarding the underrepresentation of women appears in studies that have considered the patenting behavior of academic scientists. For example, one study found that female scientists file fewer invention disclosures and gain fewer patents than male scientists (Goel & Goktepe-Hulten, 2013), while male scientists are more likely than female scientists to engage in informal technology transfer, specifically the commercialization of technology and consulting activities (Grimpe & Fier, 2010). Moreover, a study by Abreu and Grinevich (2013) found that male academics are more likely than female academics to be involved in informal, noncommercial activities that occur outside of formal university channels. Gender differences in patenting behavior might be partly explained by the findings of Fox and Xiao (2013), whose study of female academic scientists found that entrepreneurial activity was not related to promotion in academic rank. In addition, these authors found that reward structures perceived by females as supporting entrepreneurial activity negatively predicted such persons' perceived odds of being promoted. Therefore, females may presumably be less likely to engage in patenting due to fears that it will adversely affect their odds of advancing in their academic careers.

Even though several studies have found that females have a lower propensity than males to engage in start-up and patenting behavior, other research has not found such gender difference. One study found no gender differences in whether academic scientists were considering starting a new business (Alshumaimri et al., 2012), while another study failed to find any gender differences in the likelihood of university researchers being nascent entrepreneurs (Krabel & Mueller, 2009). With respect to patenting behavior, a study by Aldridge and Audretsch (2011) found no gender differences in the propensity of academic scientists to start businesses. Thus, patenting technology could be a "leveling event" that filters out potential gender differences in the desire to engage in start-up activities.

Moreover, research by Colyvas and colleagues (2012) found that female academic scientists were significantly less likely than their male counterparts to disclose inventions, but that this relationship went away after controlling for academic rank, publication record, and history of research funding. Similarly, these authors also found no gender differences with respect to the success of science commercialization (i.e., the extent to which patent disclosures led to licensing agreements) once these same controls were included. Overall, it appears that there is a general pattern of gender differences in academic scientists' engagement in science commercialization activities, but that such differences are complex and potentially dependent on a wide range of contextual moderating factors. For these reasons, future research is needed to more broadly explore the multifaceted nature of gender differences among academic scientists.

Age. Research that has considered the age of academic scientists has been mixed with respect to how this characteristic relates to patenting and start-up behaviors. Research in support of age as a positive factor includes one study (Goel & Goktepe-Hulten, 2013) that found the age of scientists to be a positive predictor of invention disclosures and patents;

another study using a sample of 60 academic scientists who are patentees (Grimm & Jaenicke, 2012) found the age of scientists to be positively related to possessing an entrepreneurial attitude.

Yet other research on age has identified null or negative findings. For example, one study (Aldridge & Audretsch, 2011) found no relationship between the age of scientists and their propensity to become entrepreneurs. On the more negative side, another study (Krabel & Mueller, 2009) found age to reduce the probability of being a nascent entrepreneur. Similarly, researchers have found the age of the scientist to be negatively related to entrepreneurial intentions (Moog et al., 2015), while another study found academic scientists who are older to be less likely to start a business (Karlsson & Wigren, 2012). Taken together, the results of these studies point to the need to examine contextual factors and/or potential curvilinear relationships that might help to make sense of the association between the age of academic scientists and their propensity to engage in technology transfer activities.

Time since earning a doctoral degree. Recent research regarding the amount of time since an academic scientist earned his or her doctoral degree has provided more consistent results than those noted above relating to age. For example, years since last degree was earned was found to be negatively related to patent disclosures filed by academic scientists (Bercovitz & Feldman, 2008), while academic scientists who had more recently completed their doctoral degrees were found to be more entrepreneurial than their more senior counterparts (Alshumaimri et al., 2012). Similarly, university researchers who start businesses to commercialize their discoveries tend to be relatively younger, with the peak time for engaging in such activities being about 12 years after earning the doctoral degree (Ding & Choi, 2011). Overall, these findings suggest that academic scientists are more likely to engage in technology transfer activities earlier in their careers, but most commonly after at least partly establishing themselves as academics.

Tenure and academic rank. Recent research linking tenure and academic rank with the science commercialization activities of university researchers has produced somewhat mixed findings. On the beneficial side of tenure and academic rank, research has shown that being a tenured professor is positively associated with founding a business (Haeussler & Colyvas, 2011). In contrast, another study found that those with tenure perceive engagement in entrepreneurial activities as being relatively unattractive (Fritsch & Krabel, 2012), and similarly, one study (Aldridge et al., 2014) found a negative relationship between years in tenure and academic rank and the likelihood of starting a business. Overall, as with the age of academic scientists, further research on tenure and academic rank is needed to disentangle the mixed findings in this literature. Such research may benefit by integrating academic life cycle models (Fini et al., 2009; Shane, 2004), which suggest that academic scientists build human capital early in their careers through their research, then are more prepared to engage in technology transfer activities in the middle of their careers before winding down toward retirement—with contingency approaches that consider potential moderating factors (e.g., marriage, number of children at home, income earned through one's academic position, field of research). Such integration may result in the identification of moderated curvilinear relationships that more fully characterize the complexities of such relationships (cf. Dawson, 2014).

