ACADEMIC COUPLES AND THE ECONOMICS OF THE CO-LOCATION PROBLEM

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Dedication

This dissertation is dedicated to my family.

Abstract

Dual career couples often face the problem of finding two jobs close to each other, mostly in the same metropolitan areas, which is called the co-location problem. The co-location problem has significant implications in the study of the distribution of human resources across cities.

In Chapter 1 of this thesis, we employ the data set of National Study of Postsecondary Faculty (NSOPF), which consists of 4 cycles of comprehensive surveys about the faculty and/or institutions in postsecondary education, to study the demographical changes and co-location problem of the postsecondary faculty in USA from year 1987 to year 2004. We document some demographical changes of the postsecondary faculty. Our work shows that the co-location problem has more impacts on the faculty in smaller cities. We find evidences of ability sorting of the faculty among cities of different sizes.

Chapter 2 of this thesis develops a parsimonious model that examines equilibrium behaviors by universities as well as by academics. The model has a deterministic structure with cities differing in the variety of schools. Schools in cities with more varieties of schools have an advantage over schools of the same type in cities with fewer varieties of schools, because schools of the other type in the same cities help accommodate spouses with different ability levels. Schools can make hiring decisions based the average of a couple's abilities, which is referred to as couple accommodation policy in this thesis, or based on the merit of each individual in isolation. We establish in this chapter that it is better off for any school to adopt the couple accommodation policy regardless of its location and quality. However, the impact on each school of the couple accommodation policy in the equilibrium where every school implements such a policy differs by school location and quality. High quality schools in large cities always get worse off and low quality schools in small cities always get better off.

Chapter 3 of the thesis provides a probabilistic model of the co-location problem for any labor market in general. In the model, cities differ solely in the number of firms. Firms are ex ante the same to all workers. We establish the theoretical results that dual career couples are more likely to locate in larger cities as compared to single career couples and that larger cities get higher ability workers. We also simulate the job choices by academics, and examine the quantitative implications of the co-location problem for the distribution of ability across cities in the academic labor market. The results show that as the labor market gets thinner or the marriage rate gets higher, the impact of co-location problem becomes stronger, i.e., the ability gap between faculty in large cities and those in small cities gets larger.

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Chapter 1

Introduction

1.1 Introduction

This thesis examines the economics of the co-location problem of academic couples. To a remarkable degree young Ph.D. trained professionals looking to make a name for themselves in academics are married to spouses with the same goal. This is tricky because the academic market tends to be a thin market making the chance for finding two suitable jobs in the same city lower than it would be for other occupations with thicker markets.

In an earlier time period where the wife typically was not in the labor force, this wasn't an issue. Great universities like Penn State and Purdue could be located in remote locations like State College, PA, and West Lafayette, IN, and they could make hiring decisions without worrying about any co-location problem. One job per household was all that was needed. In today's environment, the co-location problem is the front and center in the hiring decisions of these universities and they frequently have to deal with figuring out a way to get jobs for two academics, if they are to hire anyone.

The aim of this thesis is to develop formal models of the co-location problem and to analyze the impacts of polices the universities can take to address the co-location problem. The thesis does some preliminary investigation of data on academic couples to get a sense of the magnitudes of the issues at stake.

It is readily clear that finding academic two jobs should be much easier in locations with lots of jobs. The Boston metropolitan area has dozens of universities and colleges. There are many academic couple where one spouse works at one place (e.g. Harvard, MIT, etc) the other spouse works at another place (e.g. Tufts, Northeastern, etc.). In State College, PA, if one spouse works for the Penn State, the other spouse better have a job there as well. So the co-location problem cuts against rural colleges and universities the most. As these rural academic institutions have a more difficult time attracting faculties, the potential is there for the rural institutions to fall behind the urban institutions in quality. So a central issue in the analysis is how the distribution of quality across institutions is impacted by the emergence of the co-location problem.

