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The impacts of foreignness and cultural distance on commercialization of patents

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Abstract
Foreign-born academic scientists have been consistently shown to be more productive than the native-born in the United States with regard to research and patents. However, no study has yet analyzed whether the foreign-born are also more likely to commercialize their research after having it patented. This paper utilizes a 2010 survey of academic inventors to analyze whether a selected patent had been licensed or whether technology transfer offices were currently working with a company. Additional analysis was conducted to understand where patents were held (whether by a private company, spinoff, government, or university) for those patents that had been successfully licensed in the past. Findings show that the foreign-born are generally less likely to have their patents licensed or to be working with technology transfer offices, though the significance of the results are mixed. In addition, the foreign-born are more likely to have their licenses held by private companies, while the native-born are more likely to work with spinoffs. These results indicate that technology transfer offices can better serve a key part of the academic workforce.

Keywords Patents · Commercialization of research · Foreign-born faculty · Technology transfer offices

JEL Classification O32 · O34 · L26

1 Introduction

In 1980, the United States Congress enacted the Bayh–Dole Act to encourage the commercialization of knowledge by the country's universities. Principally, the act enabled universities to own patents developed on federally funded grants, expanding the research that could be commercialized. Since the enactment, the law has accomplished many of its intentions, leading to increased patenting and licensing of university innovation and the generation of

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startup companies based on university research (Kenney and Patton 2009; Mowery et al. 2001).

Yet the rise in commercialization of university research over the last several decades has not occurred in isolation of other significant institutional and organizational changes in the US academe. In particular, the US university research enterprise has become more international in scope and function, along with a widening of the national origin of its faculty. Foreign-born faculty now make up 24% of all full-time post-secondary faculty (Lin et al. 2009) with especially high numbers in STEM fields such as engineering and computer sciences (National Science Foundation 2018) and substantial growth since the 1980s (Kim et al. 2011a). Nevertheless, the intersection of internationalization and commercialization in US universities is rarely a focus of research.

Prior research has found that foreign-born faculty at US research universities produce more publications, conference presentations, grants, and patents than native-born faculty (e.g., Corley and Sabharwal 2007; Kerr and Lincoln 2010; Kim et al. 2012). Notwithstanding their productivity, other work has shown that foreign-born faculty receive lower salaries and are less satisfied with their work conditions, often due to unwelcoming campus cultures and workplace discrimination (Manrique and Manrique 1999; Corley and Sabharwal 2007; Collins 2008; Foote et al. 2008; Marvasti 2005). It is generally accepted that disparities due to discrimination in the academic workplace reduce work morale and satisfaction, which in turn decrease motivation for research, reduces productivity, and increases the intention to leave (Blackwell et al. 2009; Donaldson and Rosser 2007; Lopes 2006; Smart 1990; Thoman et al. 2013). Yet, despite these consistent and seemingly contradictory findings—higher productivity but lower salary and satisfaction—research has rarely examined commercialization activity of foreign-born faculty in terms of both licensing activity and assistance received from the universities during the commercialization process. Given that foreign-born faculty are a growing segment of the nation's academic workforce it is important to better understand and characterize how they contribute to and are engaged in commercial activity in US universities.

In this research, we study whether foreign and native-born academic scientists are less likely to commercialize their inventions. To answer those questions, we use data from a 2010 survey of United States faculty that were listed as inventors on university held patents. We explore multiple aspects of the commercialization process, including licensing success and the place in which inventions are licensed (spinoffs, government, industry, university). We also examine variance within different operationalizations of foreignness, based on nationality, race, ethnicity, and length of residence in the United States, as ways to improve the understanding of how foreign characteristics may matter for commercialization. Our results demonstrate that foreign-born faculty are less likely to have their patents licensed and they are less likely to have technology transfer offices (hereafter, TTOs) work on their behalf to commercialize their inventions. In particular, non-white and non-European foreign-born faculty are less likely than white foreign-born faculty to realize commercialization outcomes. Additionally, foreign-born faculty are more likely than their native-born colleagues to have their patents licensed by private companies but less likely to claim licensing in their own spinoffs.

The paper proceeds as follow. First, we discuss the literature on foreign-born faculty and commercialization in higher education to develop a set of hypotheses. Second, we test our hypotheses with a national survey on intellectual property in academia conducted in 2010. Third, we present our results, finding evidence that the foreign-born faculty are less likely to have their patents licensed, particularly by their own spinoffs. We conclude with a discussion of the findings and their implications for research and practice.

2 Literature review

Because the literature on patenting and commercialization is voluminous and complex, this section provides only sufficient background to address the case of foreign-born scientists in US universities. Commercialization of academic research is currently a common practice for scientists to transfer knowledge from universities to industry. Traditionally, scientists have been embedded in Mertonian science (Merton 1957), which strongly emphasizes advancing knowledge to scientific communities. However, recent scientific research has become more focused on commercializing discoveries, which limits public dissemination of knowledge as research outputs become private and less accessible (Bains 2005; D'Este and Patel 2007; Partha and David 1994).

Through commercializing their research outputs, scientists can demonstrate that their research has a clear impact on the economy and society (Markman et al. 2008) and gain reputation and academic prestige (Owen-Smith and Powell 2001; van Rijnsoever et al. 2008). Yet scientists' commercialization efforts also shape their research agendas (Blumenthal et al. 1996) and collaboration patterns (Boardman and Corley 2008) as they work to meet private sector expectations. Promoting the commercialization of research outputs is relevant to universities as well, as a growing number of institutions are finding that commercialization of research output increases public and private funding opportunities to attract large R&D projects (Broström 2012; Phan and Siegel 2006).

Commercialization promises distinctive rewards to academic faculty who conduct research and discover new and novel inventions. Scientists commercialize their research for different reasons: for intrinsic reasons, to privatize inventions, to increase reputation, to meet the professional expectations of their institutions, and to satisfy the needs of industry stakeholders (Audretsch and Aldridge 2009; Belitski et al. 2019; Stuart and Ding 2006; Van Looy et al. 2004). Given the rise in importance of capturing economic returns, universities have increasingly recognized inventions as important faculty outputs, calling attention to them publicly through different media venues. In addition, universities often expect faculty to engage in commercialization activities to promote new ventures and spin-offs and to bring-in public and private funding to universities (Mosey et al. 2017; Wright et al. 2009). Universities use economic incentives such as royalties to encourage faculty to identify and commercialize potential inventions, along with recognizing invention and commercialization outcomes during promotion and tenure processes (Kenney and Patton 2011; Sanberg et al. 2014; Stevens et al. 2011). As a result, academic scientists and engineers are embedded in an institutional context that encourages and facilitates commercialization.

2.1 Commercialization and foreign-born faculty

Foreign-born faculty are key contributors to the American university system, particularly in STEM fields where there is high representation (Lin et al. 2009). Researchers have demonstrated that foreign-born faculty working in the United States are more productive than their native-born colleagues with regards to patenting (Corley and Sabharwal 2007) along with other traditional academic outputs such as publications, grants, books, and conference papers (Marvasti 2005; Kim et al. 2011b, 2012; Mamiseishvili 2011; Mamiseishvili and Rosser 2010; van Holm et al. 2018; Webber 2012; Webber and Yang 2014). These differences may relate to the fact that foreign-born scientists are often among the most talented scholars from their country of origin, having endured successive rounds of applications and

vetting in order to secure a position in the United States (Borjas 1987; Stephan and Levin 2000).

Despite their greater productivity, foreign-born faculty often experience unequal treatment by colleagues or institutions. Foreign-born faculty have been found to receive lower salaries when controlling for demographic and work related factors (Corley and Sabharwal 2007; Espenshade et al. 2001; Gahungu 2011). Of note, when Corley and Sabharwal (2007) included a variable accounting for research productivity in their models, the salary gap between foreign and native-born scientists widened. Similarly, foreign-born engineers received significantly lower return for their productivity than native-born colleagues, and the gaps persisted over their career (Waldinger et al. 1998). Research has also found that foreign-born faculty are often disadvantaged in tenure reviews (Lee 2004), administrative and managerial roles (Lee 2002), and hiring processes (Gahungu 2011). Because foreign-born faculty experience rejection, isolation, and lower work satisfaction due to workplace discrimination, they may be less likely to realize their full potential and more likely to leave academia (Collins 2008).

