Evaluating the Two-Body Problem: Measuring Joint Hire Productivity within a University

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Abstract The presence of dual career couples in the labor market has distortionary effects regarding the geographic distribution of the labor force. Couples tend to locate where there are more opportunities for both partners. This geographic redistribution has been the subject of much research. However an open question remains for how the distribution of quality is affected by the presence of couples in the labor market. We examine the academic labor market as a special case of a labor market where both members of a dual-career household are likely to work in the same institution. We develop a theoretical model of this market in which couples wish to remain together but may be heterogeneous in their level of productivity. The model predicts under plausible assumptions that such couple hires will be more productive on average relative to their non-couple hire colleagues in the same institution in all but the most prestigious institutions . We test our prediction using data from Washington State University. Using research publications and grants obtained as measures of productivity, we find that individuals hired as part of a couple outperform their peers in the quantity of publications per year and in the ability to procure grants.

Keywords: Labor markets; Academic Couples; Joint Hiring; Dual-Career; Productivity; Two-Body Problem; Higher Education

JEL Classification Numbers: I23, J20, J21, J24, J44, J49

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1 Introduction

Working couples among all professions face the challenge of finding two jobs in a given location so that the couple may remain together and at the same time allow each partner to advance his or her career. About 72 percent of today's academics face this same challenge - about 36 percent of academics have a non-academic working partner and another 36 percent have a partner who also works in an academic position [Scheibinger et al., 2008]. Those academics who are partnered with another academic are known as dual-career academic couples. These couples may have a relatively greater challenge in finding employment compared to other working couples because of the highly specialized fields they work in as well as the relative geographic isolation of many universities.

As early as 1984, researchers began seriously looking at how dual-career couples affect labor markets because of their need to be employed in nearby locations. Roth [1984] examines the labor market for medical school graduates noting that increasing numbers of medical school graduates are married to one another. He observes that at the time, many med-school couples were opting to take the more challenging route of working directly with the hospitals to negotiate their own positions rather than use the centralized matching tool available for placing interns. He analyzes this central labor market mechanism and finds that even when couples are allowed to express preferences over pairs of positions, a stable matching still does not necessarily exist. The added complexity of working near each other often makes it difficult to place these couples.

In a recent follow up to Roth [1984], Kojima et al. [2010] ask why some matching clearinghouses seem to produced stable outcomes in spite of Roth [1984] showing that a stable matching in markets with couples does not necessarily exist. They conclude that it is because the markets that these clearinghouses are participating in are large enough. In other words, large cities provided enough opportunities for couples, whereas smaller communities did not. Costa and Kahn [2000] also make this observation as they show that more and more couples migrated to cities over the 1940-1990 period due to more opportunities which allowed them to remain together.

Joint Search theory from the couple's perspective has been addressed most recently by Guler et al. [2012]. The authors extend the standard single agent search model to allow for couples. They show that couples have both advantages as well as additional challenges - including the difficulty of finding two jobs in the same location - when engaging in joint searches.

Li [2009] analyzed the co-location problem of academics and also found that locations with more than a single university were better at attracting couples than were locations with just a single institution. The problem for the academic market is that many universities are located away from major metropolitan areas. In "college towns" especially, a single university may be the only employment option for both members of the academic couple. Thus when considering a career move, many academic couples often seek employment within the very same institution.[1] There is also evidence that even in locations where there are multiple universities, academic couples still prefer to work at the same institution [Scheibinger et al., 2008].

Other dual-career professionals such as those in the medical profession face similar challenges of finding two positions in the same institution or nearby institutions. The majority of the preceding studies have emphasized that couples have more opportunities in larger cities and will thus choose to locate there. Thus the presence of couples in a labor market affects the geographical distribution of labor force participants. But these studies do not address how the presence of couples affects quality distributions. There is evidence that the desire to remain together for some couples is strong enough that one or both members of the couple will choose to accept a less prestigious offer in order to remain with their partner. In a survey of over 9000 academics, Scheibinger et al. [2008] found that 20 percent of the couples in the sample reported such behavior. Clearly this sort of behavior has the potential

[1] According to Blossfield and Drobnic [2001], for many couples the decision to accept or retain an academic position is often contingent on the ability of a spouse to find suitable employment. See also Helppie and Murray-Close [2010], and Scheibinger et al. [2008] for statistical and anecdotal evidence that this is occurring.

to disrupt the typical distribution of faculty quality that would be seen if all candidates behaved as if they were single. Some universities are attempting to benefit from this sort of behavior by adopting official partner accommodation policies which allow the university greater flexibility in finding a position for the partner of a desired candidate.[2] But a commonly cited concern with joint hiring through these policies is the stigma of "less good" that may be attached to the partner hire because he or she was not recruited through the traditional method [Scheibinger et al., 2008]. Therefore an open question about how couple hiring affects the quality of an institution's faculty remains to be studied.

Our goal is to investigate the implications of joint hiring for universities and couples. Little work has been done thus far to rigorously sort out the effects on faculty quality that joint hiring may have from either a theoretical or empirical perspective. One study that has made progress on the empirical side was conducted by Scheibinger et al. [2008]. The authors surveyed faculty from 13 leading U.S. research universities and elicited responses from over 9000 academics on many issues related to joint hiring. With this information they were able to address empirically whether there is any merit to the "less good" stigma. They found that after disaggregating the data by field and accounting for gender and rank, productivity levels among "second hires" (*i.e.* those whose partner was first recruited by the hiring institution) were not significantly different from those among their peers.

We add to the literature on consequences of joint searches and hiring practices in the following ways. First, we construct a theoretical model of couple hiring in the academic labor market where under plausible assumptions, joint hiring allows at least some universities to recruit highly productive candidates who otherwise would have refused the employment offer. The key mechanism that drives this result is the willingness of one of the partners in some academic couples to accept an offer from a less prestigious school in order to be near the other. This willingness is a based on the strong preference of academic couples to work in close proximity or even work at the same school as evidenced in research by Helppie

[2] See Wolf-Wendel et al. [2003] for a thorough discussion of the various types of policies that exist.

and Murray-Close [2010] and Scheibinger et al. [2008]. We evaluate the model under the assumption that universities consider each candidate in an academic couple independently as if they were each a single candidate. As many academic couples are hired into different departments and often into different academic units entirely [Ferber and Loeb, 1997], we choose to allow the various departments the freedom to accept or deny a candidate whom they do not feel is qualified. Given our assumptions about the preferences of academic couples and the "independence" hiring rule, we predict that the average joint hire will be no worse in terms of productivity relative to their colleagues and for all but the most elite schools, joint hires will more productive than their peers, on average.

Second, we examine whether joint hire individuals are different in their productivity relative to their non-joint hire colleagues. To our knowledge, such an empirical analysis has not been done. We use a 12 year panel of administrative data representing the entire population of tenure-stream faculty at Washington State University for our analysis. While we recognize that our data comes from only a single institution (and therefore the results are not necessarily generalizable to the population of universities), because it is administrative data we do not need to address the typical concerns of selection bias and self reporting associated with survey data. In addition, the panel nature of the data enables us examine certain questions that cannot be addressed with cross-sectional data. We find that of those hired at WSU since 1999, the average joint hire individual publishes more articles per year and is more likely to obtain a grant than a comparable non-joint hire colleague.[3] Additionally, we examine differences by whether a joint hire was the primary hire - meaning they were first offered the position at the university - or partner hire - meaning they were offered a position as part of the negotiation process for their partner's job. We find that partner hires on average are no less productive than their non-joint hire colleagues and that primary hires are more productive. Our results show that at Washington State University, there is little supporting evidence for the stigma of "less good" that is often associated with partner hires

[3] Official records for those hired as couples were first kept in 1999.

and that couple hiring has allowed WSU to attract above average talent into their faculty.

2 The model

2.1 Setup

In this market let there exist K schools that each have exogenously given initial levels of prestige, ρ, and can be ranked and ordered according to their level of prestige from lowest to highest, $\rho_1 < \rho_2 <, ..., < \rho_K$. Let there also be N job candidates, each with individual productivity denoted by θ_i which is continuously distributed along any positive valued probability density function, $\theta_i \sim f(\theta)$.

We assume the total number of job candidates equals the total number of job openings so that there is no unemployment. We also normalize the number of job candidates such that $N = 1$. Finally, we assume the K schools equally divide the number of job vacancies such that each school will claim $1/K$ of the candidates.

Each job candidate seeks to maximize utility. Following Li [2009], in addition to each candidate's initial endowment of productivity, θ_i, we assume all job candidates gain additional productivity, ρ_k, according to the prestige of their employing institution. Candidates derive utility from their productivity according to the utility function

$$u(\theta_i, \rho_k) = \theta_i + \rho_k \tag{2.1}$$

where i indexes the individual, and k indexes the school.