While the academic market is the main focus of this thesis, this analysis should have a broader interest to those studying labor markets and urban economics. The co-location issue is a kind of labor pooling agglomeration benefit. Traditionally, the benefit of labor pooling is that in a thick market an individual losing her or his job has a better chance of finding a second job in a bigger market. So rather than look over time, finding two jobs over time for the same person, this analysis looks at finding two jobs in the same place at the same time for two different people that need jobs in same city because they live together. The dual career issues that we study here extend well beyond the academic market. For many high skill occupations like specialist lawyers and doctors, markets can be similarly thin. Large urban areas present a way to make these markets thick.

This thesis is divided into three chapters. This introductory chapter provides a review of the literature on the co-location problem and in particular its relevance for academic couples. It also provides some analysis of the data on academic couples that has not be examined before in the context of the co-location literature.

The second chapter develops a theoretical model that examines equilibrium behaviors by universities as well as by academics themselves. As will be seen, there is an incentive by universities to make hiring decisions on the basis of the average of a couple's abilities. This can be contrasted where the hiring rule is based on the merit of each individual in isolation.

The main work of this chapter is to compare the equilibrium when universities use a couple standard to the equilibrium when they use an individual standard. The main finding is that it is optimal for each school to adopt the couple accommodation policy regardless of its location and quality. However, the impact of the policy when every school implements the policy differs by school location and quality. High quality schools in large cities always get worse off and low quality schools in small cities always get better off.

The second chapter examines issues in a highly simplified structure. In particular there are two city size types, large and small. The large city has two types of universities, and the small city has one type of universities, and other simplifications.

The third chapter examines a more general structure. The intent is to see what kind of general results we can say. It also makes a very preliminary attempt to be quantitative. It uses the distribution of academic jobs across metro areas and the percentage of academics that are coupled with other academics to get a sense of the quantitative importance of these issues.

1.2 Review of The Literature

1.2.1 Most Closely Related Papers

There are two main papers in the literature, Costa and Kahn (2000) and Frank (1978). We begin by describing what each of these papers does and how my thesis relates to their work.

Frank provided a model of couple job choice. My model is very similar to Frank. The main thing is that we study the incentive of the universities.

Costa and Kahn (2000) noted the issue. They provide evidence that rural universities are falling behind.

The main differences of my thesis from Costa and Kahn (2000) are: (1) We uses a formal theoretical model. (2) We use data on academic couples, rather than just couples of college graduates.

Costa and Khan (2000) also tried to show that power couples, couples of college graduates, have become more concentrated in large cities because of co-location problem. However, we find that their methodology is highly problematic and thus they failed to establish the geographical patterns of power couples. Their results are built upon the concepts of coincidental couples. There are three reasons that will make the number of coincidental couples unreliable. First, they sum up the number of females or males in cities of same size, and then take the minimal for each city size. This will presumably over-estimate the number of coincidental couples. The robust way is to take the minimal of the numbers of males and females in each city and then sum up over cities in the same size category. Second, singles in large cities presumably have higher probability to form couples because large cities are a better marriage market, and therefore, there are more couples in large cities even with the same numbers of males and females in large cities and small cities. Third, power singles are not necessarily going to get married to power singles, which makes the calculation of coincidental power couples meaningless. This is also true for other types of coincidental couples.

Frank's paper has the insight that it will be easier for dual career couples to find two jobs in large cities. However, Frank's paper did not go further than the couples' higher propensity. It does not have a model with equilibrium to study the rich theoretical implications.

One weakness of Frank's paper (1978) is that Frank makes ad hoc and unrealistic assumption that only single career workers would redistribute to small cities if the markets do not clear by voluntary choices. Frank (1978) makes this assumption based on the overrated propensity of a dual career couple to locate in large cities, as calculated in equation (9) in that paper.

Another weakness of Frank's model (1978) paper is that it works only when the percentage of dual career couples are small, which is not the case nowadays. Our model works for any percentage of dual career couples.