DISCUSSION

Taking into account the studies covered in our review of the most recent research on the psychological foundations of science commercialization, we now offer suggestions for potential theoretical and methodological advances to this literature. We then review emerging trends in technology commercialization and the important part that individual academic scientists will likely need to play to ensure greater success of universities' efforts to both generate and appropriate value from such activities. As summary information, Table 2 includes aggregate information regarding theoretical and methodological characteristics that were coded for each article and used to inform portions of our discussion. In addition, Table 3 offers potential research questions associated with research gaps that were identified in our review.

The Need for Greater Theoretical Sophistication

The literature on university science commercialization has historically comprised studies that have been phenomenon and/or data driven (Djokovic & Souitaris, 2008). For example, the authors of only about one-half of the articles (55.4%) in our review specified one or more theoretical frameworks upon which their research was based. Moreover, only a small number of the studies examined mediating (8.9%) and/or moderating

(12.5%) variables—common indicators of theoretical sophistication (Whetten, 1989). These points are not entirely surprising when considering that the phenomenon of science commercialization at universities is still relatively new in many parts of the world (Aldridge & Audretsch, 2011; Grimaldi et al., 2011). Thus, there has been limited time to develop theory that specifically explains or predicts how, when, and why certain science commercialization processes and activities may be more or less effective than others—and, in particular, the role that individual academic scientists play as the elemental actors within such university programs. Instead, much of the research in this area has been exploratory and descriptive in nature.

Researchers studying these topics may be able to draw from more established, yet related, fields for theoretical insights (Kuhn, 2012). In this respect, we believe that research centered on the psychological foundations of science commercialization may benefit by borrowing from individual-level theories in social and cognitive psychology, organizational behavior, human resource management, and other related fields to extend existing knowledge regarding why some academic scientists, but not others, engage in science commercialization activities, and why some of those who do engage in commercialization activities are more or less successful than others. To this end, we next review two theoretical frameworks as illustrative examples that may prove particularly useful for helping to advance research on the psychological foundations of science commercialization: social cognitive career theory and social psychological theories of identity. We conclude the section with a brief note on several theories that may be helpful in terms of examining the engagement and performance of academic scientists in technology transfer activities. Though outside the scope of journals selected for use in our review, we briefly include a few articles that have drawn on these theories in additional research on the psychological foundations of science commercialization.

TABLE 2
Descriptive Characteristics of Target Studies Reviewed (n = 56)

Study characteristic	Percent of studies
Primary theory specified	55.4%
Quantitative methods	69.6%
Qualitative methods	17.9%
Mixed methods	12.5%
Primary data	76.8%
Secondary data	32.1%
Included moderator(s)	12.5%
Included mediators(s)	8.9%
Cross-sectional design	94.6%
Longitudinal design	5.4%
Research question 1	89.3%
Research question 2	10.7%

Social cognitive career theory (SCCT). This theory was developed by Lent, Brown, and Hackett (1994) to explain three related aspects of career development: vocational interests, career choices, and performance in an occupation. It was later expanded by Lent and Brown (2008) to explain work satisfaction. The two primary components of SCCT involve self-efficacy expectations and outcome expectations. Self-efficacy expectations involve the confidence an individual has in his ability to perform at a high level the tasks and roles associated with the requirements of a given job or occupation. Outcome expectations are the beliefs the person has about whether high performance on such tasks and roles will lead to the achievement of desired outcomes or rewards. Self-efficacy and outcome expectations are shaped by learning that occurs through both personal (e.g., personality, gender, ethnicity) and environmental (e.g., educational background, family history, socioeconomic factors) inputs. In turn, such expectations shape how occupational interests are formed, how career choices are made, how well individuals perform in their jobs, and how satisfied they are with their work.

Even though SCCT was originally applied most often to predict the careers paths of high school and college students (Lent, Brown, Nota, & Soresi, 2003), it has become increasingly applied as a framework for investigating the career transitions of older adults (Sheu et al., 2010). To this extent, it appears to be a particularly promising model for examining why some academic scientists, yet not others, decide to participate in science commercialization (e.g., to take on a new occupational role) and, in turn, why some academic scientists who do engage in such activities are more or less successful in terms of achieving high performance and personal well-being. Findings from several of the studies in our review indeed support various components of the SCCT model. For example, research by Huyghe and Knockaert (2015) demonstrated that entrepreneurial self-efficacy is an important predictor of academic scientists' engagement in new venture creation and patenting or licensing activity. Research by Fini and colleagues (2009) observed that the decision for academic scientists to start a business was positively related to the expectation of achieving desirable outcomes from such an undertaking. Moreover,