Candidate productivity is perfectly observable by the universities and each school seeks to hire the most productive candidates it can subject to the constraint that it fills all of its positions. Thus, in equilibrium each school will choose a minimum threshold level of productivity, τ_k, and make offers to all candidates whose productivity is weakly greater than that minimum threshold level. A simple argument demonstrates that this is the optimal behavior for each school.[4]

Lemma 1 *Each school, k, chooses a minimum threshold level of productivity, τ_k, and makes offers to all candidates whose individual level of productivity is weakly greater than this minimum threshold.*

Proof Suppose that using minimum thresholds is not the optimal policy and that schools make offers to candidates using some other method of allocation. Because there are more total candidates than there are positions available *in each* school, under any other allocation of offers, some candidates of lower ability will be offered and accept positions at higher ranked schools. Likewise, some candidates with higher levels of productivity who would have accepted offers from higher ranked schools will not receive them. Thus, the higher ranked schools can increase the expected level of productivity of their candidates by establishing a minimum threshold such that only candidates with productivity weakly greater than the threshold receive an offer and those candidates who accept the offers will equal the number of their open positions. ∎

In equilibrium, each school, k, sets a minimum threshold level of productivity, τ_k, which guarantees it will receive $\frac{1}{K}$ candidates as given by Equation 2.2.

$$\int_{\tau_k}^{\tau_{k+1}} \theta f(\theta)\, d\theta = \frac{1}{K} \tag{2.2}$$

τ_{k+1} represents the threshold set by the school ranked just above school k, hence each school takes its upper bound as exogenously given when solving for its own minimum threshold. For the highest ranked school, the upper bound is ∞.

[4]This lemma and proof follow closely Lemma 1 and its proof in Li [2009].

2.2 The Case with no Joint Hires

Suppose initially there are only non-couple candidates in the market. Each school is aware of its ranking and must hire $\frac{1}{K}$ fraction of the job candidates. Therefore each will choose τ_k to guarantee it fills all open positions. Then the solution for the highest ranked school, $k = K$, is to choose τ_K so that the density to the right of τ_K is equal to $\frac{1}{K}$ as shown by equation 2.3 and pictured in the left hand side of Figure 1.

$$\int_{\tau_K}^{\infty} f(\theta)\, d\theta = \frac{1}{K} \tag{2.3}$$

Equation 2.3 can be rearranged such that the school is choosing its minimum threshold level so that the area under the distribution to the left of the threshold is equal to $\frac{K-1}{K}$ as follows:

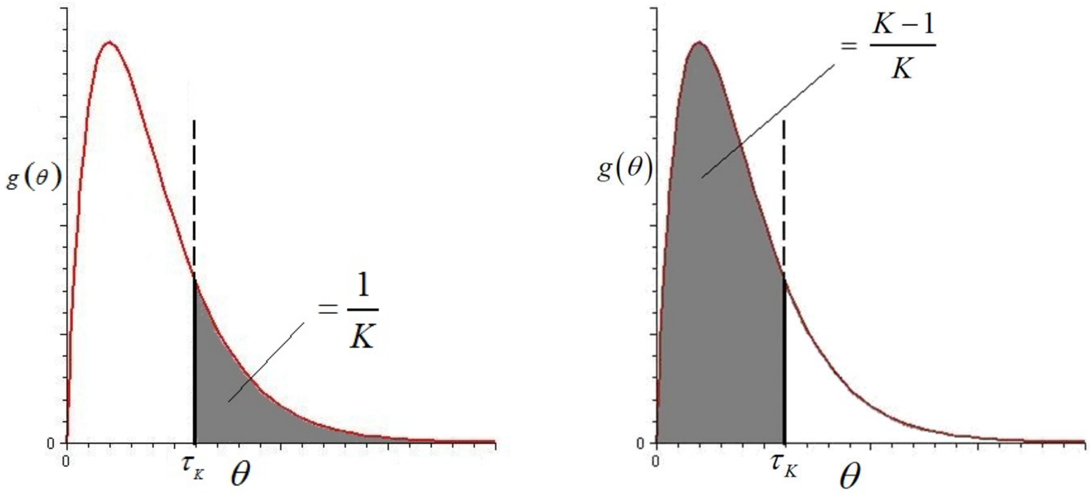
$$\begin{aligned} \int_{\tau_K}^{\infty} f(\theta)\, d\theta = \frac{1}{K} & \\ \Rightarrow 1 - \int_{0}^{\tau_K} f(\theta)\, d\theta = \frac{1}{K} & \\ \Rightarrow \int_{0}^{\tau_K} f(\theta)\, d\theta = 1 - \frac{1}{K} & \\ \Rightarrow \int_{0}^{\tau_K} f(\theta)\, d\theta = \frac{K-1}{K}. & \end{aligned} \tag{2.4}$$

Then for any school, $k = \{1, 2, ..., K\}$, the minimum threshold it chooses must solve Equation 2.5 as illustrated in the right hand side of Figure 1.

$$\int_{0}^{\tau_k} f(\theta)\, d\theta = \frac{k-1}{K}. \tag{2.5}$$

The specification in equation 2.5 is convenient because we can solve for each school's minimum threshold without having to take any differences. We need only know their ranking. For example, assume that there are five schools. Then as we previously stated, the highest quality school, $k = 5$, will want to choose τ_5 so that $\frac{1}{5}$ of the distribution is to the right or, equivalently, $\frac{4}{5}$ of the distribution is to the left of τ_5. The second best out of the five schools,

Figure 1: Desired Solution for the Highest Quality School



$k = 4$ will choose τ_4 so that $\frac{4-1}{5} = \frac{3}{5}$ of the distribution will be to the left of its threshold and so on until the lowest ranked school, $k = 1$, chooses τ_1 to be equal to $\frac{1-1}{5} = 0$ so that none of the distribution is to the left of its threshold.

2.3 Joint Hires and an Independent Hiring Policy

We now allow some portion of the job candidates to form couples. We consider a hiring policy in which all schools evaluate couples independently as if each candidate were single. Thus each candidate must meet the minimum threshold on their own merits.[5] We assume that a fraction, α, of job candidates are part of an academic couple (hence, $1 - \alpha$ is the proportion of non-couple job candidates). We also assume that the decision to form a couple is independent of the productivity level of each person, and we assume that couples' preferences are such that they will only accept offers from the highest ranked school where both partners were extended an offer. We recognize that in reality some couples place a higher priority on their careers and choose to live apart.[6] Such couples are acting as if they are two single candidates and are not the focus of the present study. We also abstract from reality by assuming that schools are far enough apart geographically that it is impossible for

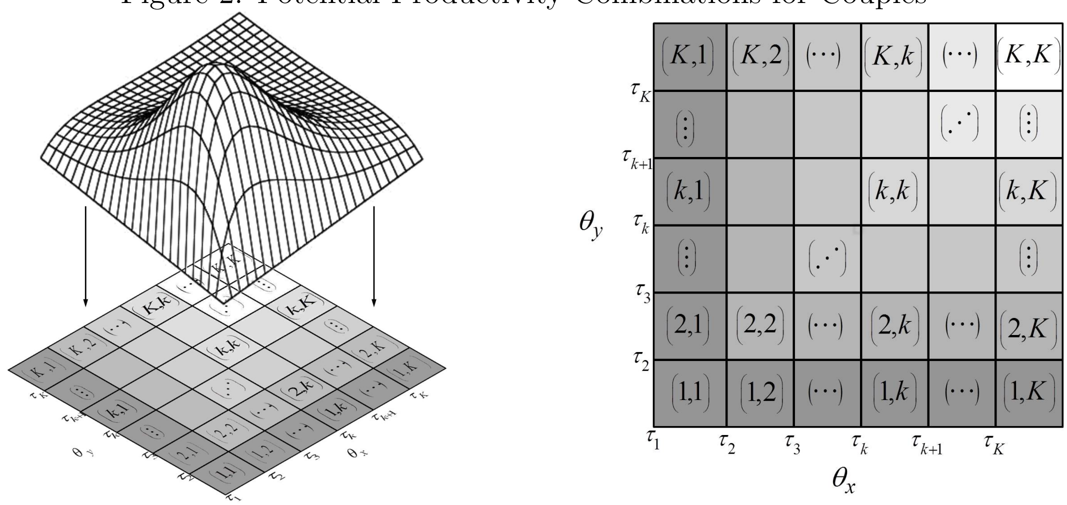
[5]Washington State University for example follows such a policy.
[6]See Helppie and Murray-Close [2010] for example.

a couple to remain together and work at two separate schools. These simplifying assumptions allows us to focus on how a couple's desire to stay together affects the quality distribution of faculty within a single institution.

Initially let us suppose that $\alpha = 1$, meaning all candidates have chosen to be part of an academic couple. As before the solution for each school is to set their minimum threshold low enough so as to attract $\frac{1}{K}$ individuals to their school.

For clarity we add subscripts to denote the different partners in a couple. Let θ_x represent the productivity of candidate x and θ_y represent the productivity of candidate x's partner. Then the left-hand side of Figure 2 is a visual representation of a generic joint density of couple candidates in the academic labor market. The minimum thresholds for each of the k schools are marked on the two axes and form the grid pattern which is displayed in the right-hand side of Figure 2. The spacing between the threshold values in the grid will vary depending on the distribution that is assumed to overlay this grid.[7]

Figure 2: Potential Productivity Combinations for Couples



As a consequence of independent hiring, the chosen minimum thresholds apply equally to both members of the couple. In the right-hand side of Figure 2, the regions between the thresholds represent each of the possible combinations of couples of type (x, y). The regions along the main diagonal (from the bottom-left to the top-right) represent those

[7]Figure 2 is only meant to illustrate the concept and is not necessarily drawn to scale.

couples whose productivity levels are very similar. The highest offers received by each of the partners in these couples comes from the same school. Those cells that are off the main diagonal represent those couple types where one candidate is able to attract an offer from a more prestigious university than their partner. The L-shaped shaded regions that are illustrated by the different shades of gray show how under an independent evaluation policy, all schools except for the top school are able to attract candidates who otherwise would accept an offer from a more prestigious school. Highly productive individuals who are part of the off-diagonal couples go to lower ranked schools - relative to what they would choose if they were single - in order to remain with their partner.