Also, we notice that the main proof in Frank's paper is not correct since there is no close form solution for the probability of a dual career couple to locate in a small city like equation (9) in that paper. Our simulation results also show that the probability in equation (9) is higher than the true value.

1.2.2 Additional Papers

This analysis is only interesting if there has been a growth in the phenomenon of academic couples. There is a literature that has documented this growth.

First, as is well known, more and more women (in particular, married women) are in the labor force. According to Ferber and Loeb (1997), in 1950, 34% of women were in the labor force, and this number grew to 58% in 1993, and 75% of women with four or more years of college entered the labor force. During 1993, fully 60% of those women with children under six were employed, and this number was 75% and 44% in 1993 and 1966 respectively, for women with children aged 6 to 17. As a result, the number of dual career couples has increased. According to Wolf-Wendel, et al (2003), dual career married couples constituted 8% of the population in 1920, and 37% of the population in 2000.

Second, the higher education sector has been especially impacted by the increasing number of dual career couples. According to Ferber and Loeb (1997), two trends other than increasing women labor participation rate also contributed to high percentage of dual career academic couples. There is increased number of women in doctoral programs, and more young people defer marriage into years of graduate schools. According to Stephan and Kassis (1997), the percentage of doctorates awarded to women had increased from 15.3% in 1920's to 33.9% in 1980's. According to Stephan and Kassis (1997), percentage of female faculty has increased from 12% during 1869-70 to 31.8% fall 1991. According to Astin and Milem (1997), by the beginning of 1990s, 35% of male faculty and 40% of female faculty nationally were partnered with faculty members, and between 1/4 and 1/3 of all full-time faculty members had spouses or partners who were also academics. The trend of more dual career couples is predicted to continue in the future.

The dual career couples in most cases had to find two jobs within commuting distances. As there are more and more dual career academic couples, in order for a university or college to successfully recruit or retain desired faculty members, with higher probability that a university or college has to consider helping their spouses find jobs on campus or off campus. Academic institutions have a lot to gain by paying attention to the needs of dual-career couples. According to Burke (1988), employment opportunities for partners were an issue in almost 20% of faculty appointments and resignation. As a result, the higher education sector has become friendlier to dual career couples. According to Raade (1997), in 1991, 44% of institutions provided some sort of job assistance for spouses, 29% provided expansion of time for achieving tenure, 36% provided accommodative scheduling, 11% provided tenure for part-time faculty, and 20% provided job sharing. According to Wolf-Wendel et al. (2000), 24% of universities have dual-career couple policies and the majority of universities provide ad-hoc assistance; research universities are more likely to have a dual-career couple policy.

Marwell, Rosenfeld, and Spilerman (1979) documented that married female academics are disproportionately more concentrated in large cities[1], arguably due to co-location problem. They also show that female academics are more likely to stay in the same city when they change jobs, which is presumably due to the co-location problem.

Compton and Pollak (2004) studied the migration pattern of power couples, and concluded that power couples are more likely to migrate to large urban areas than other kind of couples.

1.3 Motivating Facts

In this section, we provide some original analysis of data relating to the academic co-location problem. The analysis serves two purposes. First, it provides evidence to motivate the quantitative significance of the problem. Second, in the last chapter of the thesis, we do some numerical analysis. We use some of the results of this section to pin down parameters.

[1] Here, large cities include the large cities and the fringes of large cities, which is not clear in Costa and Khan (2000). Just inclusion serves better for the purpose of our study. Similarly, mid-size cities include the mid-size cities and the fringes of mid-size cities. Also, our definitions of large cities, mid-size cities and small cities are different from those in Costa and Khan (2000) in terms of population size.

1.3.1 The NSOPF Data

The data set we use is National Study of Postsecondary Faculty (NSOPF). NSOPF is the most comprehensive study of faculty in postsecondary educational institutions ever undertaken.