TABLE 3
Recommendations for Future Research on the Psychological Foundations of University Science Commercialization

Topic	Research questions and theoretical frameworks
Human capital	*RQ1:* Research on the human capital of academic scientists has focused primarily on the degree of engagement that such persons have in technology transfer activities. It is, however, not clear whether the same sources of human capital that are linked with engagement in science commercialization are similarly related to performance in such activities. Thus, what sources of human capital are most positively associated with the performance of academic scientists engaged in science commercialization activities?
	RQ2: Research examining how the human capital of academic scientists relates to science commercialization has not equally considered how such individual characteristics simultaneously affect teaching and research. As science commercialization is considered the "third mission" of universities, researchers should consider adopting a holistic perspective that does not focus on any one mission or role in isolation. Therefore, what types of human capital contribute most positively to the performance of academic scientists across their combined roles in teaching, research, and science commercialization?
	Useful theories: human capital theory*, signaling theory*, regulatory focus theory
Social capital	*RQ1:* Most research on the social capital of academic scientists has been cross-sectional and has considered only the individual's current breadth and depth of certain types of social capital or present position in a network. This stream of research has given far less consideration to the trajectories of how social capital and one's position in a network are developed over time. As such, research findings have been limited as to the degree to which they can inform the development of social capital for academic scientists or achievement of certain positions in a network for such persons. Thus, how can academic scientists best develop critical types of social capital and achieve important positions in networks that can help them to effectively contribute to their university's science commercialization programs?
	RQ2: As social capital development carries with it associated costs (e.g., it can be time-consuming), it would be useful to know which forms of social capital might benefit all three missions of the university, so that academic scientists and universities can maximize their limited resources. Therefore, which types of social capital are most effective for helping academic scientists to achieve high performance across teaching, research, and science commercialization?
	Useful theories: social capital theory*, social network theory*, process theory*, person-environment fit theory
Heterogeneous objectives	*RQ1:* Despite strong arguments for academic life cycle models regarding the times in a career in which academic scientists are likely to become more versus less involved in technology transfer activities, there is little knowledge regarding how such trajectories might be altered (e.g., sped up or slowed down). Thus, how does the motivation for academic scientists to engage in science commercialization activities evolve over the course of their careers, and what factors might alter such motivational trajectories?
	RQ2: Because research has generally found that academic scientists are primarily driven by professional success within their academic roles as opposed to business success within industry, it is unclear what types of incentives would best encourage such persons to become involved in the business-oriented activity of science commercialization. Therefore, what combinations of incentives are most useful for gaining academic scientists' participation in technology transfer activities?
	Useful theories: identity theory*, social identity theory, founder identity theory, social cognitive career theory, theory of planned behavior
Demographic characteristics	*RQ1:* Research has emphasized the importance of examining the influence of demographic factors, focusing primarily on gender, age, time since degree, and academic rank. Other demographic factors, such as marital status, presence and age of children, religion, and national origin, have received much less attention. Thus, how does the full range of demographic factors affect one's propensity for science commercialization?
	RQ2: Demographic characteristics explored in the literature thus far have focused on temporal aspects of growing an academic career. Therefore, we might ask, how do the intersections of gender, age, parenthood, and other demographics interact with institutionalized temporal rhythms to shape commercialization success?
	Useful theories: life course perspective*, social influence theory, social psychology of aging, expectancy theory

Note: Each of the theories suggested for future research is denoted with an asterisk if it has been used in at least one study included in our review. In most cases, the theories denoted with an asterisk have been introduced by a single study. Only human capital theory (five studies) and identity theory (two studies) have been used in more than one of the studies reviewed.

several studies found both personal and environmental inputs to be related to whether academic scientists participated in technology transfer activities. In terms of personal inputs, several studies observed female academic scientists to be less interested in science commercialization than their male counterparts (Clarysse et al., 2011; Fritsch & Krabel, 2012; Knockaert et al., 2015; Moog et al., 2015). With respect to environmental inputs, a study in our review by Kalar and Antoncic (2015) observed that working in a department that is high in entrepreneurial orientation is associated with the likelihood that faculty members will engage in entrepreneurial pursuits and hold positive beliefs regarding the value of technology transfer.

Moving forward, it appears that SCCT may be useful for gaining a deeper understanding regarding many aspects of academic scientists' engagement in science commercialization, as well as the achievement of outcomes associated with such involvement. First, and perhaps most important, SCCT provides a framework to simultaneously consider a wide array of outcomes relating to the nexus of academic scientists and technology transfer, including interest, participation, performance, and satisfaction. Second, SCCT has been widely used to examine why women and ethnic minorities are underrepresented in science, technology, engineering, and math (STEM) (e.g., Fouad & Santana, 2017). We suspect that this theoretical model could be similarly useful as a framework for investigating why such groups are also underrepresented among academic scientists participating in science commercialization. Finally, the SCCT model is dynamic in that it provides feedback loops from outputs including interest, (choice of) participation, performance, and satisfaction back to self-efficacy expectations and outcome expectations. For this reason, the framework appears to be ideally suited for examining how academic scientists react to both positive and negative outcomes resulting from participation (or lack thereof) in science commercialization.