Thus, even though foreign-born scientists produce more patents, they may not commericalize their inventions at the same rates. Because prior literature on foreign-born faculty has shown unequal incentives and returns for equal or superior work, it would not be surprising to find evidence that these disadvantages are also reflected in the commercialization process. While prior studies explored foreign-born academic scientists' intention or propensity for commercialization, scant research has examined differences in how foreign-born academic scientists experience the commercialization process.

Nevertheless, we can look to the literature on minorities for further insights about the challenges foreign-born faculty might face during commercialization. In general, prior research has demonstrated that women and racial-minorities often have less access to career advancement opportunities, receive lower pay and fewer promotions, and are more likely to be employed in less prestigious schools, even when controlling for their productivity (Blackaby et al. 2005; Leslie et al. 1998; Long and Fox 1995; Stephan and Levin 2000). LGBTQ workers of both genders in STEM-related fields experience lower work satisfaction (Cech and Pham 2017), a result that is partially driven by being "out" and the experience of exclusionary behavior (Patridge et al. 2014). These results collectively indicate the importance of in vs out group in the shaping of experience within the scientific workforce.

Specific to the commercialization process, Whittington and Smith-Doerr (2005) have found that women were less likely to commercialize their patents. That result was driven in part because universities and TTOs failed to provide support or give attention to their patents, even though female faculty received greater returns on average for their inventions than their male colleagues. Similarly, in the United Kingdom's universities, female faculty were less likely to lead spinoffs than their male colleagues and were less likely to be the target of external actors who initiated the commercialization process (Rosa and Dawson 2006). While some of these differences can be explained by differences in scientific disciplines and professional training (Hunt et al. 2013), women working in less hierarchical organizations are more likely to commercialize than their male colleagues (Whittington and Smith-Doerr 2008). Few studies examine minority faculty commercialization activity, but those that do find that Black faculty are less likely to apply and to be awarded patents (Ginther 2008). Thus, if differences in opportunities to commercialize inventions between foreign-born academic scientists and their US counterparts exist, they may be explained by a confluence of different factors also found in the literatures on women and minorities in science.

We argue that commercialization levels for foreign-born as compared to native-born faculty may be lower for three main reasons: (1) workplace discrimination against foreign-born faculty that reduces motivation and access to opportunities; (2) fundamental preferences of foreign-born faculty against commercialization; and (3) institutional complexity of commercialization that disadvantages individuals who have not lived in the US their whole lives. We take each of these arguments in turn.

2.2 Workplace discrimination

Social identity and self-categorization theory suggest that individuals are socially separated based on in-group similarities such as physical traits, culture, and language (Ashforth and Mael 1989; Hogg 2001; Hogg and van Knippenberg 2003), and prior research has shown that foreign-born faculty do experience discrimination in the academic workplace, which separates foreign-born faculty as an 'out-group' (Bang 2016; Foote et al. 2008; Kim et al. 2012; Manrique and Manrique 1999). Membership in an out-group has both resource and psychological effects on the individual. In terms of resources, in-group favoritism can reduce the opportunities and support that foreign-born academic scientists have to commercialize their inventions (Dasgupta 2004). As an out-group, foreign-born scientists and engineers may have less access to critical social and professional relationships, which can provide instrumental support for career advancement and productivity (DiTomaso et al. 2007). For instance, private companies are less likely to exchange information with foreign-born scientists (Boardman and Corley 2008). Psychologically, workplace discrimination that creates resource disparities and other biases may discourage foreign-born faculty from pursuing commercialization or weaken their confidence and resolve when they negotiate for returns (Libaers 2014). Ultimately, foreign-born scientists may internalize institutionalized workplace discrimination in ways that intentionally or unintentionally perpetuate out-group behaviors, including those related to commercialization (Davies et al. 2005; Festekjian et al. 2014).

2.3 Researcher preferences

Alternatively, differences in commercialization may result from different motivations underlying research rather than discrimination. Most studies have found researchers in academia to undertake patenting out of a desire for greater recognition of their research, regardless of their place of birth (D'Este and Perkmann 2011; Lam 2011), but differences exist based on nativity. For instance, Libaers and Wang (2012) found that foreign-born faculty have higher motivation to secure research resources but are less motivated to exploit economic values in their inventions. In addition, prior work has found that foreign-born scientists are primarily driven by scientific significance and its impact on their research reputation rather than by commercial rewards (Göktepe-Hulten and Mahagaonkar 2010; Libaers 2014; Sauermann et al. 2010), though field differences exist (Walter et al. 2018).

2.4 Institutional complexity

Finally, commercialization occurs in a complex institutional context involving repeated interaction and negotiations with multiple parties. All three actors—TTOs, inventors, and

firms—engage in the commercialization process to successfully transfer academic inventions to industry. Yet the complex nature of the commercialization process can discourage or disengage the foreign-born from commercializing their inventions because they are unfamiliar with or unable to navigate the complex procedures by which commercialization occurs, or because they perceive the process as burdensome.

Commercialization typically requires faculty to navigate various units within their TTO. Those units include licensing and patenting offices, small business research offices, incubators, and investment offices (Dill 1995). Once the patent is awarded, faculty have to market the invention, convince third-parties such as firms or entrepreneurs, and negotiate for a license (Siegel et al. 2004). In addition, the structure of TTOs can confuse inventors, particularly those who are less familiar with US policies and practices, as each stage of the commercialization process has different rules and expectations (Markman et al. 2005). Hence, the level of foreign-born faculty engagement in the commercialization process may vary based on the structure of the TTO and their familiarity with the commercialization process.

Because differences in commercialization may arise from workplace discrimination, researcher preference or institutional complexity, we expect that foreign-born scientists and engineers will be less likely to commercialize inventions:

Hypothesis 1 Foreign-born faculty will be less likely than US-born faculty to commercialize their inventions.

All else equal, native- and foreign-born faculty in the same US university should have similar interaction with TTOs and be given access to similar TTO commercialization services. However, prior work shows that TTO service levels are lower for foreign-born scientists (Jung and Ejermo 2014; Libaers 2014). Several rationales explain this discrepancy. Lower TTO interaction and service levels for foreign-born faculty may be due to differences in language and culture. Imperfect language skills and non-native accents can result in negative treatment of foreign-born scientists (Lawless and Chen 2017), and lack of language fluency may reduce perceived credibility of foreign-born faculty (Marvasti 2005; Lippi-Green 2011; Skachkova 2007). Finally, as with the prior hypothesis, it is possible that foreign-born scientists prefer not to engage with TTOs, possibly because they do not have confidence in their services.

In sum, we expect that foreign-born scientists and engineers are less likely to report that TTOs assist them in the commercialization process:

Hypothesis 2 Foreign-born faculty will be less likely than US-born faculty to report that TTOs work on their behalf to commercialize their inventions.

Academic scientists are more likely to commercialize their technology when they are effectively linked with industry (Casper 2013; Sauermann et al. 2010). Yet, companies are more reluctant to invite foreign-born scientists to engage in joint commercialization than their US-born counterparts (Göktepe-Hulten and Mahagaonkar 2010; Libaers 2014). Language skills and cultural distance may limit the ability of foreign-born faculty to access resourceful professional networks and can even worsen their ties with industry (Agrawal et al. 2008; DiTomaso et al. 1993).

Moreover, foreign-born faculty may experience greater workplace discrimination when cultural distance is higher. Cultural distance is defined as the extent to which cultural

norms and expectations from the country of origin are different from the United States (Kogut and Singh 1988; Morosini et al. 1998). Literature has shown that racial, language and cultural distance increase discriminatory treatment toward foreign-born faculty and hamper their inventive activities (Skachkova 2007; Zheng and Ejermo 2015). Thus, even differences in commercialization propensities among foreign-born faculty may be further explained by cultural distance.