There are 4 cycles of NSOPF. In all four cycles of NSOPF, some numbers of faculties were surveyed and information was gathered about the backgrounds, responsibilities, workloads, salaries, benefits, attitudes, and future plans of both full- and part-time faculty. In some cycles, institutions and department chairpersons were surveyed, and information was gathered from institutional and department-level respondents.

The first cycle was conducted in 1987-1988 (NSOPF: 88) It includes a sample of 480 postsecondary institutions (including 2-year, 4-year, doctorate-granting, and other colleges and universities), over 3,000 department chairpersons, and over 11,000 instructional faculty. The second cycle was conducted in 1992-93 (NSOPF: 93). It includes surveys of institutions and faculties only. The sample of institution survey is 974 public and private not-for-profit degree-granting postsecondary institutions, with 94 percent response rate. The sample of the faculty survey is 31,354 faculty and instructional staff, with 84 percent response rate. The third cycle of NSOPF was conducted in 1998-99 (NSOPF: 99). It included a sample of 960 degree-granting postsecondary institutions and a sample of approximately 28,600 faculty and instructional staff from those institutions. Out of the initial sample of 28,600 faculty and instructional staff sent with questionnaires, a sub-sample of 19,813 faculty and instructional staff was drawn for additional survey follow-up. Approximately 18,000 faculty and instructional staff completed the questionnaires for a weighted response rate of 83 percent. The response rate for the institution survey was 93 percent. The fourth cycle of NSOPF was conducted in 2003-04 (NSOPF: 04). It included a sample of 1,080 public and private not-for-profit degree granting postsecondary institutions and a sample of 35,000 faculty and instructional staff, with 86 percent and 76 percent weighted response rates respectively.

The individual level NSOPF data is not available in the raw data format, but it is accessible online for creating tables and running regressions. The institution level NSOPF data can be downloaded and we use the institution level NSOPF data to pin down some parameters of simulation in chapter 3.

1.3.2 Variables

Three main categories of variables are relevant for the purpose of our thesis.

The first main category of the variables includes the demographic variables, income variables, and educational variables. For example, we use gender, age, marital status, race, education level, income. The second main category of the variables includes job description variables, such as variables about the institutions, part-time or full time, main activity and so on. The third main category of the variables includes information about spouses.

Geographical information of the institutions where the academic faculties are employed is one of the most important variables. According to the population size of the PMSA or the county where an institution is located, we classified the cities where institutions are located into three types of cities: small cities, medium cities, and large cities [See Appendix for more details].

1.3.3 Results about Demographics

This subsection just presents for figures about demographics to give some sense of the potential scope of this issue.

We study three key aspects of the demographic composition of the postsecondary faculty: gender, education level, and marital status. These three aspects have direct impacts on the extension of co-location problems. Gender composition and the marital status of the faculty members determine the number of couples in the faculties. A higher education level of the spouse implies more specific skills and higher cost of sacrificing the spouse' career development.

We start by showing that the patterns established earlier over the longer time period

Year	All Degrees	Doctorates	Ph.D.	First Professional
1988	32.30%	22.57%	24.31%	16.75%
1993	38.60%	26.67%	27.09%	25.33%
1999	41.20%	29.87%	30.88%	25.65%
2004	42.50%	33.26%	33.09%	34.13%

Table 1.1: Percentage of Female Faculties

(1950-1993) regarding female labor force share hold in this shorter time frame. As can be seen in Table 1.1, the female faculty share is increasing from 32.3% in year 1988 to 42.5% in year 2004. If female faculties have higher tendency to marry up in education levels, then their spouses would also hold high education degrees. Then there will be more and more dual-career couples facing co-location problem in the academic labor market.

Second, we look into the marital status of the faculties. The share of the married among female faculty is increasing over time [Table 1.2]. Since both the female faculty share and the share of the married among female faculties have been increasing over time, we know that percentage of married female faculty among all faculties increased over time. Such a phenomenon call for more attention to the co-location problem of these married female faculty and their spouses. Further we find that the married share increase among female faculties is mainly driven by those with doctorates[2], not by those without doctorates [Table

[2] Doctorates include Ph.D. degrees and first professional degrees.