Social psychological theories of identity. Entrepreneurship researchers have documented the striking heterogeneity of motivations that drive entrepreneurs' behavior and shape their strategies (Hmieleski & Baron, 2009; Sapienza, Korsgaard, & Forbes, 2003). Extending this theme, a study in our review by Glenna and colleagues (2011) explored both heterogeneous motivations and values unique to the scientists to understand their impact on research output. The authors inferred that structural factors and funding sources shaped the underlying decisions of academic scientists to engage in technology transfer activities. Several other studies in our review examined a variety of motivational relationships important in the academic environment. These ranged from supportive university departments and role models (e.g., Huyghe & Knockaert, 2015; Kalar & Antoncic, 2015) to scientists' collaboration with start-up members to improve the likelihood of licensing (e.g., Wu et al., 2015).

Work exploring the heterogeneous motivations that influence entrepreneurs' behavior has recently begun to coalesce around explanations built on the foundation of social psychological theories of identity. This work investigates founder identity—the sense of "who I am" and "who I want to be" as a central driver of entrepreneurs' behavior and the structuring and strategies of their firms (Powell & Baker, 2014, 2017). Recent research has found identity processes to be central sources of the meanings that entrepreneurs associate with their work (Cardon, Wincent, Singh, & Drnovsek, 2009; Fauchart & Gruber, 2011; Mathias & Williams, 2014; Meek & Wood, 2016). Founders' identities therefore help us understand the rich variation in motivations for new venture creation, further decentering and complementing a historically narrow and somewhat inaccurate focus on financial motivations (Baker & Pollock, 2007). Indeed, we found two studies that specifically highlight the challenges of managing identity tensions such as those between academic and entrepreneur role identities (e.g., Jain et al., 2009; O'Kane et al., 2015).

Recent work in founder identity theory (FIT) draws directly on two mainstream social psychological theories of identity. First, identity theory (also known as role identity theory) (Stryker, 1980; Stryker & Burke, 2000) positions an individual squarely within the context of the social environment in which his or her role is constructed and defined. A primary motivation for creating, or playing, a role is to achieve positive reflected appraisals (Gecas & Burke, 1995) from others that the individual is performing the role appropriately. Interactions between entrepreneurs and those with whom they interact thereby help to reciprocally shape the development of a role as well as others' expectations of the person's behavior while in that role. Second, social identity theory (Tajfel, 1978; Tajfel & Turner, 1979) highlights the meaning and significance of categorizing oneself as a member of various social groups. Groups provide a footing into the social structures through which entrepreneurs attempt to navigate.

They afford a sense of belonging and provide behavioral norms and values associated with group membership (Bartel & Wiesenfeld, 2013; Powell & Baker, 2017).

Common across these two theories is the recognition that every individual has multiple identities that can come into play across varied situations. Individuals, including scientists who are engaged in entrepreneurial endeavors, draw identities both from the roles they inhabit and from the groups to which they believe they belong. Recent research has found not only that the congruence or incongruence of such multiple identities is meaningful, but that the patterning and structure of founders' social identities can serve as aspirations for the roles and identities they attempt to create in their firms (Powell & Baker, 2014). Exploring these ideas with academic scientists could both reveal new insights about the psychological dynamics of science commercialization and extend our current knowledge relating to identity theories.

The combination of social identity theory (Tajfel & Turner, 1979) and role identity theory (Stryker, 1980) provides a basis to explore how varied demands from multiple roles affect not only the decision to engage in new venture creation, but also the success of such efforts. Jain and colleagues' (2009) discovery of a specific hybrid identity is an example of research exploring the interaction among multiple role identities of scientist entrepreneurs. Building on this foundation, future research could consider other identities and contexts that affect who becomes an academic entrepreneur and with what results.

Moreover, contemporary work on FIT has emphasized the usefulness of a life course approach (Elder, 1974; Elder, Johnson, & Crosnoe, 2006) to understanding how identity processes shape entrepreneurs' motivation and behavior (Powell & Baker, 2017). The roots of founders' sense of "who I am" and "who I want to be" are often deeply rooted in their life histories. Equally important, the patterns and rhythms of academic careers and how they intertwine with other role demands are likely, we believe, to shape whether, when, how, and with what outcomes academic scientists become entrepreneurs. For example, for most academic scientists, spending time on commercialization activities—and hence signaling interests that might interfere with research efforts—might make little sense prior to achieving tenure. Similarly, differences in demands based on both social identities and role expectations might help to explain differences between male and female scientists in whether, when, and how they become involved in entrepreneurial activities.