While it is the job of TTOs to make the appropriate connections between scientists and industry, higher cultural distance and negative credibility bias may reduce the TTOs inclination to assist foreign-born scientists. Because foreign-born faculty may have spent a relatively short amount of time living and working in the US (Kim et al. 2011a, b), they may experience a connectivity disadvantage with industry and other market actors. Native-born faculty, particularly those in STEM fields, on average have larger, more resourceful, and more trusted personal and professional network ties with industry than foreign-born faculty who have only resided in the US for 5 to 10 years (DiTomaso et al. 1993; Skachkova 2007; Stuart and Sorenson 2007). Overall, this literature implies that the longer foreign-born faculty reside in the US, the more they will increase their own credibility and enhance their networks, and thus commercialize their inventions at higher rates.

Cognitive distance or differences in knowledge between TTOs and inventors has been shown to negatively impact the chances for commercialization (Knockaert et al. 2011). Similar patterns are likely for cultural distance. TTO officials are gatekeepers who decide which invention to commercialize and whether to assist faculty to navigate commercialization process (Jensen et al. 2003). Prior studies found that the officers use characteristics of inventions as well as attributes of inventors as selection criteria (Shane 2004; Vohora et al. 2004). For example, representative heuristics can influence licensing officers' decision-making (Åstebro et al. 2012) and when deciding whose invention is commercialized, licensing officers have been found to favor individuals who match the "typical" inventor or entrepreneur (Shane et al. 2015). Thus, cultural distance may play a role in the commercialization process which involves continuous interaction and negotiation among multiple parties each of which must understand the other's cultural and behavioral expectations and norms. Because TTO officers may favor those who understand US culture and commercialization processes, they may be less likely to assist foreign-born faculty, particularly those with greater cultural distance from the US.

As such, we hypothesize:

Hypothesis 3 Foreign-born faculty with greater cultural distance from the United States will be less likely to commercialize their inventions.

Hypothesis 4 Foreign-born faculty with greater cultural distance from the United States will be less likely to report that TTOs work on their behalf to commercialize their inventions.

3 Study design

In this paper we analyze the differences in access to commercialization opportunities for foreign and native-born academic scientists in the United States. To do so, we use data from the 2010 *National Survey on Intellectual Property in Academic Science and Engineering* (Hayter and Feeney 2017; Huang et al. 2011; Wu et al. 2015), which studied

faculty who held a university-owned patents.[1] The survey was administered to a sample of faculty-scientists that held a patent in 2006 along with a matched sample of academics from similar departments and universities with no patents. This study fits into the stream of research using web-based surveys to investigate innovation activities of academic scientists both within and outside of universities (Fini et al. 2010; Sauermann and Roach 2013; Wu et al. 2015). While similar to prior work surveying individual scientists on licensing activity (Jensen et al. 2003; Jensen and Thursby 2001), we focus on the invention as the unit of analysis and the universe of patents assigned to universities in 1 year. The survey was administered to a total of 2898 university inventors with a total response rate of 36%. The relatively high response rate is well above the norm for national surveys of this type (Sauermann and Roach 2013), which is likely due to significant efforts to tailor the surveys for each participant, piping in the patent names and asking specific questions related to each patent.

The survey was cross sectional and queried respondents on their attitudes, decisions, and experience related to invention disclosure and patenting at their university. One set of questions in the survey asked respondents to select which of their patents (if they had multiple) they were most involved with for further questions on that specific invention. Because our study is primarily concerned with commercialization, we focus only on the responses of those faculty that held a patent in 2006. The following analyses focus on these questions related to a specific patent and the sample of respondent who answered that set of questions completely. That limitation provided 645 complete responses.

3.1 Dependent variables

The primary analysis study the status of commercialization using two dependent variables. The first variable is whether the patent has been licensed at the time of the survey, while the second accounts for whether the TTOs had worked with a company to commercialize the selected patent. We use the second variable to examine whether TTOs are working on the commercialization process on behalf of the faculty. All respondents who were uncertain about whether their patent had been licensed were removed from the final sample.

[1] The sampling frame for the survey which provided the core data used in this study contained both a patentor sample and the non-patentor sample. The patentor sample targets the population of scientists and engineers who are listed as inventors on the U.S. patents assigned to U.S. universities or affiliated foundations/hospitals in 2006. The list of such patentors was developed based on a review of the Patents CLASS CD-ROM, with those removed who did not have contact information or who were no longer employed by academic institution. That provided 3034 patentors, of which 1600 were randomly selected to be surveyed. In order to investigate the difference between scientists and engineers who patent and those who do not patent in terms of their perceptions and attitudes towards university patenting, we construct a non-patentor sample by pairing each patentor with a randomly selected non-patentor from the patentor's university department. The data has previously been used in three studies. Huang et al. (2011) studied how department incentives and individual characteristics impacted whether an academic-scientist held a patent while Wu et al. (2015) studied inventors attitudes towards the commercialization of their research. In this study we focus on differences between the native and foreign-born, which neither previous study had done, and only focus on the sample of respondents that held a patent rather than the reasons that predict whether an individual has patented. The third study, Hayter and Feeney (2017), focused on inventors, but sought to understand why scientists patented externally rather than within their university and did not look at differences based on nationality.

3.2 Independent variables

We develop a model used across all analyses in order to study patents and commercialization. In all, we use four variables to account for foreignness because a single dichotomous indicator based on place of birth may obscure heterogeneity within the experience of faculty (Welch et al. 2018). In addition to whether the respondent was born in the United States or not, we include three other variables to account for cultural distance between foreign-born faculty and the United States. First, we use self-reported race, a binary variable, to determine whether they are White and foreign-born or whether they are non-White and foreign-born. Second, we use the respondents' continent of origin, to indicate whether they were born in Europe, Asia, or any other continent. Finally, we create a continuous variable that accounts for the percentage of one's life in America. In the survey, all respondents were asked how many years they had lived in the United States. The response to that question is divided by their age to account for the percentage of one's life lived in America; the variable will take a value of 1 for anyone born in the US that has not lived abroad and will range close to 0 for recent arrivals.

These operationalizations of foreignness allow us to collectively test the four hypotheses outlined above, relating to access to commercialization opportunities as well as how cultural distance moderates these relationships. We predict that foreign-born faculty are less likely to commercialize their patents, and that non-white, non-European, and more recent arrival foreign-born have an even larger penalty because they have a greater cultural distance from the United States.

3.3 Control variables

In addition to foreignness, we model other aspects that can predict licensing of patents for an academic scientist. These variables cluster around two concepts, related to the specific patent and the individual scientist.

Relating to the specific patent, we first include a measure of the overall significance of each invention. Respondents were asked about the commercial, technological, and scholarly significance of the patent and these ideas collectively point towards the overall perceived quality of the invention and should positively predict the chances that it is being licensed or that the TTO has worked with a company on commercial opportunities (Svensson 2012). The three questions on significance were highly correlated and were reduced to a single variable with the factor loadings included in "Appendix 1".

We include two variables gathered directly from the patent applications on the United States Patent and Trademark Office website to account for the impact of team-level factors on commercialization. Patents with larger teams of inventors have been shown to have a larger impact (Breitzman and Thomas 2015; Wuchty et al. 2007) but that there are costs related to communication particularly as distance grows (Bercovitz and Feldman 2011) The first variable is the count of foreign-affiliated faculty that were on the patent application, and the second is the count of United States-affiliated faculty on the patent. These variables only account for where the inventors were located at the time of the application and cannot distinguish their places of birth. However, these variables should account for how many other inventors were involved in the development of each patent, as well as potential differences in the success at commercialization based on the international makeup of the team. Having foreign-affiliated inventors on the patent may increases the difficulty of

coordinating a commercialization strategy, as well as introduce additional communication challenges in negotiating.

We next include aspects of the process of patenting with two variables. First, we test how early the respondent realized the research they were completing would be patentable. Such research should be more valuable and viable, and thus more likely to be commercialized. In addition, we include how early the respondent disclosed their research to the TTO. Inventions disclosed early should provide the TTO more opportunity to find commercial opportunities and thus be more likely to be licensed or working towards commercialization.

Inventions that are generated by research funded by industry should be more directly applicable to their needs and have greater commercial appeal (Blumenthal et al. 1996; Perkmann et al. 2013). Thus, we include a measure for the percentage of funding from industry that was used for the research that generated each specific patent. For that variable we predict a positive result.

Contact with the TTOs should increase the chances of a patent being commercialized. Respondents were asked whether they had been contacted by their TTO in three different ways: via email, face-to-face, or departmental visits. These three variables were reduced to a single measure using factor analysis to account for overall contact from the TTO. Factor loadings appear in "Appendix 2".