In some fields, especially those linked to a profession (e.g. medicine, dentistry, law, architecture, pharmacy, social work, religious ministry, engineering, accounting, education, etc.), a distinction is to be drawn between a first professional degree, an advanced professional degree, and a terminal academic degree.

A first professional degree is generally required by law or custom to practice the profession without limitation. An advanced professional degree provides further training in a specialized area of the profession. A first professional degree is an academic degree designed to prepare the holder for a particular career or profession, fields where scholarly research and academic activity are not the work, but rather the practice of a profession. In many cases, the first professional degree is also the terminal degree because no further advanced degree is required for practice in that field even though more advanced academic research degrees may exist.

The American DDS (Doctor of Dental Surgery) is a requisite for the MS (Master of Science) in Dentistry which is a requisite for the Ph.D. in this field. Similarly, the American MD (Doctor of Medicine) is a notch below the MS and Ph.D. in Medical Science (such as anatomy, pathology, microbiology, etc.).

The first professional degrees include the following degrees: Dentistry (D.D.S. or D.M.D.: Doctor of Dental Surgery or Doctor of Dental Medicine), Medicine (M.D.: Doctor of Medicine), Optometry (O.D.: Doctor of Optometry), Osteopathic medicine (D.O.: Doctor of Osteopathic Medicine), Pharmacy (Pharm.D. Doctor of Pharmacy), Podiatry (Pod.D. or D.P. : Doctor of Podiatry), podiatric medicine (D.P.M.: Doctor of Podiatric Medicine), Veterinary medicine (D.V.M.: Doctor of Veterinary medicine), Chiropractic medicine (D.C. or D.C.M.: Doctor of Chiropractic , Doctor of Chiropractic medicine), Naturopathic medicine(Doctor of Naturopathic medicine), Law (LL.B. or J.D. : Bachelor of Laws or Juris Doctor.), theology (M.Div.,

Year	1988	1993	1999	2004
Percentage of Female among Faculties	33.30%	38.60%	41.20%	42.50%
Percentage of The Married among Female Faculties	66.17%	67.41%	68.19%	71.03%
Percentage of Doctorates among Female Faculties	38.56%	33.83%	35.82%	38.37%
Percentage of Female with Doctorates among Faculties	12.84%	13.06%	14.76%	16.31%
Percentage of The Married among Female Faculties with Doctorates	59.90%	65.08%	68.74%	69.53%
Percentage of Married Female with Doctorates among Faculties	7.69%	8.50%	10.14%	11.34%

Table 1.2: Trends Of Female Faculties

Year	Both Genders	Female	Male
1988	78.59%	59.90%	84.03%
1993	79.70%	65.08%	85.02%
1999	78.75%	67.20%	83.67%
2004	79.74%	69.53%	84.82%

Table 1.3: Percentage of The Married for Faculties with Doctorates

1.3 and Table 1.4]. We also compare the marital status across genders. We also find that the married share of female faculty is substantially lower than that of male faculty [Table 1.5]. However, we find that female faculties are having less difficulty getting married over time [Table 1.5].

Third, we look into the marriage patterns of both male and female faculties. Female faculties have higher tendency than male faculties to marry up in education level. However, over time, male faculties become less likely to marry down in education levels, while female faculties become less likely to marry up in education levels [Table 1.6].

Fourth, we study the difference in education levels between male and female faculties.

M.H.L., B.D., or Ord.: Master of Divinity, Master of Hebrew Letters, Bachelor of Divinity, Ordinatio).