Other theoretical frameworks. There are several additional psychological theories that may prove useful for future studies of science commercialization by university scientists. We will now briefly describe three: the theory of planned behavior, expectancy theory, and regulatory focus theory.

The theory of planned behavior (TBP) provides a framework for articulating how human behavior may be predicted by intentions that are, in turn, shaped by attitude toward the behavior, subjective norms, and behavioral control (Fishbein & Ajzen, 2010). Attitude toward the behavior is the extent to which the person possesses a positive or negative evaluation of the specific behavior (e.g., the general belief an individual possesses regarding whether science commercialization is good or bad). Subjective norms involve the degree to which peers and other significant persons within the individual's network approve or disapprove of engagement in the behavior (e.g., the extent to which peers in one's academic department are supportive of engagement in science communization). Behavioral control is the extent to which the individual believes that she is able to exert control over factors that enable her to perform and/or inhibit her from performing the behavior (e.g., an academic scientist's belief that she can easily engage in science commercialization without running into significant barriers or obstacles).

The theory of planned behavior is arguably the most common framework used in the entrepreneurship literature for studies examining factors shaping individuals' inclinations to participate in entrepreneurial activities (e.g., Douglas, 2013; Douglas & Fitzsimmons, 2013; Kautonen, van Gelderen, & Fink, 2015; Lee, Wong, Foo, & Leung, 2011; Obschonka, Silbereisen, & Schmitt-Rodermund, 2010; Van Gelderen, Kautonen, & Fink, 2015). It is therefore likely to be particularly helpful in addressing our first research question regarding why some academic scientists, yet not others, decide to participate in science commercialization activities such as licensing intellectual property or starting a new business. As examples, this theoretical framework was used in research by Brettel, Mauer, and Walter (2013) to investigate what sets of incentives are most useful for encouraging participation in science commercialization, and in studies by Goethner, Obschonka, Silbereisen, and Cantner (2012) and Obschonka, Goethner, Silbereisen, and Cantner (2012) to examine the entrepreneurial intentions of academic scientists.

Expectancy theory (Vroom, 1995) suggests that motivation for an individual to perform a specific behavior (i.e., intensity of effort) is jointly determined by three primary factors: expectancy, instrumentality, and valence. Expectancy is the perceived probability that an individual's effort will lead to high performance when engaging in the behavior (e.g., an academic scientist's perception of the likelihood that if he works hard on an invention, he will successfully develop the invention). Instrumentality is the perceived probability that if an individual performs at a high level, he will receive desired rewards (e.g., an academic scientist's perception of the likelihood that successfully patenting an invention will result in substantial licensing revenue). Valence is the value of expected outcomes to the individual (e.g., the degree to which an academic scientist values the rewards and/or accolades associated with the commercialization of his work). Prior research has demonstrated that expectancy theory is a useful framework for investigating individuals' commitment toward starting their own business (Renko, Kroeck, & Bullough, 2012), as well as the persistence of entrepreneurs once they have launched a new venture (Tietz, Lejarraga, & Pindard-Lejarraga, 2017). We similarly suspect that expectancy theory could prove useful in terms of investigating the commitment and persistence of academic scientists' involvement in technology transfer activities.

Regulatory focus theory (Higgins, 1998; Hmieleski & Baron, 2008) suggests that the motivation of individuals to engage in specific behaviors is shaped by ideal and ought self-guides, which lead to independent and distinct strategic orientations. Ideal self-guides elicit a promotion focus, which is characterized by a desire for achieving growth, advancement, and accomplishment. Individuals operating through a promotion focus are inclined to take risks to increase the likelihood that they will be able to achieve their ultimate goals (i.e., they seek to maximize gains). In contrast, ought self-guides evoke a prevention focus, which is distinguished by a desire for safety, protection, and responsibility. People operating through a prevention focus tend to play it safe and work toward preventing failure (i.e., they seek to minimize losses). Applying these logics to academic scientists, those operating through a promotion focus are likely to view involvement in science commercialization from a perspective of what they can gain through their participation, whereas those operating through a prevention focus are likely to view such activities through a lens of what they have to lose by participating. Consistent with this logic, recent findings from a study by Johnson, Monsen, and MacKenzie (2017) suggest that the greater the promotion focus of academic scientists, the more likely they are to intend to engage in science commercialization. Moreover, these authors found that having a leader with a promotion focus positively enhanced this relationship.