For example, the darkest shaded region in the right hand side of Figure 2 represents all possible couple types who would opt to go to the lowest-tier school. Each couple type in this region contains at least one member of the couple with productivity commensurate with the lowest-tier school. This partner will not receive offers from any of the other schools. Therefore the other candidate in the couple forgoes a more prestigious offer in order to remain with the partner. This is in contrast to the unshaded region in the top-right corner where the only possible couple type who is qualified to work at the highest-tier school is the type where each member of the couple has productivity that meets the high threshold standard.

Different distributional assumptions merely change the value of the thresholds and their spacing along the two horizontal axes. The distribution that is assumed to overlay this grid does not affect the main result that lower-tier schools are able to attract highly qualified candidates. Nor does it affect the ordering of the thresholds. The result is driven by the strong preference of couples to remain together and an independent hiring rule. In a world where only couple candidates exist, each school chooses τ_k to solve Equation 2.6.

$$\int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \int_0^{\tau_k} f(\theta_y)\, d\theta_y + 2 \cdot \int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \int_{\tau_k}^{\infty} f(\theta_y)\, d\theta_y = \frac{k-1}{K} \tag{2.6}$$

Each integral simply represents school k's probability of hiring an individual with productivity greater than τ_k. Because the decision to form a couple is independent of productivity levels, and because schools evaluate couples as independent candidates, we simply need to multiply two densities together to obtain the probability that a school will be able to recruit a couple. The first term in Equation 2.6 represents the probability of hiring a couple type along the main diagonal with similar productivity levels. The second term incorporates the potential each school has for hiring the off-diagonal couples where one member of the couple has a higher level of productivity than this school could otherwise attract.[8]

2.4 Couple and Single Candidates in the Same Market

Now suppose the labor market is composed of both couples and singles such that $0 < \alpha < 1$. Also assume that universities use the same minimum threshold to evaluate both non-couple and couple candidates as universities are still evaluating couples as if they are two single candidates and therefore have no reason to use different threshold levels. Then school k will choose τ_k to satisfy Equation 2.7.

$$(1+\alpha)\int_0^{\tau_k} f(\theta)\,d\theta - \alpha\int_0^{\tau_k} f(\theta)\,d\theta\int_0^{\tau_k} f(\theta)\,d\theta = \frac{k-1}{K} \tag{2.7}$$

Equation 2.7 is a general equation which each school can use to solve for their optimal τ_k. The precise derivation of this equation is found in Section A.1 of the Appendix. Each school chooses τ_k so that the weighted sum of the couple and single densities to the left of the threshold is equal to $\frac{k-1}{k}$.

The new threshold values are a function of the proportion of couples in the labor market, α. As the proportion of couple candidates increases, the minimum thresholds set by the higher-tier schools decreases. This happens because as highly productive individuals who are part of the off-diagonal couple types opt to go to lower-tier schools, vacancies are created

[8]Due to symmetry, we multiply the second term by 2 rather than include an additional term where only the x and y subscripts are switched

in the higher-tier schools. Thus the higher-tier schools must lower their thresholds slightly in order to pick up a few more candidates who otherwise would not have received offers from those schools.

2.5 How Expected Productivity Levels Compare Within each School

We set out to determine how the productivity of those candidates hired as part of a couple compares to those hired as single candidates within the same institution. Theoretically we take the expectation of productivity for a single candidate and compare it to the expectation of productivity for a couple candidate within each school. This is a conditional expectation where the conditioning arguments are the threshold bounds. For the single candidate we simply calculate the expected value conditioned on being hired by school k:

$$E\left[\theta|\theta \in (\tau_k, \tau_{k+1})\right]. \tag{2.8}$$

For a couple candidate, we calculate the expected value given that they come with a partner and that both are hired by school k:

$$E\left[\theta_x|\left(\theta_x \in (\tau_k, \tau_{k+1}) \text{ and } \theta_y \in (\tau_k, \infty)\right), \text{ or } \left(\theta_x \in (\tau_{k+1}, \infty) \text{ and } \theta_y \in (\tau_k, \tau_{k+1})\right)\right]. \tag{2.9}$$

We then compare the two values. In order to do this, we re-weight the densities for each school so that the density claimed by each school integrates to one and can be used to calculate a proper expectation.

For a single candidate at school k, the expected value is calculated using Equation 2.10.

$$\frac{\int_{\tau_k}^{\tau_{k+1}} \theta f(\theta)\, d\theta}{\int_{\tau_k}^{\tau_{k+1}} f(\theta)\, d\theta} \tag{2.10}$$

Due to the symmetrical nature of the distribution, for either candidate hired as part of a couple at school k, we can represent the expected value using Equation 2.11.

$$\frac{\int_{\tau_k}^{\tau_{k+1}} \theta_x f(\theta_x)\, d(\theta_x) \int_{\tau_k}^{\infty} f(\theta_y)\, d(\theta_y) + \int_{\tau_{k+1}}^{\infty} \theta_x f(\theta_x)\, d(\theta_x) \int_{\tau_k}^{\tau_{k+1}} f(\theta_y)\, d(\theta_y)}{\int_{\tau_k}^{\tau_{k+1}} f(\theta_x)\, d(\theta_x) \int_{\tau_k}^{\infty} f(\theta_y)\, d(\theta_y) + \int_{\tau_{k+1}}^{\infty} f(\theta_x)\, d(\theta_x) \int_{\tau_k}^{\tau_{k+1}} f(\theta_y)\, d(\theta_y)} \tag{2.11}$$

We compare these two expected productivities and derive Lemma 2 in section A.2 of the Appendix.

Lemma 2 *The expected level of productivity for a candidate hired as part of a couple is greater than the expected level of productivity for a single candidate within any school other than the highest ranked school. In the highest ranked school the expected levels of productivity are equal for the two types of candidates.*

The result that the expected productivity of a couple candidate will always exceed the expected productivity of a single candidate in any given school (except in the very top school where they are equal) holds regardless of the distributional assumption. The result hinges on universities requiring each candidate to independently have productivity weakly greater than their minimum threshold, and the strong preference of couples to remain together such that high quality candidates go to lower-tier schools. These two assumptions result in the weighted density for couple candidates in school $k \neq K$ to include more of the upper tail than the weighted density for single candidates.

Our theory predicts that because couples exist in the academic labor market and have strong preferences to remain together, couple candidates in non top-tier schools should exhibit higher levels of productivity than their otherwise equal single colleagues. We empirically examine this implication further in this work.[9]

[9] Additionally, lower-tier schools stand to benefit in terms of recruiting highly productive candidates who otherwise would not be available to them. The implication here is that the quality gap between lower-tier and higher-tier universities may diminish as the proportion of academic couples increase. It is beyond the scope of this work to explore this implication further and we leave it to future research.

3 Data

Washington State University began keeping detailed records on joint-hire couples who were hired using an established partner accommodation policy beginning in 1999. This policy allows the provost's office to provide temporary funding to cover a portion of the salary for the partner of a desired candidate in order to help a receiving department hire someone they may not have been looking for at the time. The policy closely resembles an independent approach to recruiting couples as we have defined it and includes the following language:

> "Partner and spouse accommodation and assistance is a nonmandated program available throughout the mulitcampus University system to assist units in recruiting and retaining employees. No unit is required to participate in this program. Prospective employees are not to view partner and spouse accommodation and assistance as an entitlement."

The language in the policy closely resembles an independent approach to hiring couples. Conversations with university administrators have also verified this practice. Using the records kept on those hired under this policy we are able to identify which individuals have been hired as part of an academic couple as well as whether an individual is the primary hire or the partner in a couple. It is the only administrative data available that contains such information.[10] The majority of our other variables come from an administrative database at WSU.

The productivity measures we have available to us come from a separate self-reporting system that was implemented campus wide (with the exception of the business school) beginning in 2005. Faculty members use this system to track various productive activities such as grants awarded, book publications, book chapters, journal articles, conference presentations, student evaluations, and the like. The self-reported nature of these variables is not a concern however because this database is used in tenure and promotion decisions and the

[10]There may have been couples who both independently sought positions and were hired into those positions without seeking help via this policy. Couples such as this would not be identified in our data.

self-reported entries are cross-validated by department heads for accuracy. We use the number of publications per year as well as whether an individual obtained a grant during their time at WSU as dependent variables in our analysis on productivity. We recognize that these measures do not perfectly capture productivity for the broad range of a university's faculty; however in a large research university such as WSU, these are two important measures of the productivity of a tenure stream faculty member. Thus our data consists of all tenure stream faculty who were hired during the years 1999-2010.