Year	Both Genders	Female	Male
1988	73.90%	69.58%	77.27%
1993	72.97%	68.49%	77.46%
1999	73.23%	68.74%	78.16%
2004	75.07%	71.96%	78.37%

Table 1.4: Percentage of The Married for Faculties without Doctorates

Year	Both Genders	Female	Male
1988	76.58%	66.17%	81.53%
1993	76.25%	67.41%	81.81%
1999	75.96%	68.19%	81.41%
2004	77.36%	71.03%	82.05%

Table 1.5: Percentage of Married Faculties

	1988		1999	
	Female	Male	Female	Male
Percentage of Married to Those with Doctorates among All Faculties with Doctorates	56.10%	13.20%	42.90%	19.80%
Percentage of Married to Those with Master or Higher Degrees among Faculties with Master Degrees	57.50%	27.20%	49.40%	33.30%
Percentage of Married to Those with Master or Higher Degrees among Faculties with Lower Than Master Degrees	31.70%	11.60%	24.30%	17.50%

Table 1.6: Marry-up in Education level

Year	Both Genders	Male	Female
1988	54.97%	62.73%	38.56%
1993	48.98%	58.51%	33.83%
1999	49.44%	59.00%	35.82%
2004	49.08%	57.01%	38.37%

Table 1.7: Percentage of Faculties with Doctorates

Female faculties are less likely to have doctorates as compared with male faculties [Table 1.7].

Let's summarize the demographic composition of the academic labor market. More female faculties have entered the academic labor market. At the same time, the marriage rate of female faculty, especially female faculty with doctorates, has increased. Therefore, there is an increase in married female faculties in the academic labor market. Since female faculties have a higher tendency to marry up in education levels, more female faculties will be in the dual career couples, where the husbands are highly educated.

1.4 Evidence that the Co-Location Problem Matters

The evidence presented above just shows there is a potential problem because there are indeed married academic couples and there are more of them than there used to be. But does this really cause any problem? If labor markets are fluid and thick enough, then a couple can get two jobs even in a small town with only one university. Maybe this doesn't matter? We will present some preliminary evidence that things matter. We will look at the data two ways. We will start with some basic cross-tabulations, and then show that the results continue to hold when we put in more co-variates to control for other factors.

There are 4 aspects of the co-location problems we can look at: importance of spouse job opportunities if leaving for other jobs, satisfaction with spouse employment, and same-institution employment and couple accommodation policy.

The main results are that co-location problem has more impacts on faculties in smaller cities. Table 1.8 provides a raw cross-tabulation show that in 1999, in smaller cities, higher

	Small Cities	Medium Cities	Large Cities
Percentage of Spouses Working in The Same Institutions among All Faculties	16.5%	13.3%	11.3%
Percentage of Spouses Working in The Same Institutions Among Faculties in Couples Both with Doctorates	55.0%	36.5%	25.2%
Percentage of Spouses Working in The Same Institutions among Faculties in Academic Couples Both with Doctorates	80.0%	65.3%	55.5%
Percentage of Answering That Spouse Job Opportunity Is The Most Important Factor If Leaving for Other Jobs for Faculties in Couples Both with Doctorates and with Spouses Not Working in The Same Institutions	12.3%	10.7%	7.3%
Percentage of Very Satisfied With Spouse Job Opportunities for Faculties in Couples Both With Doctorate Degrees and with Spouse Not Working in the Same Institutions	28.0%	39.6%	47.2%

Table 1.8: Spouse Employment of Year 1999

percentage of married faculties have spouses working in the same institutions, higher percentage of them answer that spouse job opportunities is the most important factor if leaving for other jobs, and lower percentage of those faculties with spouses not working in the same institutions are satisfied with spouse job opportunities.

Table 1.8 doesn't control for other things that may matter. So we run logit regressions that control for possibly relevant variables, such as age, gender, income, race, school type, and so on. Table 1.9 [3]shows the logit regression coefficients, which shows similar conclusions.

[3] In Table 1.9,The numbers in the paratheses are standard errors. In the above logit regressions, gender, age, faculty rank, basic salary from the institution, school type are incuded as other explanatory variables. In the above regressions except the first regression, 3 more explanatory variables are also included, which are race, highest degree, highest degree of the spouse.