Separately from the invention itself, an academic scientists views and traits have been shown to impact the patenting process as well (Huang et al. 2011). The respondent's level of past experience with patenting and commercialization are both separately included. Experience with patenting is accounted for with a continuous measure of the total number of patents they reported having received, while commercialization is measured by whether they have successfully profited off a prior invention. The number of patents held by the inventor is logged in the final model, while having commercialized is a dichotomous variable. Higher levels of such experience should provide applicable training and preparation for their selected patent to be commercialized and thus should be positive.

We also test the impact of the respondents' stated view towards open science. Academic scientist who strongly believe in open science may be less willing to push for commercialization (and privatization) of their research and inventions, and therefore be less likely to work with the TTO to have their patents licensed (Huang et al. 2011). We follow Huang et al. (2011) in creating a variable for how strongly the respondent believes in open science by taking the sum of responses from 0 (strongly disagree) to 3 (strongly agree) to four statements that collectively measure one's attitude toward open science:

1. Commercial opportunity distracts academic scientists from doing good research;
2. Pressures to patent prevent faculty from focusing on publishable research;
3. Patenting activity reduces the ability to present research findings at conferences and other public venues; and
4. Publishing and protecting IP are two goals that are fully compatible in modern universities (reversed).

Thus, the variable open science attitude can range from 0 to 12, with a high score indicating that the respondent believes patenting and IP protection conflicts with the conduct of science. The final variable has a Cronbach's Alpha of 0.71, demonstrating a good level of internal consistency.

We further assess the interests and aspirations of academic scientists by including two reasons that faculty patented their inventions. We include in the model two questions,

relating to how influential the desire was to commercialize the research and to generate licensing revenue as reasons that faculty may have patented their research (D'Este and Perkmann 2011). Motivation is recoded from the four levels of influence given in the survey to a dichotomous variable in which a strong and moderate influence was coded one (1) and no influence and weak influence were coded zero (0). Both these questions should positively predict their likelihood of having their patents commercialized.

We also control for the respondent's gender. Literature has demonstrated the ways that female scientists are disadvantaged through the commercialization process (Whittington and Smith-Doerr 2005), so the variable should negatively predict licensing and commercialization in our models.

In addition, the academic field of an inventor's work may impact how commercially viable their patent becomes. In particular, we control for whether they work in engineering and life sciences fields, in contrast with the respondents from chemistry, physics, or medical science, and predict that both should have a positive effect on commercialization.

Finally, we include fixed-effects for the university the inventor that worked at during the invention of the patent about which they chose to answer questions.

Descriptions for all the variables in the analysis are included in Table 1. All analyses apply logistic regression due to the dichotomous dependent variables; as shown in Table 1, our dependent variables are largely balanced in the sample, so the presence of zeros does not need to be corrected for. The estimations are made with conditional logistic models to account for the inclusion of university-level fixed effects and coefficients report odds-ratios for both sets of regressions. Correlations for the independent and control variables are reported in Table 2.

4 Results

Table 3 displays results for the models predicting whether a patent has been licensed by the time of the survey and reports odds ratios. Across all four models, results indicate that the foreign-born are less likely to have commercialized their patents, providing some support for Hypothesis 1, although these results are not consistently statistically significant. However, the directions of the relationship in the sample are clear and consistent regardless of how foreignness is defined, based on where the respondent was born, or including additional factors such as race or ethnicity. In addition, spending a greater share of one's life in the United States makes the result for the foreign-born closer to that of the native, though that variable is insignificant. Specifically, the foreign-born have odds 0.66 times lower of reporting that one's patent was licensed compared to the US-born, though the effect is insignificant. The effect is larger and significant for the white foreign-born and for the foreign-born from outside of Europe and Asia, providing mixed support for Hypothesis 3 that cultural distance also plays a role in shaping the impact of foreignness and access to opportunities to commercialize inventions.

The additional control variables in the model generally behave as predicted, though with limited significance in predicting whether the patent was commercialized. Having successfully commercialized a patent in the past increased the odds by a factor of 2.82 of having licensed their selected patent, as did rating the patent as being more significant overall (79% increase in the odds). The odds of having your patent licensed were 0.55 times lower for each foreign-affiliated collaborator on the application, though there was no significant effect from having a larger team of inventors overall.

Table 1 Summary statistics and description of variables used

Variable	*N*	Mean	SD	Min	Max	Description
Dependent variables						
Patent is licensed	645	0.46	0.499	0	1	Has selected patent already been licensed
TTO worked with company	645	0.337	0.473	0	1	Has the Technology Transfer Office (TTO) worked with a company to further develop this invention for commercial use
Licensed with spinoff	288	0.375	0.485	0	1	Patent is licensed with spinoff
Licensed with private company	288	0.376	0.482	0	1	Patent is licensed with external private company
Licensed with university	288	0.118	0.323	0	1	Patent is licensed with university
Licensed with government	288	0.122	0.32	0	1	Patent is licensed with government
Foreignness						
Foreign-born	645	0.391	0.488	0	1	Respondent born outside United States
White foreign-born	645	0.225	0.418	0	1	Respondent born outside United States and racially white
Non-White foreign-born	645	0.166	0.373	0	1	Respondent born outside United States and not racially white
European foreign-born	645	0.155	0.363	0	1	Respondent born in European continent
Asia foreign-born	645	0.146	0.354	0	1	Respondent born in Asian continent
Other foreign-born	645	0.089	0.285	0	1	Respondent born outside United States, Europe, and Asia
% Years in US	645	0.812	0.267	0	1	% of years respondent reported living in United States (100% for native born)
Control variables						
Overall significance of patent	645	0	0.976	− 3.03	1.253	Factor for technological, Scholarly, and Commercial significance of Patent
Foreign-affiliated collaborators on patent	645	0.125	0.366	0	3	Number of collaborators listed on patent application affiliated with Universities outside the United States
USA-affiliated collaborators on patent	645	3.534	2.012	1	15	Number of collaborators listed on patent application affiliated with Universities inside the United States
Early determination of patentability	645	0.52	0.5	0	1	Was research determined to be patentable prior to the presentation or publication of results?
Early filing with TTO	645	0.478	0.5	0	1	Was invention disclosed to TTO office at least 6 months prior to filing for patent?
% Funding from industry	645	3.777	13.078	0	100	Percentage of funding for patent from industry
Overall contact from TTO	645	0	0.879	− 0.52	2.246	Factor for receiving contact from TTO by email, visits, and face to face
Number of patents ever held (logged)	645	11.181	19.169	1	201	Number of patents held during career (logged)

Table 1 (continued)

Variable	*N*	Mean	SD	Min	Max	Description
Has successfully commercialized	645	0.569	0.496	0	1	Has received payments from past patents
Open science attitude	645	5.263	1.869	0	11	Combination of four questions concerning attitude towards open science
Motivation-commercialization	645	0.528	0.5	0	1	Commercialization was a strong or moderate motivation for patenting research
Motivation-licensing	645	0.865	0.342	0	1	Licensing was a strong or moderate motivation for patenting research
Female	645	0.106	0.308	0	1	Respondent is Female
Engineering	645	0.328	0.47	0	1	Primarily affiliated with an engineering field
Life Sciences	645	0.414	0.493	0	1	Primarily affiliated with a life science field

The total number of complete surveys was 1055. $N=645$ is for the total sample with no missing observations used to study whether patents are licensed or whether the TTO is working with a company. Most descriptive statistics are reported for this complete sample, but there are few differences with the entire sample or the limited sample used to study where patents are licensed. $N=288$ is for the sample of just patents that have been licensed