Table 1: Variable Names and Definitions

Joint Hire	= 1 if the individual was part of a jointly hired couple, 0 otherwise
Admin	= 1 if the individual is an administrator, 0 otherwise
Female	= 1 if the individual is female, 0 otherwise
Prior	Number of years between highest degree and starting year at WSU
Seniority	Indicators for years of seniority
Rank	Indicators for Assistant, Associate, and Full Professor
Publications	Number of journal articles, book chapters, or books published per year
Grantee	indicator for whether an individual obtained a grant at WSU
Field	Indicator variables representing broad fields of study
Year	Indicator variables for each year of our data

Table 1 gives a list of variable names which are used in the estimations. *Joint Hire* is defined as an individual who was hired either as the primary or the partner hire in a couple hire at WSU. *Admin* is an indicator variable denoting whether or not an individual was serving in an administrative position that year. *Female* is a sex dummy variable, *Prior* captures the number of years of professional experience an individual had prior to their work at WSU. It is calculated by subtracting the individual's degree year from their WSU hire year. *Seniority* is a series of indicator variables for those with 1-3 years, 4-6 years, 7-9 years, and 10 or more years of seniority at WSU. *Rank* is a series of indicator variables for those whose rank is assistant, associate, or full professor in a particular year. *Publications* is a simple sum of all peer reviewed journal articles, book chapters, and books that were published in a given year.[11] *Grantee* is an indicator variable that takes a value of 1 if an

[11]Unfortunately, we do not have information about the quality of the publications, only the quantity and type in a particular year.

individual ever obtained a grant while at WSU. We have access to the dollar amount of the grant(s) as well but we are not able to account for multiple co-PI's or other confounding influences, therefore we examine grant success only on the external margin. We also include year indicator variables to control for secular influences in our data that may have changed year to year. We also include indicator variables for field of discipline broadly defined. Joint hiring varies considerably across fields of study as does productivity as we have measured it. Including the field indicator variables accounts for the potential that joint hiring occurs predominantly in either the most or least productive fields.

Table 2: Joint Hire Faculty Composition

	All	Males	Females
Number of person/year observations	2740	1625	1115
Number of individuals	681	406	275
Joint hire individuals	94	54	40
Primary hire individuals	71	43	28
Partner hire individuals	23	11	12

Table 2 displays information about how the composition of faculty in the data set divides among those who are joint hires and those who are not. It also contains information about how joint hire individuals are divided between primary hires and partner hires. Primary hire (or first hire) refers to the individual who first was offered a position at WSU. Partner hires (or second hires) are those were offered a job second as part of the negotiation process. The total number of unique individuals hired at WSU between 1999 and 2010 is 754. Since our productivity data begins in 2005, we only use those individuals hired since 1999 who were still here in 2005, which is 681 faculty.[12] The attrition in our data has the potential to strengthen or weaken our results. If those non-joint hires who left who are systematically different than the joint hires who left our results could be biased. If the joint hire individuals were raided because of hire quality while the non-joint hire individuals left because they were performing poorly then our results will be biased downward relative to what we would have

[12]There were 73 individuals who were hired between 1999 and 2004 who left the university prior to 2005 which represents just less than 10 percent attrition.

found without attrition. If on the other hand, the non-joint hire individuals performed well and left because of better offers while the joint hire individuals performed poorly and left because they did not expect to be granted tenure then our results are biased upward and we are overestimating the effects. We are unable to determine which if either of these effects dominates. Of those 681 individuals, 94 of them, or 14 percent, were hired as part of a joint hire couple which is in line with the estimate of 13 percent given by Scheibinger et al. [2008] for the proportion of new hires that were part of a joint hire during the 2000's. 71 out of the 94 joint hires were primary hires and 23 were partners.[13]

To get an idea of how these different groups perform in terms of productivity we tabulate data on mean publications per year, mean grant dollars obtained per year, and the number and percentage of various groups who ever obtained a grant in Table 3.

Table 3: Productivity Measures

	All	Males	Females
Mean Publications: Non Joint Hire	1.08	1.08	1.10
Mean Publications: Joint Hire	1.63	1.96	1.18
P-value for differences	0.001	< 0.001	0.721
% of Group who Obtained a Grant: Non Joint Hire	57%	53%	61%
% of Group who Obtained a Grant: Joint Hire	68%	69%	68%
P-value for differences	0.036	0.038	0.455

What is striking is that joint hire individuals publish on average 0.55 more articles per year than those who were not joint hires. This number is largely driven by the males. Male joint hires publish almost an additional article per year relative to those males who are not joint hires with 1.96 publications per year compared to just 1.08 publications per year for non-joint hire males. Female joint hires publish slightly more but the difference is not large with 1.18 publications per year relative to the non-joint hire female average of 1.10 publications per year.

[13]The reason for having more primary hires than partner hires is that our data includes only tenure-track faculty. There are many partner hires who were hired into lecturer positions or administrative positions and do not show up in our data.

With grant dollars we look at the proportion of faculty who receive grants. 68 percent of joint hires received a grant at some point during their employment compared to 57 percent of non-joint hires. Thus in terms of both the ability to obtain grants and the number of publications, it appears at least initially that joint hires exhibit higher levels of productivity.[14]

3.1 Methodology

We first estimate a regression with publications per year as the dependent variable to formally test whether an individual who is recruited as part of a joint hire at WSU is more productive on average in terms of the quantity of publications. We conduct the estimation twice. First we estimate the equation using the Joint Hire indicator as our variable of interest. We then replicate the same estimation again except that we divide the Joint Hire variable into two variables that represent whether an individual was hired as the primary or partner candidate of the couple. These estimations are specified formally in equations 3.1 and 3.2:

$$pubs_{it} = \beta_0 + \beta_1 JointHire_i + \mathbf{Z}_{it}\gamma + \mathbf{Y}_i\delta + \varepsilon_{it} \tag{3.1}$$

$$pubs_{it} = \beta_0 + \alpha_1 primary_i + \alpha_2 partner_i + \mathbf{Z}_{it}\gamma + \mathbf{Y}_i\delta + \varepsilon_{it} \tag{3.2}$$

where $pubs_{it}$ is the number of publications for individual i in year t. $\mathbf{Z}_{it}$ is a vector of time varying control variables including seniority and rank indicator variables, administrative status, and year indicators. $\mathbf{Y}_i$ is a vector of time constant variables including sex, prior experience, and field indicator variables. We use a random effects model to estimate the equations.[15]

For our grants estimation, we look only on the extensive margin to determine the effect

[14]In the next section, we use regression analysis and include extensive control variables in addition to just looking at the means.

[15]A fixed effects model is not available to us since our variables of interest are time constant. We also estimated the equations using pooled OLS and the results change little. Additionally, because the number of publications per year could be considered count data as opposed to a continuous variable, we could use a Poisson model. We find little difference between the results from our random effects model and the Poisson model and include our results from the Poisson specification in Section A.4 of the Appendix for reference.

that being hired as part of a couple has on whether an individual obtains a grant during his or her career at WSU. And as we do with publications, we divide *JointHire* into the *primary* and *partner* variables and estimate the same equation a second time as modeled in equations 3.3 and 3.4.

$$EverGotGrant_{it} = \beta_0 + \beta_1 JointHire_i + \mathbf{Z}_{it}\gamma + \mathbf{Y}_i\delta + \varepsilon_{it} \tag{3.3}$$

$$EverGotGrant_{it} = \beta_0 + \alpha_1 primary_i + \alpha_2 partner_i + \mathbf{Z}_{it}\gamma + \mathbf{Y}_i\delta + \varepsilon_{it}. \tag{3.4}$$

4 Results and Discussion

4.1 Productivity

Our theory predicts that joint hires should be more productive on average than their colleagues within each school except in the very top school. We present the the random effects results which test this prediction in Table 4.

Our key finding is that holding other factors constant, joint hire individuals produce on average just less than half a publication more per year than their non-joint hire colleagues. We also conduct separate estimations for males and females to observe how strong the effects are within genders. We find that the the average joint hire male produces 0.8 more publications per year than other males while there is no statistical difference in publishing rates for joint hire females relative to other females.

When we look at primary hires and partner hires we find that the average primary hire produces 0.78 more publications per year than non-joint hires and the difference is statistically significant at the 1 percent level. At the same time, the average partner hire produces about 0.6 fewer publications per year than non-joint hires but the difference is only marginally significant. However, when we look at differences within gender, male primary hires produce 1.2 more publications per year than other males and again the positive difference is significant at the 1 percent level, while male partners produce about 0.8 fewer articles per year

Table 4: Publications per year, random effects

VARIABLES	All-1	All-2	Male-1	Male-2	Female-1	Female-2
Joint Hire	0.472***		0.801***		0.059	
	(0.180)		(0.253)		(0.255)	
Primary Hire		0.782***		1.198***		0.209
		(0.199)		(0.275)		(0.289)
Partner Hire		-0.609*		-0.805		-0.396
		(0.357)		(0.529)		(0.480)
Administrator	-0.764**	-0.804***	-0.758**	-0.825**	-0.453	-0.469
	(0.303)	(0.300)	(0.370)	(0.367)	(0.550)	(0.550)
Female	-0.089	-0.071				
	(0.132)	(0.130)				
Prior Experience	-0.014	-0.011	-0.028*	-0.022	0.013	0.013
	(0.012)	(0.012)	(0.016)	(0.015)	(0.019)	(0.019)
4-6yrsSen	-0.023	-0.009	-0.105	-0.097	0.130	0.139
	(0.134)	(0.133)	(0.177)	(0.177)	(0.204)	(0.204)
7-9yrsSen	0.107	0.097	0.030	0.000	0.231	0.228
	(0.194)	(0.193)	(0.265)	(0.263)	(0.285)	(0.285)
10+yrsSen	0.049	0.029	-0.106	-0.147	0.255	0.248
	(0.294)	(0.292)	(0.386)	(0.384)	(0.460)	(0.460)
Associate	0.255	0.284	0.333	0.378	0.116	0.131
	(0.177)	(0.176)	(0.243)	(0.241)	(0.259)	(0.259)
Full	0.272	0.235	0.668*	0.623*	-0.589	-0.603
	(0.276)	(0.274)	(0.359)	(0.355)	(0.453)	(0.453)
Constant	-0.183	-0.238	-0.084	-0.137	-0.315	-0.338
	(0.265)	(0.263)	(0.369)	(0.366)	(0.356)	(0.356)
Observations	2,740	2,740	1,625	1,625	1,115	1,115
No. of Unique Individuals	681	681	406	406	275	275
Overall R-squared	0.042	0.047	0.048	0.057	0.053	0.055

Standard errors in parentheses
Field and year effects not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

but the difference is not statistically significant relative to other males. With females, there is not enough evidence to say their publishing rates are any different for either primary or partner hires.