Future research applying regulatory focus theory to the domain of science commercialization is likely to prove particularly fruitful with respect to determining how a promotion-focus orientation might be built into science and engineering graduate training without undermining the need for the precision and ethical care that are cornerstones of the scientific method. In addition, regulatory focus theory may be useful for considering how incentive and reward systems might be best designed to encourage science commercialization. For example, if academic scientists have more to gain and less to lose by participating in science commercialization, they may be more likely to act through a promotion, rather than prevention, focus. Increased assistance from TTOs and receiving a greater share of royalties from licensing might reduce academic scientists' perceived risk (i.e., threat of losses) and enhance their perceived gains (Markman, Gianiodis, & Phan, 2008).

In partial support of this logic, findings of a study by Bourelos, Magnusson, and McKelvey (2012) suggest that allowing inventors to allocate ownership rights for intellectual property can have beneficial effects for enhancing participation and performance relating to science commercialization. Finally, it may be interesting to examine the degree to which academic scientists are respectively (un)able to switch between prevention and promotion focuses when engaged in scientific research as opposed to technology transfer activities. It might be that those individuals who are most effective in both domains can most fluidly shift between regulatory orientations.

Potential Methodological and Empirical Advances

Even though the majority of studies in our review drew from primary data (76.8%) to explore factors that might predict participation in and/or performance of science commercialization activities, most of these studies were focused on establishing main effect relationships. Therefore, much of the research in our review has failed to consider "when" and "how" such relationships occur. Moreover, the majority of studies were focused on predicting engagement of university scientists in technology transfer activities (89.3%), whereas only a few studies considered related performance outcomes (10.7%). The findings of these studies have provided many interesting insights, which have in turn led to the current opportunity to employ a broader range of methodological and empirical techniques to build an even richer and more contextualized understanding of the psychological foundations of science commercialization. To this end, we briefly review how specific quantitative and qualitative advances could be made to build this area of research moving forward. In addition, we discuss the need for more studies examining the relationship between the individual characteristics and behaviors of academic scientists and their achievement of high performance and well-being from involvement in science commercialization activities.

Quantitative research. As the majority of studies we reviewed employed purely quantitative methods (69.6%), we begin by considering some potential advances that could be made to research adopting such an approach. In so doing, we consider the need to examine moderating effects, the opportunity for multilevel analyses, the potential for capturing a broader range of variables, and reasons why more longitudinal research is needed.

First, we observed mixed findings among studies, which made it difficult to draw reliable conclusions about important relationships (e.g., the effects of scientists' age, gender, academic rank, and tenure). Inconsistent research findings, such as those noted, are often due to biased estimates resulting from omitted variable interactions (Cohen, Cohen, West, & Aiken, 2003). This situation points toward the need to consider potential moderating factors (Dawson, 2014; Hayes, 2013). It might therefore be informative to consider research from the mainstream entrepreneurship literature, which has been criticized in the past for failing to identify an overarching set of characteristics defining a prototypical successful entrepreneur (Gartner, 1989). The failings of this literature have been explained as being largely the result of researchers ignoring the tremendous heterogeneity among entrepreneurs, the various types of businesses that they start, and the wide range of environments in which they operate (Baum, Frese, & Baron, 2007). To overcome these confounds, entrepreneurship researchers have moved toward contingency approaches to examine the psychological foundations of new venture development (e.g., Baron, Franklin, & Hmieleski, 2016; Carr & Hmieleski, 2015; Davis, Hmieleski, Webb, & Coombs, 2017; Hmieleski, Corbett, & Baron, 2013). We similarly expect that research considering why some academic scientists, but not others, engage in productive forms of science commercialization (i.e., technology transfer activities that generate meaningful value, such as revenue and jobs) would also benefit from adopting a contingency approach that takes into account a broad range of potential moderating variables.

Second, data used in research on the psychological foundations of science commercialization tend to have an inherently nested structure. For example, academic scientists often work as members of research teams, residing in academic departments and/or centers, located within schools or colleges, which are part of a university. Each of these levels has the potential to influence another level in an upward or downward fashion (Preacher, Zhang, & Zyphur, 2016). Moreover, a misspecification of the appropriate unit of analysis without consideration of within- and between-levels of agreement can lead to findings that are uninterpretable or misleading (Kozlowski & Klein, 2000). Research on academic scientists within the scope of university science commercialization might therefore benefit by considering exemplars of multilevel research from the field of organizational behavior, which commonly deals with nested data structures when studying individuals and teams within organizational settings (e.g., Mathieu, Maynard, Taylor, Gilson, & Ruddy, 2007; Richter, Hirst, van Knippenberg, & Baer, 2012).