Table 2 Correlation table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Foreign-born (1)	1															
Overall significance of patent (2)	0.12**	1														
Foreign-affiliated coauthors on patent (3)	0.01	0.05	1													
USA-affiliated coauthors on patent (4)	−0.02	0.01	0.2***	1												
Early determination of patentability (5)	0.06	−0.06	−0.02	−0.01	1											
Early filing with TTO (6)	0.01	−0.03	0.02	−0.06	0.01	1										
% Funding from industry (7)	0.04	0.05	0.05	0.02	−0.05	0.04	1									
Overall contact from TTO (8)	−0.01	0.14***	0.03	−0.02	−0.17***	−0.02	0.09*	1								
Number of patents ever held (9)	−0.06	0.12**	−0.05	0.01	−0.13***	−0.06	0.01	0.26***	1							
Has successfully commercialized (10)	−0.05	0.07	−0.02	−0.01	−0.05	−0.08*	0.03	0.18***	0.25***	1						
Open science attitude (11)	0.10*	−0.08*	−0.01	−0.01	0.08*	0.11**	0.09*	−0.11**	−0.16***	−0.07	1					
Motivation-commercialization (12)	0.06	0.09*	−0.01	−0.06	−0.01	−0.08	0.04	0.10**	0.04	0.05	−0.01	1				

Table 2 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Motivation-licensing (13)	−0.05	0.10*	0.04	−0.01	−0.12**	−0.01	0.06	0.12**	0.1*	0.08*	−0.04	0.31***	1			
Female (14)	−0.01	−0.03	−0.02	0.02	0.06	0.06	−0.02	−0.05	−0.09*	−0.1*	0.09*	−0.06	−0.10**	1		
Engineering (15)	0.10*	0.17***	0.03	−0.01	−0.05	0.08	0.07	0.037	0.07	−0.04	−0.08*	0.08*	0.11**	−0.05	1	
Life sciences (16)	−0.09*	−0.2***	−0.03	−0.05	0.06	−0.04	−0.08*	−0.03	−0.10*	0.08*	0.02	−0.03	−0.12**	0.13***	−0.58**	1

Pearson correlation coefficients for the full sample used to model which patents are licensed

Table 3 Conditional logit regression results for whether patent is licensed

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	0.66 (0.17)			
White foreign-born (omitted: US-born)		0.53** (0.16)		
Non-White foreign-born (omitted: US-born)		0.92 (0.35)		
European foreign-born (omitted: US-born)			0.89 (0.30)	
Asian foreign-born (omitted: US-born)			0.45*** (0.14)	
Other foreign-born (omitted: US-born)			0.72 (0.26)	
% of years in US				1.57 (0.72)
Overall significance of patent	1.79*** (0.24)	1.78*** (0.24)	1.75*** (0.23)	1.76*** (0.23)
Foreign-affiliated collaborators on patent	0.55** (0.13)	0.55** (0.13)	0.56** (0.14)	0.54** (0.13)
USA-affiliated collaborators on patent	0.98 (0.059)	0.98 (0.060)	0.97 (0.061)	0.98 (0.058)
Early determination of patentability	0.85 (0.18)	0.83 (0.18)	0.83 (0.19)	0.84 (0.18)
Early filing with TTO	1.02 (0.25)	1.04 (0.26)	1.03 (0.26)	1.00 (0.24)
% Funding from industry	0.99 (0.15)	0.98 (0.14)	0.98 (0.14)	0.99 (0.15)
Overall contact from TTO	0.88 (0.13)	0.87 (0.13)	0.87 (0.13)	0.88 (0.13)
Number of patents ever held (log)	1.16 (0.15)	1.19 (0.16)	1.18 (0.16)	1.15 (0.15)
Has successfully commercialized	3.82*** (0.97)	3.84*** (0.95)	3.87*** (0.99)	3.78*** (0.94)
Open science attitude	0.89 (0.065)	0.90 (0.067)	0.90 (0.066)	0.89 (0.065)
Motivation-commercialization	1.16 (0.28)	1.18 (0.29)	1.16 (0.28)	1.14 (0.27)
Motivation-licensing	0.75 (0.29)	0.70 (0.28)	0.70 (0.28)	0.76 (0.29)
Female (omitted: male)	1.07 (0.49)	1.10 (0.51)	1.09 (0.49)	1.09 (0.51)
Engineering (omitted: chemistry, physics, and medical science)	0.89 (0.32)	0.88 (0.32)	0.92 (0.34)	0.86 (0.30)
Life sciences (omitted: chemistry, physics, and medical science)	1.04 (0.28)	1.05 (0.28)	1.09 (0.30)	1.04 (0.28)
Observations	650	650	650	650
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.19	0.20	0.20	0.19
Log likelihood	− 167	− 166	− 165	− 168

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 4 shows whether the TTO has worked directly with a company to commercialize the respondent's patent. The findings are generally consistent with those shown in Table 3 above, particularly with respect to the relationship of foreignness and commercializing research. When looking at the foreign-born as a single category, their odds of having the TTO working to commercialize their patent are only 0.66 times as high as the native born when holding all else constant, though this difference only reaches the 0.1 level of significance. In addition, non-white foreign-born and Asian foreign-born have odds only 0.51 and 0.45 times as high as the native-born of having the TTO work on their behalf, holding all else constant. Despite the low levels of statistical significance, the relationship between foreignness and commercialization is consistent, collectively providing limited support for Hypotheses 2 and 4.

The overall significance of the patent is similarly a strong predictor of having the TTO work with one's patent, increasing the odds by roughly 50% across the models. In addition, having higher levels of contact with the TTO has a similar relationship in magnitude and significance. This increased contact may relate directly in part to work on the specific patent, but the survey queries about contact over a longer period of time, so the variable helps to demonstrate how relationships between TTOs and faculty may be important in commercializing one's research within a university. Finally, the TTOs are most likely to work to commercialize the patents for scientists from the life sciences, in comparison to the hard sciences.

The remaining control variables in the model generally behave as predicted, though with limited significance in predicting whether the patent had been worked on by the TTO. The model performed marginally better when predicting licensing than which inventions the TTO had worked with to commercialize, though the differences are more related to the significance of individual variables rather than their directions.

4.1 Additional analyses

As an exploratory effort and in order improve our understanding of commercialization behavior of foreign-born faculty, we analyze where patents have been licensed once they are commercialized. Here, the sample is limited only to those patents that were licensed, reducing the number of responses studied from 645 to 288. The survey asked respondents whether licenses were held by respondents' own spinoffs, private companies, universities, or the government, each of which is converted to a dichotomous dependent variable. Table 5 presents summary statistics for these four variables. The same models as those tested above and described in the methodology section are utilized.

Tables 6, 7, 8 and 9 display additional differences in the commercialization process for native and foreign-born faculty. The models are generally consistent with the results from Tables 3 and 4 relating to which patents are commercialized. However, clear differences are apparent in where different groups, based on foreignness, have their patents licensed.

In particular, as shown in Table 6, the foreign-born are less likely than native-born academic scientists to have their selected patent used as part of a spinoff they have started; the foreign-born have odds of having their patents licensed to a spinoff they own that are 0.34 times as high as that for the native born. The results are statistically significant and similar in magnitude regardless of whether foreignness is measured dichotomously, or if the race and ethnicity of respondents is considered as well. In addition, the percentage of an individual's life spent in the United States has a positive effect, indicating that greater experience in

Table 4 Conditional logit regression results for whether TTO is currently working with company

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	0.66* (0.15)			
White foreign-born (omitted: US-born)		0.78 (0.22)		
Non-White foreign-born (omitted: US-born)		0.51** (0.16)		
European foreign-born (omitted: US-born)			0.89 (0.30)	
Asian foreign-born (omitted: US-born)			0.45*** (0.14)	
Other foreign-born (omitted: US-born)			0.72 (0.26)	
% of years in US				1.93 (0.79)
Overall significance of patent	1.47*** (0.19)	1.49*** (0.20)	1.51*** (0.20)	1.46*** (0.19)
Foreign-affiliated collaborators on patent	0.74 (0.22)	0.76 (0.23)	0.76 (0.23)	0.74 (0.23)
USA-affiliated collaborators on patent	0.95 (0.061)	0.95 (0.062)	0.95 (0.061)	0.95 (0.061)
Early determination of patentability	0.94 (0.23)	0.96 (0.24)	0.97 (0.24)	0.94 (0.23)
Early filing with TTO	0.94 (0.23)	0.93 (0.22)	0.92 (0.22)	0.93 (0.22)
% Funding from industry	0.92 (0.098)	0.93 (0.10)	0.94 (0.10)	0.92 (0.100)
Overall contact from TTO	1.66*** (0.21)	1.64*** (0.21)	1.65*** (0.21)	1.65*** (0.21)
Number of patents ever held (log)	1.19 (0.15)	1.18 (0.14)	1.17 (0.14)	1.18 (0.14)
Has successfully commercialized	0.76 (0.18)	0.75 (0.18)	0.75 (0.18)	0.76 (0.18)
Open science attitude	1.03 (0.050)	1.03 (0.051)	1.03 (0.050)	1.03 (0.050)
Motivation-commercialization	1.12 (0.22)	1.13 (0.22)	1.13 (0.22)	1.10 (0.21)
Motivation-licensing	1.15 (0.39)	1.20 (0.41)	1.21 (0.41)	1.17 (0.40)
Female (omitted: male)	0.86 (0.32)	0.86 (0.32)	0.85 (0.32)	0.85 (0.32)
Engineering (omitted: chemistry, physics, and medical science)	1.32 (0.38)	1.31 (0.38)	1.32 (0.39)	1.32 (0.39)
Life sciences (omitted: chemistry, physics, and medical science)	1.75** (0.47)	1.71* (0.47)	1.70* (0.47)	1.79** (0.48)
Observations	650	650	650	650
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.12	0.12	0.12	0.12
Log likelihood	−176	−175	−175	−176