We now turn our attention to grants. The results shown in Table 5 are the marginal effects of the estimation and not the point estimates themselves. They show the differences in the propensity to obtain a grant for joint hires relative to their colleagues. We find that the average joint hire individual is 12 percent more likely to obtain a grant relative to an otherwise equal colleague. A primary hire is 10 percent more likely and a partner hire is about 20 percent more likely to obtain grants. There is no difference for male primary hires relative to other males but male partner hires are 31.6 percent *more* likely to obtain a grant. Thus while there is some indication that they publish less as shown in the publications estimation, when the scope of productivity measures is broadened, the difference in publications might be offset to some degree by an increased likelihood of obtaining a grant. For female joint hires, primary hires, and partner hires, we find a positive but insignificant difference in the likelihood that a female joint hire obtains a grant relative to other females. Thus we have found that on average an individual who is part of a couple hire at WSU publishes more and is more likely to obtain a grant at some point in their career. Additionally, our results are mixed concerning the productivity of partner hires relative to their peers. We find on average that they publish 0.6 fewer articles per year, but we also find that they are 20 percent more likely to obtain a grant and both results are only marginally significant. Thus there is little evidence in support of the stigma that partner hires at WSU are "less good" than their peers.

4.2 Is it a marriage effect?

One concern over the validity of our findings of higher average productivity among joint hires is that because the majority of joint hires are married couples, we are simply capturing the well documented effect that married men are more productive than single men. One

Table 5: Marginal Effects for the Propensity to Obtain a Grant, probit model

VARIABLES	All - 1	All - 2	Males - 1	Males - 2	Females - 1	Females - 2
Joint Hire	0.120**		0.129*		0.091	
	(0.053)		(0.072)		(0.077)	
Primary Hire		0.100*		0.089		0.095
		(0.059)		(0.080)		(0.088)
Partner Hire		0.198*		0.316**		0.077
		(0.111)		(0.148)		(0.139)
Administrator	-0.267***	-0.265***	-0.282***	-0.274***	-0.235	-0.235
	(0.083)	(0.083)	(0.092)	(0.091)	(0.172)	(0.172)
Female	0.061	0.060				
	(0.039)	(0.039)				
Prior Experience	-0.002	-0.002	-0.004	-0.004	0.000	0.000
	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)	(0.006)
4-6yrsSen	0.061***	0.061***	0.092***	0.092***	0.020	0.020
	(0.022)	(0.022)	(0.027)	(0.027)	(0.037)	(0.036)
7-9yrsSen	0.041	0.042	0.055	0.059	-0.000	-0.000
	(0.043)	(0.043)	(0.057)	(0.057)	(0.066)	(0.066)
10+yrsSen	0.048	0.050	0.079	0.083	-0.027	-0.027
	(0.069)	(0.069)	(0.087)	(0.086)	(0.107)	(0.107)
Associate	0.028	0.026	0.076	0.073	-0.030	-0.029
	(0.041)	(0.041)	(0.053)	(0.054)	(0.062)	(0.062)
Professor	-0.007	-0.004	0.089	0.096	-0.160	-0.161
	(0.070)	(0.070)	(0.084)	(0.083)	(0.126)	(0.126)
Observations	2,740	2,740	1,625	1,625	1,115	1,115

Robust standard errors in parentheses
Field and year effects not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

theory proposed by Nakosteen and Zimmer [1987] that seeks to explain this phenomenon is that there is selection in the marriage market; essentially, potential spouses recognize higher earning potential and choose their partner accordingly. Another popular theory originally proposed by Becker [1985] is that marriage makes men more productive through specialization and division of household labor. We do not seek to explain this effect in this work. However, since the majority of our joint hires are married it is important for us to control for this possibility.

Marital status is not tracked in official university records. Therefore, to probe into this concern, we obtained survey data that was randomly administered to a subsample of tenure-stream WSU faculty in 2009 which contains marital status information. We were able to match the marital information from the survey to our administrative data for 322 individuals who were employed at WSU in 2009. Table 6 contains summary information on this reduced sample. Of those 322 individuals, 46 of them (14 percent) are joint hires which corresponds precisely to the 14 percent who are joint hires in our larger data set. This close correspondence gives us confidence that the survey is representative of the larger population. Based on the survey data we find that a very large portion (83 percent) of tenure stream faculty at WSU in 2009 were married and it is unlikely that this has changed much in the years prior or since because of relatively low turnover in the university as well as the slow speed at which cultural norms tend to shift. Using this much smaller sample of faculty, and adding a time constant control variable for marital status as of 2009, we estimate the

Table 6: Summary Statistics on Marital Status Data

	Married Data	Males	Females
Number of person/year observations	1540	845	695
Number of individuals	322	175	147
Married individuals	266	150	116
Not married individuals	56	25	31
Joint hire individuals	46	24	22
Married joint hires	43	21	22
Primary hires	35	20	15
Partner hires	11	4	7

same productivity equations as before with the understanding that statistical power will be reduced because of a smaller sample size.

The small sample effect is not much of a concern with the publications estimation because of the panel nature of the data. There is variation in two dimensions, both across individuals (between variation) and within the same individual over time (within variation). Having two sources of variation helps isolate the effects with greater accuracy. However because the dependent variable for whether an individual obtained a grant is time constant, estimation for this model relies almost completely on between variation. The combined effect of one dimension of variation and small samples for joint hires makes these estimates unusable.[16] We report the estimations for males and females separately but caution the reader about the interpretation on the partner hire variable as the sample sizes for partner hires are 4 and 7 for males and females, respectively. Table 7 contains the publications results for the random effects specification. For brevity we report only on the variables for joint hire, primary hire, partner hire, and marital status.

Table 7: Publications with marital data, random effects specification

VARIABLES	All-1	All-2	Males-1	Males-2	Females-1	Females-2
Joint Hire	0.425		0.521		0.252	
	(0.286)		(0.441)		(0.375)	
Primary Hire		0.697**		0.880*		0.458
		(0.317)		(0.480)		(0.429)
Partner Hire		-0.508		-0.990		-0.312
		(0.558)		(0.945)		(0.679)
Married	0.196	0.208	0.214	0.241	0.183	0.174
	(0.276)	(0.274)	(0.448)	(0.445)	(0.344)	(0.345)
Observations	1,540	1,540	845	845	695	695
No. of Unique Individuals	322	322	175	175	147	147

Standard errors in parentheses
All other controls not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Looking at the publications results we see that after controlling for marital status using

[16]It may interest some readers to know that all four of the male partner hires who were included in this survey obtained grants and six of the seven female partner hires obtained grants.

this smaller sample of faculty, the point estimates for joint hire, primary hire, and partner hire are very similar to those from the full data set. In our full data set we found that the average joint hire produces 0.472 more publications per year than a non-joint hire and in this reduced sample where we control for marital status, the point estimate is reduced by less than a tenth to 0.410. We attribute the loss of statistical significance to the reduced sample size and corresponding loss of statistical power. The estimates for all other variables are also quite similar. Primary hires in our full data set produced 0.782 more publications per year than their colleagues and in this reduced subsample the estimate again fell by less than a tenth to 0.697. The estimate for partner hires increased by approximately a tenth. The similarity in the point estimates between the two samples adds further evidence that the effect we are capturing is not a marital effect but rather some other factor related to being a joint hire. Our theory explains this additional effect based on selection where highly productive individuals choose to go to lower ranked schools because of a strong desire to work near or with their partner.

5 Summary and Conclusion

The presence of couples in particular labor markets can have dramatic effects on the quality distribution of employees within a single firm because of the additional constraint couples face of wanting to work near each other or even in the same institutions. We hypothesize that in the academic labor market specifically, some universities may benefit from the strong desire many academic couples have to work at the same institution. Highly productive candidates may choose to accept an offer from a less prestigious institution in order to be near their partner. Thus, all but the most elite universities can attract talent above their average by offering jobs to both partners of a couple. As a result the expected level of productivity for the average joint hire individual in schools other than the most elite schools should be higher than their colleagues.

We examine this implication using data on tenure stream faculty at Washington State University. We estimate two different sets of productivity equations. In the first set we use the quantity of publications as the dependent variable. In the second set we look at whether an individual obtained a grant as the dependent variable. We find that joint hires publish more and have a higher propensity to obtain a grant. We also find that partner hires on the whole are no less productive than their colleagues and thus concerns that couple hiring may dilute faculty quality are unfounded and in most cases the opposite may be true.

Future work in this area should look into the additional implication of our theory that as the proportion of couples participating in the academic labor market increases, the average productivity differences across schools should diminish. Our data comes from only a single university thus, we are not able to explore this implication currently. Also, given that joint hires are more productive (as our theory predicts and we empirically demonstrate), it would be interesting to explore whether there are salary and tenure differences for joint hires. If there are differences, how big are they? Our current model is salary neutral and cannot address this aspect of couple hiring. We suspect that there are two competing effects that might influence differences in salary. As opposed to the positive influence that higher productivity may have on salary, there may exist a negative effect on joint hire salary due to the bargaining process. Universities are aware of high mobility costs associated with being part of a dual-career academic couple and may be able to exercise a degree of monopsony power over these couples as Ransom [1993] suggests.