Third, due to a reliance on the use of cross-sectional data (94.6%), research examining the psychological foundations of science commercialization has been restricted in its ability to incorporate time and adopt a process perspective (McMullen & Dimov, 2013; Rasmussen, 2011). Considering the convenient proximity of academic scientists as university co-workers of researchers who conduct research on technology transfer activities (e.g., management, entrepreneurship, and economics professors), it is somewhat surprising that more research on academic scientists has not included repeated-measures data collections. It would, therefore, seem that the opportunity for analyzing convenience samples of academic scientists at one's home (or neighboring) research institution(s) would represent low-hanging fruit in terms of longitudinal data collection opportunities. Moreover, even though such data collections might not lend themselves to large sample sizes, fewer participants are typically needed in repeated-measures studies to reach adequate statistical power (Bing, Davison, & Arvey, 2009). One example of such research would be the use of experience sampling methods, which require participants to stop what they are doing at particular times of the day to take note of their experiences as they unfold in their natural environment (Uy, Foo, & Aguinis, 2010). Such research could help to create a more complete picture of the academic scientist in relation to his lived experience while engaging in science commercialization activities.

Finally, research evaluating performance indicators for academic scientists engaged in commercialization activities has typically focused on whether a discrete event has occurred (e.g., invention disclosure, patent filing, business founding), without more deeply considering the quality of the given event (e.g., the amount of revenue that a patent has generated, the number of jobs that a spin-out company has created). This situation presents a critical problem because without longitudinal research that accounts for whether an event has actually led to a value-adding outcome, it is impossible to develop well-informed policy implications. It may be, for example, that some factors incenting engagement in science commercialization activities could simultaneously undermine the performance of such activities. Thus, in order for this field of research to mature, there is a need for more longitudinal research that considers the unfolding process of engagement in commercialization activities along with the actual outcomes that are ultimately produced by such efforts.

Qualitative research. Baker, Powell, and Fultz (2017) recently conducted a search for entrepreneurship studies focused on new venture creation in elite general management journals and closely reviewed and examined qualitative studies across those and leading entrepreneurship journals. They found that approximately 15% of articles in the entrepreneurship journals were qualitative and only approximately 3% of articles in management journals were both qualitative and about entrepreneurship. In the current review, we included all of the journals from that review and included the primary journals for technology and innovation management for the same 10-year period. While a call for more qualitative studies is common and could be expected, especially given the approximately 17.9% of pure qualitative studies in this review, we believe these methods are particularly suitable for the types of questions that should be asked about scientists and entrepreneurship given the relative state of theoretical development.

Qualitative methods allow us to ask how and why questions that are less tractable to deductive quantitative approaches (Edmondson & McManus, 2007; Eisenhardt, 1989). Therefore, grounded theory development allows researchers to induct novel theoretical ideas based on observation (both participant and nonparticipant), sometimes resulting in rich insights into processes and behavioral interactions (Glaser & Strauss, 1967). For example, questions regarding the continuity and change in the motivations of scientists choosing to, or not to, commercialize their research would seem to call for longitudinal data collection and observations of circumstances and meanings that inform such decisions. Several of the studies on motivation in our review did use qualitative methods, yet much work remains to fully understand a wide range of persistent process- and motivation-oriented questions, including understanding why such a range of motivations exists among scientists becoming entrepreneurs.

Case studies can be particularly useful units of analysis—for example, to simultaneously focus on the scientists as individuals while also investigating the meaning and impact of their relationships with colleagues (both within and outside of their focal institutions), departments, institutions, and entities responsible for commercialization. The use of such methodological techniques would allow us to develop deep understanding of multi- and cross-level phenomena (Rousseau, 1985; Yin, 2009), providing theory to undergird later quantitative multilevel modeling strategies. Case study approaches are also useful for studying the extreme situations or contrasts between situations in ways that can uncover general and basic processes (Eisenhardt & Graebner, 2007). Further, we discussed in this review of research on academic scientists how little is known about relevant identity processes and even less about how gender differences play out in them. Providing an adequate account of these issues demands that we understand what it means to a scientist to consider or start becoming an entrepreneur and how being a male or female affects this meaning. Future research exploring these questions could be aided by the use of detailed inductive qualitative methods to establish theoretical frameworks and processes to be elaborated and tested through later deductive studies.

Overall, inductive methods allow us to interact directly with participants to gain an emic understanding of lived and perceived experiences

(Evered & Louis, 1981). As we become the instruments through which to observe, interpret, and make sense of the phenomena that capture our own intellectual curiosity (Baker et al., 2017), we are able to induct theory about how the world works and from which we can then gain important insights for further scientific discovery and practical application. The commercial underutilization of scientific discovery impoverishes society in many ways. More specifically, many grand challenges, both in the present and in the future, can potentially be solved through scientists' discoveries within our universities. Inductive methods are critical for understanding those challenges (Eisenhardt, Graebner, & Sonenshein, 2016) and, by association, the processes of science commercialization that will enable the discoveries to be leveraged for the betterment of humankind.