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 5 Summary statistics for additional analyses

Variable	*N*	Mean	SD	Min	Max	Description
Dependent variables						
Licensed with spinoff	288	0.375	0.485	0	1	Patent is licensed with spinoff
Licensed with private company	288	0.376	0.482	0	1	Patent is licensed with external private company
Licensed with university	288	0.118	0.323	0	1	Patent is licensed with university
Licensed with government	288	0.122	0.32	0	1	Patent is licensed with government

The total number of complete surveys was 1055. $N=288$ is for the sample of just patents that have been licensed. There are few differences with the descriptive statistics for foreignness or the control variables from the entire sample reported in Table 1

the United States increases the odds of having their patent licensed with a spinoff. Finally, it is worth noting that more significant patents are more likely to be licensed with spinoffs, though this effect only reaches low levels of significance in one model.

Conversely, as shown in Table 7, the patents of foreign-born scientists are more likely to be licensed by a private company. These results are significant for all specifications except in the cases of white and European foreign-born, lending further evidence to the importance of cultural distance. In addition, having a foreign-affiliated collaborator on the patent application lowers the odds of having the patent licensed by a private company.

Table 8 displays mixed results for the impact of foreignness on having one's patent licensed by a university. White foreign-born and European foreign-born both have lower odds of having their patents licensed there, and the difference is significant. While the other results do not reach significance, they show greater variation than in the other models, with non-white foreign-born and Asian foreign-born having higher odds of licensing with a university. Of note, patents with foreign-affiliated collaborators on them have higher odds of licensing with universities, though the result only reaches low levels of significance. Finally, inventors that file early with the TTO, are in the life sciences, or are female have greater odds of having their inventions licensed by universities.

Finally, no operationalization of foreignness reached significance for licensing with a government, and the coefficients are mixed in their direction. However, patents with more foreign-affiliated collaborators have significantly higher odds of being licensed by a government. Conversely, patents rated with less significance or were invented by those motivated by licensing were less likely to be licensed to governments.

5 Discussion

In this paper we investigated the intersection of internationalization and commercialization of inventions in US universities, using the patent as the unit of analysis. Commercialization is defined broadly and measured as three dimensions of a process: licensing a patent, working with the TTO to commercialize, and the type of organization that holds the license. In addition, we measure internationalization in multiple ways, looking at the nationality, race, continent of origin and time residing in the US for academic inventors. Our findings provide relatively specific detail about how foreign-born scholars are involved

Table 6 Conditional logit regression results for whether patent is licensed by spinoff owned by inventor

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	0.34*** (0.11)			
White foreign-born (omitted: US-born)		0.36** (0.15)		
Non-White foreign-born (omitted: US-born)		0.30** (0.13)		
European foreign-born (omitted: US-born)			0.49 (0.28)	
Asian foreign-born (omitted: US-born)			0.32** (0.18)	
Other foreign-born (omitted: US-born)			0.19*** (0.10)	
% of years in US				10.4*** (7.14)
Overall significance of patent	1.50 (0.37)	1.51 (0.38)	1.54* (0.40)	1.45 (0.36)
Foreign-affiliated collaborators on patent	1.95 (1.17)	1.94 (1.15)	1.88 (1.08)	2.04 (1.18)
USA-affiliated collaborators on patent	1.15 (0.12)	1.14 (0.12)	1.15 (0.11)	1.16 (0.12)
Early determination of patentability	0.83 (0.27)	0.84 (0.29)	0.87 (0.30)	0.86 (0.29)
Early filing with TTO	1.46 (0.34)	1.45 (0.34)	1.50* (0.35)	1.46 (0.36)
% Funding from industry	1.34 (0.96)	1.32 (0.99)	1.40 (1.04)	1.62 (1.14)
Overall contact from TTO	0.17*** (0.085)	0.17*** (0.087)	0.17*** (0.084)	0.17*** (0.084)
Number of patents ever held (log)	0.77* (0.12)	0.77* (0.12)	0.76* (0.12)	0.73* (0.12)
Has successfully commercialized	1.24 (0.53)	1.23 (0.51)	1.32 (0.55)	1.27 (0.53)
Open science attitude	0.94 (0.74)	0.97 (0.80)	0.89 (0.73)	0.93 (0.74)
Motivation-commercialization	0.54 (0.43)	0.54 (0.43)	0.52 (0.39)	0.52 (0.42)
Motivation-licensing	1.34 (0.61)	1.34 (0.61)	1.48 (0.65)	1.49 (0.65)
Female (omitted: male)	0.91 (0.45)	0.91 (0.45)	1.00 (0.47)	0.95 (0.45)
Engineering (omitted: chemistry, physics, and medical science)	1.50 (0.37)	1.51 (0.38)	1.54* (0.40)	1.45 (0.36)
Life sciences (omitted: chemistry, physics, and medical science)	1.95 (1.17)	1.94 (1.15)	1.88 (1.08)	2.04 (1.18)
Observations	288	288	288	288
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.26	0.26	0.27	0.27
Log likelihood	−56.4	−56.3	−55.7	−55.6

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant. The sample size of 288 indicates the number of individual observations with a licensed patent in the sample

***$p<0.01$; **$p<0.05$; *$p<0.1$

Table 7 Conditional logit regression results for whether patent is licensed by private company

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	7.14** (6.86)			
White foreign-born (omitted: US-born)		2.99 (4.32)		
Non-White foreign-born (omitted: US-born)		8.02*** (6.58)		
European foreign-born (omitted: US-born)			1.51 (2.67)	
Asian foreign-born (omitted: US-born)			3.19*** (2.54)	
Other foreign-born (omitted: US-born)			1.92*** (2.92)	
% of years in US				0.0096*** (0.016)
Overall significance of patent	0.62 (0.26)	0.55 (0.22)	0.57 (0.25)	0.60 (0.27)
Foreign-affiliated collaborators on patent	0.12*** (0.083)	0.098*** (0.085)	0.13** (0.13)	0.088*** (0.064)
USA-affiliated collaborators on patent	0.63 (0.27)	0.57 (0.24)	0.62 (0.20)	0.59 (0.28)
Early determination of patentability	1.66 (0.89)	0.92 (0.65)	0.88 (0.53)	1.46 (0.92)
Early filing with TTO	4.09*** (1.74)	4.07*** (2.06)	4.34** (2.53)	5.52*** (2.72)
% Funding from industry	2.27 (2.70)	3.27 (3.94)	1.35 (1.44)	1.54 (2.33)
Overall contact from TTO	0.24* (0.20)	0.21* (0.17)	0.18** (0.13)	0.22** (0.16)
Number of patents ever held (log)	0.89 (0.22)	0.84 (0.20)	0.80 (0.24)	0.93 (0.24)
Has successfully commercialized	0.81 (0.38)	0.91 (0.51)	1.34 (1.15)	0.85 (0.49)
Open science attitude	7.77** (6.97)	7.34* (8.14)	4.82 (5.62)	9.60*** (8.13)
Motivation-commercialization	1.50 (2.27)	3.06 (5.79)	3.39 (5.23)	1.49 (2.43)
Motivation-licensing	1.97 (1.57)	2.08 (1.55)	1.59 (1.46)	2.13 (1.74)
Female (omitted: male)	6.20*** (3.57)	5.57*** (3.51)	6.41*** (4.24)	8.03*** (4.92)
Engineering (omitted: chemistry, physics, and medical science)	0.62 (0.26)	0.55 (0.22)	0.57 (0.25)	0.60 (0.27)
Life sciences (omitted: chemistry, physics, and medical science)	0.12*** (0.083)	0.098*** (0.085)	0.13** (0.13)	0.088*** (0.064)
Observations	288	288	288	288
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.47	0.52	0.56	0.50
Log likelihood	−17.1	−15.5	−14.3	−16