Our work can provide important insights for university administrators who may be considering policies to aid in the recruitment of couples. We have not explicitly discussed whether having policies aimed at recruiting couples is beneficial for the university and are not recommending that a university should or should not adopt such policies. Rather we are demonstrating that because couples have a strong desire to remain together, schools outside of the most elite may stand to benefit from the presence of couples in the academic labor market.

A Appendix

A.1 Deriving the General Solution with Couples and Singles when Couples are Evaluated Independently

As shown in Equation 2.5, the probability of hiring a single candidate for each school is

$$\int_0^{\tau_k} f(\theta)\, d\theta. \tag{A.1}$$

And as shown by Equation 2.6, the probability of hiring a couple for each school is

$$\int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \int_0^{\tau_k} f(\theta_y)\, d\theta_y + 2 \cdot \int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \int_{\tau_k}^{\infty} f(\theta_y)\, d\theta_y \tag{A.2}$$

which can be rewritten as:

$$\int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \int_0^{\tau_k} f(\theta_y)\, d\theta_y + 2 \cdot \int_0^{\tau_k} f(\theta_x)\, d\theta_x \cdot \left(1 - \int_0^{\tau_k} f(\theta_y)\, d\theta_y\right) \tag{A.3}$$

In order to determine the appropriate minimum threshold values in a world where both single and couple candidates exist, we need to form a convex combination of these two densities as given by equation A.4.

$$\alpha \underbrace{\int_0^{\tau_k} f(\theta_x)\, d\theta_x \int_0^{\tau_k} f(\theta_y)\, d\theta_y + 2\left(\int_0^{\tau_k} f(\theta_x)\, d\theta_x\right)\left(1 - \int_0^{\tau_k} f(\theta_y)\, d\theta_y\right)}_{\text{Probability of a couple hire}} + (1+\alpha) \underbrace{\int_0^{\tau_k} f(\theta)\, d\theta}_{\substack{\text{Probability of a} \\ \text{single hire}}} = \frac{k-1}{K} \tag{A.4}$$

Each member of the couple has productivity that is drawn from the same distribution and the subscripts are merely for expositional convenience. Therefore to avoid cumbersome notation, we represent the integral from 0 to τ_k over the general distribution, $f(\theta)$, for any candidate type, whether single or part of a couple, as

$$P \equiv \int_0^{\tau_k} f(\theta)\, d(\theta) \tag{A.5}$$

and form the combination. Then school k's decision is to choose τ_k such that the weighted probability of hiring a couple plus the weighted probability of hiring a single candidate is equal to $\frac{k-1}{K}$ as derived in Equation A.6.

$$\begin{aligned}
\alpha\left[(P)^2 + 2\left(P\left(1-P\right)\right)\right] + \left(1-\alpha\right)P &= \frac{k-1}{K} \\
\alpha P^2 + 2\alpha P - 2\alpha P^2 + P - \alpha P &= \frac{k-1}{K} \\
\left(1+\alpha\right)P - \alpha P^2 &= \frac{k-1}{K} \\
\left(1+\alpha\right)\left(\int_0^{\tau_k} f\left(\theta\right)d\left(\theta\right)\right) - \alpha\left(\int_0^{\tau_k} f\left(\theta\right)d\left(\theta\right)\right)^2 &= \frac{k-1}{K} \\
\left(1+\alpha\right)\int_0^{\tau_k} f\left(\theta\right)d\theta - \alpha\int_0^{\tau_k} f\left(\theta\right)d\theta\int_0^{\tau_k} f\left(\theta\right)d\theta &= \frac{k-1}{K}
\end{aligned} \tag{A.6}$$

If desired, the theory allows for different distributional assumptions among singles and couples, as well as for partners within couples. However doing so will prevent the preceding simplification of the equation.

A.2 Proof of Higher Expected Productivity for Couple Candidates

Proof We want to answer the question of whether the inequality in Equation A.7 is true.

$$\frac{\int_{\tau_k}^{\tau_{k+1}}\theta_x f\left(\theta_x\right)d\left(\theta_x\right)\int_{\tau_k}^{\infty} f\left(\theta_y\right)d\left(\theta_y\right) + \int_{\tau_{k+1}}^{\infty}\theta_x f\left(\theta_x\right)d\left(\theta_x\right)\int_{\tau_k}^{\tau_{k+1}} f\left(\theta_y\right)d\left(\theta_y\right)}{\int_{\tau_k}^{\tau_{k+1}} f\left(\theta_x\right)d\left(\theta_x\right)\int_{\tau_k}^{\infty} f\left(\theta_y\right)d\left(\theta_y\right) + \int_{\tau_{k+1}}^{\infty} f\left(\theta_x\right)d\left(\theta_x\right)\int_{\tau_k}^{\tau_{k+1}} f\left(\theta_y\right)d\left(\theta_y\right)} \overset{?}{>} \frac{\int_{\tau_k}^{\tau_{k+1}}\theta f\left(\theta\right)d\left(\theta\right)}{\int_{\tau_k}^{\tau_{k+1}} f\left(\theta\right)d\left(\theta\right)} \tag{A.7}$$

Since all productivities are drawn from the same distribution and the subscripts are simply there to aid in the presentation of the theory, we can remove the subscripts. Also to simplify the notation further, let us also re-label the bounds as follows: let $a \equiv \tau_k$ and $b \equiv \tau_{k+1}$ such that $0 < a < b$. Then the inequality becomes

$$\frac{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)\int_a^{\infty} f\left(\theta\right)d\left(\theta\right) + \int_b^{\infty}\theta f\left(\theta\right)d\left(\theta\right)\int_a^b f\left(\theta\right)d\left(\theta\right)}{\int_a^b f\left(\theta\right)d\left(\theta\right)\int_a^{\infty} f\left(\theta\right)d\left(\theta\right) + \int_b^{\infty} f\left(\theta\right)d\left(\theta\right)\int_a^b f\left(\theta\right)d\left(\theta\right)} \overset{?}{>} \frac{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)}{\int_a^b f\left(\theta\right)d\left(\theta\right)} \tag{A.8}$$

We proceed to simplify and rearrange this inequality until we can produce a form that clearly holds true.

$$\frac{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)\int_a^{\infty} f\left(\theta\right)d\left(\theta\right) + \int_b^{\infty}\theta f\left(\theta\right)d\left(\theta\right)\int_a^b f\left(\theta\right)d\left(\theta\right)}{\cancel{\int_a^b f\left(\theta\right)d\left(\theta\right)}\left(\int_a^{\infty} f\left(\theta\right)d\left(\theta\right) + \int_b^{\infty} f\left(\theta\right)d\left(\theta\right)\right)} \overset{?}{>} \frac{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)}{\cancel{\int_a^b f\left(\theta\right)d\left(\theta\right)}} \tag{A.9}$$

$$\cancel{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)\int_a^{\infty} f\left(\theta\right)d\left(\theta\right)} + \int_b^{\infty}\theta f\left(\theta\right)d\left(\theta\right)\int_a^b f\left(\theta\right)d\left(\theta\right) \overset{?}{>} \cancel{\int_a^b\theta f\left(\theta\right)d\left(\theta\right)}\left(\cancel{\int_a^{\infty} f\left(\theta\right)d\left(\theta\right)} + \int_b^{\infty} f\left(\theta\right)d\left(\theta\right)\right) \tag{A.10}$$

$$\int_b^{\infty}\theta f\left(\theta\right)d\left(\theta\right)\int_a^b f\left(\theta\right)d\left(\theta\right) \overset{?}{>} \int_a^b\theta f\left(\theta\right)d\left(\theta\right)\int_b^{\infty} f\left(\theta\right)d\left(\theta\right) \tag{A.11}$$

$$\frac{\int_b^\infty \theta f(\theta)\, d(\theta)}{\int_b^\infty f(\theta)\, d(\theta)} > \frac{\int_a^b \theta f(\theta)\, d(\theta)}{\int_a^b f(\theta)\, d(\theta)} \tag{A.12}$$

Equation A.12 clearly holds true. It states that the expected value of θ over the reweighted density region on the interval b to ∞ is greater than the expected value of θ over the reweighted density region on the interval a to b. Since $0 < a < b$, the inequality clearly holds. Hence the original inequality must also hold.