Need for the examination of performance and well-being outcomes. With the exception of only a few studies in our review (e.g., Agrawal, 2006; Criaco et al., 2014), the vast majority (89.3%) of research we covered focused *only* on the participation of academic scientists in technology transfer activities, without considering associated outcomes such as performance or satisfaction. Without a deeper knowledge of such outcomes, it is difficult to determine precisely which attitudes, beliefs, actions, and behaviors to encourage or discourage on the part of academic scientists. This shortcoming makes it challenging to use the findings of extant research to inform policy decisions regarding the engagement of university researchers in science commercialization. Therefore, it is critical that future research on the psychological foundations of academic scientists be extended to include a broad range of performance and well-being outcomes associated with science commercialization.

Emerging Trends in Technology Commercialization

As we examined the recent literature on the psychological foundations of science commercialization, there were a few trends that became apparent and that present potentially important implications with respect to the roles that academic scientists play at their home institutions. Three of these trends are students as agents of technology transfer, a broadening view of intellectual property and faculty stakeholders, and relationships between academic scientists and industry partners.

Even though academic scientists are appropriately considered the elemental actors in the science commercialization process, many university spin-outs are created by students. For example, work by Åstebro, Bazzazian, and Braguinsky (2012) has suggested that, in the United States, the number of start-ups launched by individuals within three years of graduating with a degree in science or engineering is approximately double the number of those that are founded by faculty members. Additional work has demonstrated significant entrepreneurial outcomes produced by students who have gone through training programs focused on technology entrepreneurship and science commercialization (Barr, Baker, Markham, & Kingon, 2009). Moreover, new businesses created by recent graduates are typically of higher quality in terms of potential for growth as compared to those that are started by faculty in these fields. It may, therefore, be that universities should focus on licensing the scientific discoveries and inventions of their faculty to existing corporations, while helping students launch start-up firms regardless of the source (if any) of intellectual property. In some cases, faculty members who do become involved in start-ups might be best suited to do so as joiners rather than founders (Roach & Sauermann, 2015). Such an approach may allow faculty to maintain their primary role as academics, and potentially open outlets for them to provide an advisory, rather than founding, role in university spin-outs.

The traditional view that universities have taken toward focusing on the innovations developed by faculty in engineering and the physical and life sciences has led to an underexploited opportunity to capitalize on the creative productions of those working in other areas, such as the arts, humanities, and social sciences. For example, findings of a study by Hughes and Kitson (2012) suggest that a primary focus on academic scientists ignores the innovative outputs that take place as a result of knowledge exchanges between faculty members of all disciplines. Moreover, advances in low-tech innovation processes such as design thinking (Kelley & Kelley, 2013), lower barriers to acquiring start-up capital (e.g., crowdfunding), and easy access to markets (e. g., online retail portals) have in many ways leveled the playing field in terms of who is able to generate contributions that can be commercialized. Therefore, it may benefit universities to widen their view as to the types of disciplines in which high-potential ideas that can be commercialized might be found and developed. Moreover, if commercialization activities truly comprise a "third mission" of universities (Abreu, Demirel, Grinevich, & Karataş-Özkan, 2016), then it would seemingly be logical to assume that such a mission would involve faculty across *all* disciplines.

The need of universities to find new sources of income to support faculty research in combination with the desire of large corporations to identify additional avenues to innovation has fostered an environment in which academic scientists are increasingly collaborating with industry partners on science commercialization (Goktepe-Hulten & Mahagaonkar, 2010; Lockett et al., 2008). This scenario has created a situation that is ripe for research that integrates academic science commercialization with that of corporate entrepreneurship (Hornsby, Kuratko, Holt, & Wales, 2013; Hornsby, Kuratko, Shepherd, & Bott, 2009). An example would be research examining similarities and differences in the extent to which academic scientists, as compared to managers, working in innovation and/or venture development roles within existing organizations adhere to specific cognitive scripts (e.g., Corbett & Hmieleski, 2007) or institutional logics (Fini & Toschi, 2016). This type of study may provide insights regarding how to nurture relationships between such parties so as to maximize mutual benefits.

CONCLUSIONS

Even though some academic scientists continue to express skepticism about the potential for university science commercialization to generate meaningful value and maintain concern regarding the potential for skewing of research agendas (Davis, Larsen, & Lotz, 2011), there appears to be no slowing the momentum that has built for such programs to move forward and expand into the future (Grimaldi et al., 2011; Lockett et al., 2013; Siegel, Veugelers, & Wright, 2007). Nonetheless, we suggest that it may be the right time for the field to pause for reflection upon how a more holistic view may be formed that considers how both top-down processes from university administration and bottom-up behaviors of individual academic scientists jointly influence the overall success of science commercialization programs. Such an approach would likely benefit from an integrative analysis that acknowledges the interdependence of individual academic scientists within the context of both government policy and university strategy (Dodgson & Staggs, 2012). We hope that our review of the micro-oriented literature will help to move the field in this direction, and also provide a basis for future research that will take this mission even further—so that universities will be able to more fully realize the promise of science commercialization.

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