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant. The sample size of 288 indicates the number of individual observations with a licensed patent in the sample

***$p<0.01$; **$p<0.05$; *$p<0.1$

Table 8 Conditional logit regression results for whether patent is licensed by a university

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	0.54 (0.22)			
White foreign-born (omitted: US-born)		0.26** (0.15)		
Non-White foreign-born (omitted: US-born)		1.57 (1.03)		
European foreign-born (omitted: US-born)			0.18*** (0.11)	
Asian foreign-born (omitted: US-born)			1.49 (0.95)	
Other foreign-born (omitted: US-born)			0.38 (0.31)	
% of years in US				3.84* (2.82)
Overall significance of patent	1.07 (0.31)	1.08 (0.34)	1.07 (0.33)	1.08 (0.33)
Foreign-affiliated collaborators on patent	2.63* (1.49)	2.97* (1.76)	3.04* (1.81)	2.70* (1.52)
USA-affiliated collaborators on patent	0.84 (0.13)	0.82 (0.12)	0.83 (0.11)	0.84 (0.13)
Early determination of patentability	1.59 (1.14)	1.28 (0.89)	1.34 (0.96)	1.66 (1.16)
Early filing with TTO	2.16*** (0.57)	2.15*** (0.56)	2.19*** (0.55)	2.15*** (0.57)
% Funding from industry	0.41 (0.41)	0.42 (0.38)	0.38 (0.36)	0.48 (0.47)
Overall contact from TTO	0.24** (0.17)	0.21* (0.17)	0.20* (0.16)	0.22** (0.17)
Number of patents ever held (log)	1.19 (0.17)	1.18 (0.18)	1.20 (0.19)	1.18 (0.16)
Has successfully commercialized	1.90 (1.07)	2.27 (1.28)	2.18 (1.20)	1.78 (0.99)
Open science attitude	0.39 (0.42)	0.30 (0.34)	0.28 (0.31)	0.36 (0.42)
Motivation-commercialization	0.68 (0.64)	0.65 (0.56)	0.62 (0.53)	0.58 (0.54)
Motivation-licensing	1.73 (1.18)	2.05 (1.65)	1.86 (1.63)	1.71 (1.20)
Female (omitted: male)	2.98** (1.59)	3.30** (1.95)	3.17** (1.85)	3.09** (1.70)
Engineering (omitted: chemistry, physics, and medical science)	1.07 (0.31)	1.08 (0.34)	1.07 (0.33)	1.08 (0.33)
Life sciences (omitted: chemistry, physics, and medical science)	2.63* (1.49)	2.97* (1.76)	3.04* (1.81)	2.70* (1.52)
Observations	288	288	288	288
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.19	0.22	0.23	0.19
Log likelihood	−34.8	−33.2	−33	−34.6

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant. The sample size of 288 indicates the number of individual observations with a licensed patent in the sample

***$p<0.01$; **$p<0.05$; *$p<0.1$

Table 9 Conditional logit regression results for whether patent is licensed by a government

	(1)	(2)	(3)	(4)
Foreign-born (omitted: US-born)	0.95 (1.00)			
White foreign-born (omitted: US-born)		1.00 (1.09)		
Non-White foreign-born (omitted: US-born)		0.88 (1.14)		
European foreign-born (omitted: US-born)			0.31 (0.39)	
Asian foreign-born (omitted: US-born)			0.63 (0.66)	
Other foreign-born (omitted: US-born)			3.20 (4.06)	
% of years in US				3.65 (6.89)
Overall significance of patent	0.23** (0.17)	0.22** (0.16)	0.17** (0.14)	0.23** (0.16)
Foreign-affiliated collaborators on patent	18.2*** (16.4)	18.4*** (16.5)	34.9*** (45.8)	23.1*** (23.7)
USA-affiliated collaborators on patent	0.79 (0.24)	0.79 (0.24)	0.88 (0.24)	0.73 (0.26)
Early determination of patentability	0.098 (0.14)	0.096* (0.14)	0.11 (0.15)	0.079* (0.11)
Early filing with TTO	16.5*** (11.5)	16.9*** (10.7)	21.7*** (13.4)	20.2*** (17.8)
% Funding from industry	0.49 (0.68)	0.48 (0.65)	0.26 (0.30)	0.48 (0.76)
Overall contact from TTO	0.0037** (0.0080)	0.0035*** (0.0075)	0.0021*** (0.0045)	0.0025*** (0.0047)
Number of patents ever held (log)	1.67*** (0.28)	1.68*** (0.30)	1.89*** (0.35)	1.84*** (0.35)
Has successfully commercialized	1.29 (1.14)	1.31 (1.07)	1.86 (1.28)	1.48 (1.45)
Open science attitude	0.36 (0.39)	0.35 (0.40)	0.22 (0.24)	0.29 (0.32)
Motivation-commercialization	0.35 (0.62)	0.36 (0.62)	0.30 (0.49)	0.27 (0.52)
Motivation-licensing	0.097** (0.11)	0.091** (0.085)	0.074** (0.089)	0.074** (0.092)
Female (omitted: male)	0.21 (0.33)	0.20 (0.30)	0.23 (0.36)	0.20 (0.31)
Engineering (omitted: chemistry, physics, and medical science)	0.23** (0.17)	0.22** (0.16)	0.17** (0.14)	0.23** (0.16)
Life sciences (omitted: chemistry, physics, and medical science)	18.2*** (16.4)	18.4*** (16.5)	34.9*** (45.8)	23.1*** (23.7)
Observations	288	288	288	288
Institution FE	Yes	Yes	Yes	Yes
Pseudo R^2	0.63	0.63	0.64	0.64
Log likelihood	− 14.2	− 14.2	− 13.7	− 13.9

Robust standard errors in parentheses. Coefficients reported as odds-ratios—an odds ratio of 1 indicates no effect of the variable on the dependent; a value below one indicates lower odds of the dependent variable, and a value above one indicates higher odds, holding all else constant. The sample size of 288 indicates the number of individual observations with a licensed patent in the sample

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

in commercialization activities and point to potential opportunities for US university and national policy changes to better capture invention output.

More specifically, across all models we first find that foreign-born faculty are generally less likely to have their patents licensed or have the TTO work with a company to commercialize their inventions, providing some support for Hypotheses 1 and 2. These results fit within a growing literature on the challenges and issues minorities and women face in higher education, particularly with the added finding that non-white foreign-born were driving much of the differences in licensing of university inventions. In addition, our exploratory work found that foreign-born, no matter how measured, were less likely than the native-born to license their patents to a spinoff, though they were more likely to license to an established private company.

As anticipated, our findings present a more complex picture than is normally found in the patenting literature on foreign-born faculty in US higher education institutions. Foreign status does not lead to more licensing, as it does with patenting (Corley and Sabharwal 2007; Hunt and Gauthier-Loiselle 2010); in fact, it leads to less licensing, even controlling for motivation and a multitude of other factors. Foreign status is negatively associated with whether the TTO is currently working with a company on behalf of the inventor, in line with previous research (Jung and Ejermo 2014; Libaers 2014). We posited in our hypotheses that a negative relationship could be due to workplace discrimination, researcher preference or the complex institutional setting of commercialization. However, the percentage of the respondent's lifetime spent in the US does not significantly affect the probability the patent is licensed or the probability the TTO worked on their behalf to commercialize their invention. By contrast, non-whites and Asians are less likely to receive TTO commercialization assistance, while Asians and white foreign-born are less likely to have licensed their patent. Thus, there appears to be greater support for the 'workplace discrimination' and 'researcher preference' arguments, rather than the 'institutional complexity' rationale for explaining lower licensing of foreign-born faculty. It is possible that non-white and 'other' origin foreign-born faculty are less motivated to license and therefore fail to invest the effort to pursue licensing either independently or with a TTO. But because we control for motivation and patent quality, the evidence tends to support the workplace discrimination rationale. Nevertheless, we cannot discount the possibility that foreign-born faculty prefer not to fully engage the TTO in commercialization due to lack of confidence, perceived burden or some other reason.