In the top school however, the bounds on the couple side of the inequality change a little. Here τ_{k+1} doesn't exist and becomes ∞. So the inequality becomes

$$\frac{\int_{\tau_k}^\infty \theta_x f(\theta_x)\, d(\theta_x) \int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y) + \int_\infty^\infty \theta_x f(\theta_x)\, d(\theta_x) \int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y)}{\int_{\tau_k}^\infty f(\theta_x)\, d(\theta_x) \int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y) + \int_\infty^\infty f(\theta_x)\, d(\theta_x) \int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y)} \overset{?}{>} \frac{\int_{\tau_k}^\infty \theta f(\theta)\, d(\theta)}{\int_{\tau_k}^\infty f(\theta)\, d(\theta)}. \tag{A.13}$$

The integrals from ∞ to ∞ are zero and drop out of the inequality which leaves

$$\frac{\int_{\tau_k}^\infty \theta_x f(\theta_x)\, d(\theta_x) \cancel{\int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y)}}{\int_{\tau_k}^\infty f(\theta_x)\, d(\theta_x) \cancel{\int_{\tau_k}^\infty f(\theta_y)\, d(\theta_y)}} \overset{?}{>} \frac{\int_{\tau_k}^\infty \theta f(\theta)\, d(\theta)}{\int_{\tau_k}^\infty f(\theta)\, d(\theta)}. \tag{A.14}$$

And since the subscripts can be removed we are left with

$$\frac{\int_{\tau_k}^\infty \theta f(\theta)\, d(\theta)}{\int_{\tau_k}^\infty f(\theta)\, d(\theta)} = \frac{\int_{\tau_k}^\infty \theta f(\theta)\, d(\theta)}{\int_{\tau_k}^\infty f(\theta)\, d(\theta)}, \tag{A.15}$$

which is clearly an equality. ∎

A.3 Theoretical Solutions Using a $U[0,1]$ distribution with $K = 3$ Schools and a $\Gamma[\alpha = 2, \beta = 2]$ distribution with $K = 5$ Schools

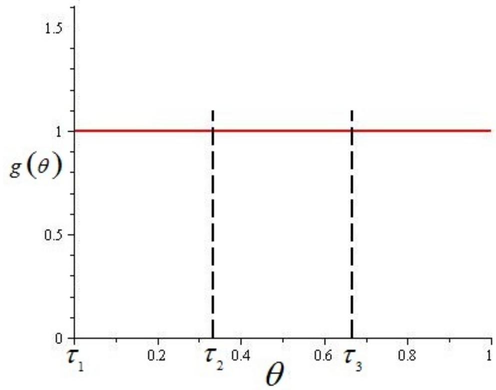
We solve Equation 2.5 under 2 cases for illustrative purposes. We first assume candidate productivity is uniformly distributed along the unit interval with $K = 3$ schools. In Figure 3 we show this distribution with the τ_k's marked and their corresponding values given in the table next to the figure.

For the second case we assume productivity follows a gamma distribution, with shape and scale parameters arbitrarily set equal to 2, and $K = 5$ schools. Figure 4 illustrates this solution.

We illustrate how these threshold values change using our earlier uniform and gamma distributed examples. With the uniform distribution and $K = 3$ schools, it is possible to derive the analytical solutions for threshold values as a function of α. These solutions are reported as a column vector in Equation A.16.

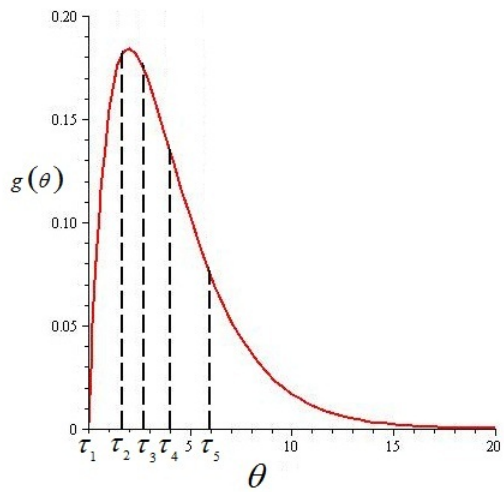
$$\begin{bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{3+3\alpha-\sqrt{9+6\alpha+9\alpha^2}}{6\alpha} \\ \frac{3+3\alpha-\sqrt{9-6\alpha+9\alpha^2}}{6\alpha} \end{bmatrix} \tag{A.16}$$

Figure 3: Equilibrium Values for τ_k with $\theta_i \sim U[0,1]$ and $K = 3$



k	τ_k
1	0
2	0.33
3	0.67

Figure 4: Equilibrium thresholds with $\theta_i \sim \Gamma[\alpha = 2, \beta = 2]$ and $K = 5$



k	τ_k
1	0
2	1.65
3	2.75
4	4.04
5	5.99

In Figure 5 we plot how these threshold values change as α increases from zero to one. As the proportion of couples in the labor market increases, the minimum thresholds set by the higher-tier schools decreases. This happens because as highly productive individuals who are part of the off-diagonal couple types opt to go to lower-tier schools, vacancies are created in the higher-tier schools. Thus the higher-tier schools must lower their thresholds slightly in order to pick up a few more candidates who otherwise would not have received offers from those schools.

We observe the same pattern when we apply the gamma distribution to candidate productivity. We are not able to calculate a clean analytical solution as a function of alpha in this case. However, we are able to specify various values of alpha and obtain numerical solutions for the threshold values. Figure 6 is a plot for how the threshold values change as we increase alpha from 0 to 1 using a gamma distribution and $K = 5$ schools. Again, we observe that as the proportion of couples in the market increases, the minimum thresholds set by the higher-tier schools decrease.

We finish off the earlier examples with the uniform and gamma distributions by cal-

Figure 5: Change in Threshold Values for $\alpha \in (0, 1)$, Uniform Distribution

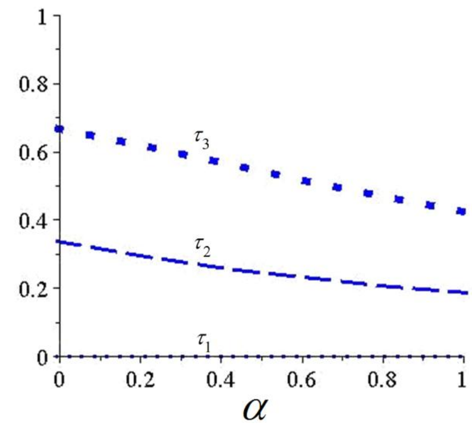
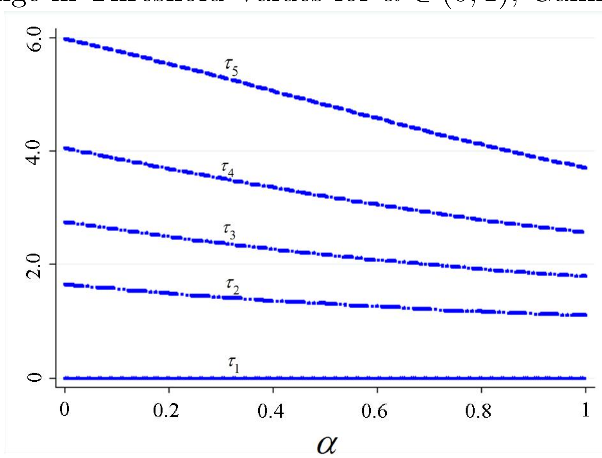


Figure 6: Change in Threshold Values for $\alpha \in (0, 1)$, Gamma Distribution



culating the expected productivity levels for the average single candidate and the average candidate who is part of a couple at each of the K schools. We arbitrarily choose $\alpha = 0.1$ in order to obtain our threshold values which are then used in calculating the expectations. For the uniform case with $K = 3$ schools, Table 8 gives the minimum threshold values, the expected level of productivity for single candidates, the average of the expected levels of productivity for couple candidates, and the percent difference in productivity for each of the 3 schools. Table 9 provides the same information under a gamma distribution with $K = 5$ schools.

Table 8: Comparison of Expected Productivity, $U[0, 1]$ and $K = 3$ Schools

School	Minimum Thresholds	EV Singles	Average EV couples	% greater
1	0.00	0.16	0.36	131%
2	0.31	0.48	0.60	25%
3	0.64	0.82	0.82	0%

The results in the tables illustrate what was proved earlier, that given our assumptions

Table 9: Comparison of Expected Productivity, $\Gamma\left(\alpha=2, \beta=2\right)$ and $K=5$ Schools

School	Minimum Thresholds	EV Singles	Average EV couples	% greater
1	0.00	0.97	2.64	172%
2	1.57	2.09	3.56	70%
3	2.62	3.22	4.57	42%
4	3.87	4.73	5.93	25%
5	5.77	8.28	8.28	0%

about couple and university behavior, when couples exist in the marketplace the expected level of productivity for someone who is hired as part of a couple will be greater on average than someone who is not hired as part of a couple. This difference is greatest in the lowest-tier schools and shrinks to zero as we look at progressively higher ranked schools.

A.4 Poisson Model for Publications

We include in this section Table 10 which contains the results from the publications regression using a Poisson regression model and note that the point estimates and significant variables change little from the random effects specification with an exception for the male partner hires who publish less than other males and the difference is statistically significant.

Table 10: Publications per year, poisson model

VARIABLES	All	All	Male	Male	Female	Female
Joint Hire	0.365**		0.561***		0.046	
	(0.172)		(0.211)		(0.258)	
Primary Hire		0.546***		0.739***		0.176
		(0.171)		(0.206)		(0.274)
Partner Hire		-0.643		-1.174***		-0.352
		(0.395)		(0.397)		(0.524)
Administrator	-1.041***	-1.072***	-0.888**	-0.941**	-1.849***	-1.860***
	(0.395)	(0.390)	(0.424)	(0.418)	(0.630)	(0.625)
Female	-0.081	-0.061				
	(0.130)	(0.127)				
Prior Experience	-0.015	-0.012	-0.030**	-0.024*	0.012	0.012
	(0.012)	(0.012)	(0.014)	(0.014)	(0.021)	(0.021)
4-6 years of seniority	-0.009	0.003	-0.071	-0.059	0.123	0.128
	(0.122)	(0.122)	(0.149)	(0.149)	(0.194)	(0.195)
7-9 years of seniority	0.059	0.047	-0.005	-0.040	0.197	0.195
	(0.202)	(0.200)	(0.224)	(0.222)	(0.355)	(0.351)
10+ years of seniority	-0.003	-0.022	-0.171	-0.214	0.214	0.212
	(0.264)	(0.263)	(0.291)	(0.287)	(0.470)	(0.470)
Associate	0.223	0.245	0.297	0.339	0.061	0.070
	(0.203)	(0.201)	(0.229)	(0.224)	(0.353)	(0.350)
Professor	0.296	0.258	0.647**	0.617*	-0.620	-0.640
	(0.269)	(0.270)	(0.328)	(0.329)	(0.535)	(0.537)
Constant	-2.661***	-2.710***	-2.412***	-2.463***	-3.264***	-3.280***
	(0.502)	(0.503)	(0.618)	(0.620)	(0.695)	(0.695)
Observations	2,740	2,740	1,625	1,625	1,115	1,115

Robust standard errors in parentheses
Field and year effects not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

A.5 Evaluating the Productivity of Joint Hires in STEM Fields

A.5.1 Summary Statistics

We narrow our data to include only those fields defined as STEM according to WSU's ADVANCE program and conduct our empirical estimation using only this subset.[17] Table 11 contains summary information on the composition of joint hires in STEM Disciplines.

Table 11: Joint Hire Faculty Composition

	All	Males	Females
Number of person/year observations	1034	745	289
Number of individuals	246	178	68
Joint hire individuals	45	28	17
Primary hire individuals	34	22	12
Partner hire individuals	11	6	5

The summary statistics are not all that different from the larger sample. The proportion of individuals in STEM Fields who are joint hires is slightly greater for males (15.7%) and significantly greater for females (25%) than in the full sample. The differences in mean productivity levels are larger as well. Table 12 shows the mean productivity comparison. The data suggest the same trend that we found in the full sample.

Table 12: Productivity Measures

	All	Males	Females
Mean Publications: Non Joint Hire	1.30	1.33	1.22
Mean Publications: Joint Hire	2.03	2.42	1.44
P-value for differences	0.009	0.002	0.625
% of Group who Obtained a Grant: Non Joint Hire	55%	53%	63%
% of Group who Obtained a Grant: Joint Hire	75%	71%	83%
P-value for differences	0.014	0.077	0.139

A.5.2 Productivity Estimations

We formally test the implication that joint hires are more productive in STEM Fields by first estimating the productivity equations for publications and grants that were specified in equations 3.1 through 3.4 using only those in STEM fields. The results of these estimations are presented in Tables 13 through 15

The average joint hire in a STEM field has 0.73 more publications per year than a non-joint hire. Male joint hires publish just over one more publication per year on average relative to other males while there is no statistical difference for female joint hires relative to other females. The average primary hire publishes just shy of one more time per year while a male primary hire publishes 1.5 more times per year relative to other males. Partner hires in STEM Fields overall are no different in their publication rates however partner hires who

[17]See Table 16 at the end of this section for a list of those departments identified as STEM.

Table 13: Publications per Year: STEM Fields, Random Effects

VARIABLES	STEM-1	STEM-2	Male-1	Male-2	Female-1	Female-2
Joint Hire	0.730***		1.013***		0.225	
	(0.279)		(0.352)		(0.476)	
Primary Hire		0.994***		1.555***		0.047
		(0.308)		(0.387)		(0.526)
Partner Hire		-0.200		-1.036		0.800
		(0.545)		(0.716)		(0.861)
Administrator	-0.773	-0.777	-0.652	-0.687	-0.578	-0.579
	(0.493)	(0.493)	(0.533)	(0.529)	(1.399)	(1.400)
Female	-0.424*	-0.414*				
	(0.248)	(0.248)				
Prior Experience	-0.051**	-0.048**	-0.074***	-0.067***	0.054	0.054
	(0.020)	(0.020)	(0.022)	(0.022)	(0.048)	(0.048)
4-6 years of seniority	0.123	0.135	0.015	0.048	0.522	0.517
	(0.248)	(0.248)	(0.300)	(0.298)	(0.442)	(0.442)
7-9 years of seniority	-0.100	-0.133	-0.087	-0.187	0.332	0.327
	(0.342)	(0.342)	(0.401)	(0.399)	(0.700)	(0.700)
10+ years of seniority	-0.007	-0.040	0.106	0.010	-0.045	-0.115
	(0.543)	(0.542)	(0.595)	(0.592)	(1.574)	(1.578)
Associate	0.655**	0.705**	0.519	0.656*	0.616	0.593
	(0.306)	(0.306)	(0.363)	(0.363)	(0.602)	(0.603)
Full	0.960**	0.943**	1.255**	1.263***	-1.071	-1.057
	(0.433)	(0.433)	(0.487)	(0.484)	(1.073)	(1.074)
Constant	0.300	0.276	0.767	0.769	-0.692	-0.665
	(0.449)	(0.449)	(0.567)	(0.563)	(0.730)	(0.732)
Observations	1,034	1,034	745	745	289	289
No. of Unique Individuals	253	253	182	182	71	71
R-squared	0.05	0.054	0.07	0.084	0.078	0.8

Robust standard errors in parentheses
Field and year effects not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

are male do publish just over 1 less article per year. There is no statistical difference for female partner hires.

Table 14 gives the publication results using the reduced sample for which we have marital status information. The point estimates are again similar though they are no longer statistically significant. This is a result of the loss of statistical power due to the smaller sample size.

Table 14: Publications with marital data, random effects, STEM fields

VARIABLES	STEM-1	STEM-2	Male-1	Male-2	Female-1	Female-2
Joint Hire	0.670		0.670		0.545	
	(0.491)		(0.762)		(0.624)	
Primary Hire		0.839		1.360		0.373
		(0.560)		(0.857)		(0.698)
Partner Hire		0.224		-1.140		1.026
		(0.860)		(1.318)		(1.071)
Married	0.177	0.179	-0.116	-0.078	0.683	0.682
	(0.520)	(0.521)	(0.811)	(0.794)	(0.674)	(0.675)
Observations	570	570	380	380	190	190
No. of Unique Individuals	124	124	81	81	43	43
R-squared	0.069	0.07	0.088	0.097	0.136	0.138

Robust standard errors in parentheses
Unreported controls include admin, female, experience, seniority, field, and year effects
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Concerning their ability to obtain grants, Joint hires in STEM fields are 22 percent more likely to obtain a grant than their colleagues. Remarkably, we were not able to obtain an estimate for partner hires in STEM fields because there was no variation in the variable. Every partner hire in a STEM field at WSU hired since 1999 obtained a grant. Primary hires are 17 percent more likely to obtain a grant relative to their colleagues. Also there are stronger effects for the seniority variables in STEM fields compared to the full sample. As seniority increases so does the propensity to obtain a grant.

Table 16 displays those departments at WSU with a STEM designation as defined by the WSU ADVANCE program.

Table 15: Marginal Effects for the Propensity to Obtain a Grant, probit model, STEM Fields

VARIABLES	All-1	All-2	Male-1	Male-2	Female-1	Female-2
Joint Hire	0.220***		0.218**		0.159	
	(0.077)		(0.095)		(0.117)	
Primary Hire		0.168*		0.157		0.136
		(0.086)		(0.106)		(0.133)
Partner Hire†						
Administrator	0.011	0.017	0.019	0.026		
	(0.128)	(0.131)	(0.130)	(0.132)		
Female	0.093	0.100				
	(0.069)	(0.072)				
Prior Experience	0.001	0.001	0.003	0.003	-0.007	-0.008
	(0.005)	(0.005)	(0.006)	(0.006)	(0.009)	(0.010)
4-6 years of seniority	0.110***	0.113***	0.140***	0.141***	0.025	0.026
	(0.031)	(0.032)	(0.037)	(0.039)	(0.055)	(0.060)
7-9 years of seniority	0.160**	0.175**	0.156**	0.169**	0.013	0.013
	(0.068)	(0.070)	(0.078)	(0.080)	(0.118)	(0.128)
10+ years of seniority	0.215**	0.234**	0.190*	0.206*	0.085	0.082
	(0.097)	(0.100)	(0.113)	(0.115)	(0.192)	(0.206)
Associate	0.015	0.004	0.053	0.041	-0.021	-0.023
	(0.062)	(0.066)	(0.073)	(0.076)	(0.098)	(0.107)
Full	-0.126	-0.134	-0.033	-0.039	-0.338*	-0.347*
	(0.095)	(0.101)	(0.109)	(0.114)	(0.174)	(0.194)
Observations	1,034	993	745	721	281	264

Standard errors in parentheses
Field and year effects not reported
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
†Every partner hire in a STEM field obtained a grant

Table 16: STEM Fields at WSU by College

College of Sciences
School of Biological Sciences
Chemistry
School of Earth and Environmental Sciences
Mathematics
Physics and Astronomy
Statistics
College of Engineering and Architecture
Chemical Engineering and Bioengineering
Civil and Environmental Engineering
Electrical Engineering and Computer Science
Engineering and Computer Science
Mechanical and Materials Engineering
College of Liberal Arts
Anthropology
Psychology
Sociology
College of Agricultural, Human, and Natural Resource Sciences
Animal Sciences
Institute of Biological Chemistry
Biological Systems Engineering
Crop and Soil Sciences
School of Economic Sciences
Entomology
School of Food Science
Horticulture and Landscape Architecture
Natural Resource Sciences
Plant Pathology
College of Veterinary Medicine
School for Global Animal Health
School of Molecular Biosciences
Veterinary and Cmparative Anatomy, Pharmacology, and Physiology
Veterinary Microbiology and Pathology

Source: `http://advance.wsu.edu/default.asp?PageID=4506`

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