This picture holds upon further review of the findings on licensing with spinoffs and private companies. Here the results show that foreign-born faculty are more likely to license with private companies and less likely to enter into spinoffs. This finding is somewhat unexpected given prior studies showing that companies are less likely to work with foreign-born faculty (Göktepe-Hulten and Mahagaonkar 2010; Libaers 2014), though that research did not control for motivation of the academic scientist or quality of the specific invention. Recognizing that foreign-born faculty receive less commercialization assistance from TTO, either due to workplace discrimination or researcher preference, they may be responding directly to opportunities with industry rather than relying on university TTOs to generate opportunities or broker arrangements for them. By contrast, foreign-born faculty are less likely to engage in the more complex and possibly more lucrative (Bray and Lee 2000) equity-based spinoffs. Because residence time in US reduces the likelihood of licensing with industry but increases the likelihood of licensing with a spinoff, we believe our complexity argument applies here. The longer foreign-born faculty reside in the US, the more able they are to navigate the various institutions, finances and networks necessary to establish spinoffs. Nevertheless, we cannot discount the workplace discrimination thesis as

'other foreign-born' (non-European) and Asians are much less likely to license by spinoff, but much more likely to license by private company. Findings show a similar pattern for non-white foreign-born, compared to white foreign-born for licensing by private company, though both white and non-white foreign-born are less likely to license by spinoff.

These findings present significant challenges for universities and TTOs, particularly in the face of current national policy on immigration and globalization. The current national policy context has created an environment of high uncertainty for international scholars, many of whom depend on long-term visas and the effective functioning of university international services to work on their behalf. Negative rhetoric and new anti-immigration policies create a national environment that does little to attenuate workplace discrimination, including structural bias that may exist in the university commercialization system. Within universities and companies, the negative national context can exacerbate perceived credibility bias brought on by cultural distance, race differences, and perceive language imperfections. Given the size and dimensions of the foreign-born community of scholars that exists in the US national science and innovation system, the impact of national anti-immigration policy on university-led commercialization should not be underestimated.

Universities and their TTOs should recognize the potential that workplace discrimination against foreign-born faculty, particularly those of Asian and other non-European origin, exists in their organizations. It is now common for universities and departments to address potential racial, gender or ethnic bias through faculty and student training, diversity committees and policies. It is not clear if these efforts extend to the commercialization system. Universities and their TTOs are well positioned to either muddle through the policy environment or relieve uncertainty of the full set of inventors who are critical potential sources of revenue and financial stability. TTOs have an opportunity to assess their limitations and potential shortcomings regarding equal treatment of inventors regardless of national background. Prior studies have shown how the lack of adequate staff at TTO have impacted their returns (Carlsson and Fridh 2002); it may be necessary to consider the impact that cultural competencies have on returns as well. But TTOs likely need to move beyond training to set in place new activities and redesign services to minimize the potential for bias.

Despite the contributions of this study, our analysis is not without limitations. While we have been able to show that foreign-born faculty commercialize less and receive less TTO assistance to commercialize, we have not been able to specify the cause or causes. We offered three possible rationales—workplace discrimination, researcher preference and institutional complexity—but there may be others. It is also possible that these three factors interact over time such that are particularly long lasting and resilient to intervention. However, our limited data, including its cross-sectional nature, precluded our ability to explore this. Future qualitative work could gain insights to these issues. The data used in this research also did not allow us to specifically test for discriminatory practices occurring in the workplace, only a form of perceived discrimination, nor did it allow us to separate out experiences with discrimination from the resource and psychological consequences.

In addition, many of the specific patents included in our sample were generated by multiple authors. It is possible that the input and influence of co-authors has much to do with commercialization, but our data are limited. We expected, for example, that collaboration between the foreign and native-born would reduce the impact of cultural distance on commercialization, but our results did not show this. Future work could further explore how co-authorship, particularly among researchers from different national backgrounds and ethnicities contributes to commercialization activity. Last, our findings on the impact of cultural distance on commercialization highlights a need to move beyond a dichotomous measurement of foreign-born scientists and to better account for how national background,

language skills and experiences shape faculty work experience and production. However, we believe strongly that even these more refined measures are insufficient to capture the complexities of national origin, ethnicity and culture. Future work studying how motivations differ between immigrant groups, and particularly the mechanisms associated with how residence time in the United States matters for different commercialization outcomes, would help to further clarify the causal relationships between internationalization and commercialization for academic scientists.

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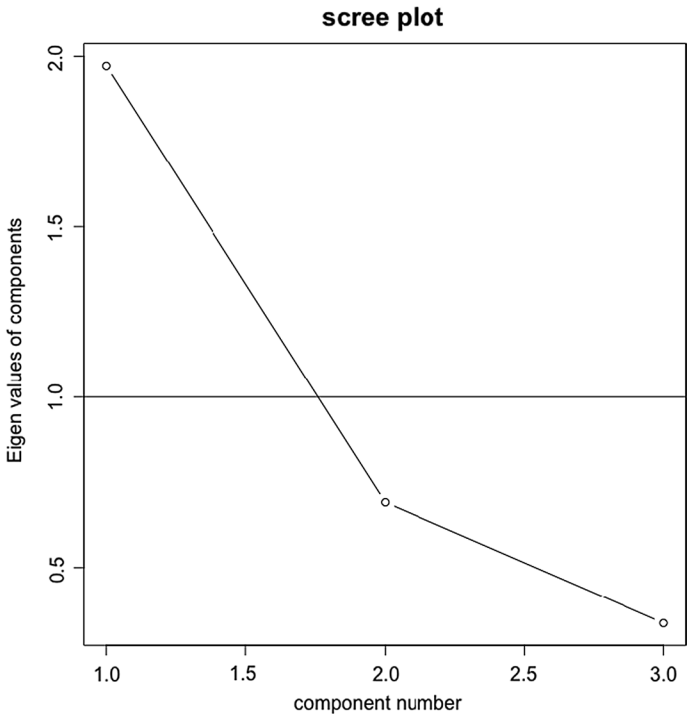
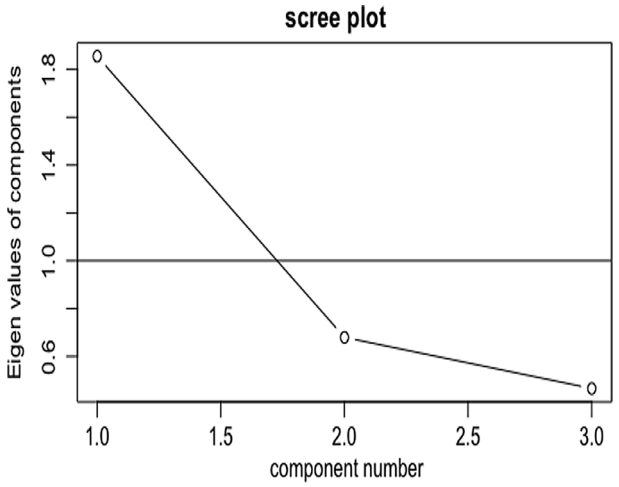
Appendix 1



Uniquenesses	
Commercial	0.611
Technological	0.014
Scholarly	0.741
Loadings	
	Factor 1
Commercial	0.624
Technological	0.993
Scholarly	0.509
	Factor 1
SS loadings	1.634
Proportion variation	0.545

Appendix 2



Uniquenesses	
Emails	0.660
Visit	0.696
Face-to-face	0.291
Loadings	
	Factor 1
Emails	0.583
Visit	0.552
Face-to-face	0.842
	Factor 1
SS loadings	1.353
Proportion variation	0.451

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