Dependent Variables	Medium Cities vs.Small Cities	Large Cities vs.Small Cities
Whether Or Not Spouse Working in The Same Institutions, for Faculty in Couples Both with Doctorate	-0.933 (0.187)	-1.487 (0.206)
Whether Or Not Spouse Working in The Same Institutions, for All Faculty	-0.713 (0.103)	-0.455 (0.113)
Whether Or Not Spouse Job opportunity Being The Most Important Factor if Leaving For Other Jobs	-0.537 (0.244)	-0.297 (0.248)
Whether Or Not Very Satisfied With Spouse Job Opportunities	0.489 (0.111)	0.303 (0.103)

Table 1.9: Logit Regression Coefficients, Year 1999

Table 1.10 shows calculated probabilities from the logit model, evaluating at the mean of the covariates. So Table 1.8 and Table 1.10 are similar, except that Table 1.10 includes the additional control. Note that adding the additional controls makes little difference.

We also find out that couple accommodation policies make bigger differences in smaller cities. In smaller cities, for faculties in couples both with doctorates, the difference of the percentages of very satisfied with spouse job opportunities for those with spouses working in the same institutions and for those with spouses not working in the same institutions is much higher [table 1.11]. In small cities, faculties with spouses employed in the same institutions on average hold current jobs much longer (12.5 years) than faculties with spouses employed in other higher educational institutions (7.5 years).

There is ability sorting of faculties among cities of different sizes. We find significant difference in the average number of refereed publications for research faculties with doctorates in research universities among cities of different sizes. In large cities, the average is 50.6 and in small cities, the average is 27.7.

	Small Cities	Median Cities	Large Cities
Probability of Spouse Working In the Same Institutions for A Faculty in A Couple Both with Doctorates and in 4 Year Doctoral Schools	63.9%	40.9%	28.4%
Probability of Spouse Working In the Same Institutions for An Assitant Professor With The Spouse with doctorate and in 4 Year Doctoral School	45.9%	34.9%	29.3%
Probability of Spouse Job Opportunity Being The Most Important Factor If Leaving for Other Jobs for A 30 Years Old Female Assitant Professor with Spouse with Doctorate	25.2%	20.1%	16.3%
Probability of Very Satisfied with Spouse Job Opportunities for A Female Assitant Professor with Doctorate and with Spouse Not Working in The Same Institution	30.4%	36.8%	41.0%

Table 1.10: Computed Probability, Year 1999

	Small Cities	Median Cities	Large Cities
Spouse Working In the Same Institution	0.504	0.464	0.494
Spouse Not Working In the Same Institution	0.280	0.396	0.472

Table 1.11: Percentage of Very Satisfied with Spouse Job Opportunities for Faculties in Couples Both with Doctorates, Year 1999

Chapter 2

The Co-location Problem, College Hiring Behavior, and College Quality

2.1 Introduction

The goal of this chapter is to study the co-location problem and the impact of couple recruiting policy on faculty welfare and school quality. We build a model with three types of cities - city 1H, city 1L, and city 2. A type 1H city has one high quality school, a type 1L city has one low quality school, and a type 2 city has both a high quality school and a low quality school. Each city type has one unit measure continuum of cities. In accordance with the city distributions, there are four types of schools: 1H (high quality schools in type 1H cities), 1L (low quality schools in type 1L cities), 2H (high quality schools in type 2 cities), and 2L (low quality schools in type 2 cities). Each school type has one unit continuum measure of schools. Each school has one unit measure of job openings that has to be filled up. The goal of each school is to maximize its average faculty ability by making job offers to workers subject to the constraint that it has to fill up its job openings.

There are two types of workers depending on the dual career couple status: some are dual career couple workers and the rest are single workers. Workers also differ in their ability. The research output function of each worker is the sum of individual ability and school quality he or she works in. The goal of a single worker is to maximize research output by choosing the school among the ones who make job offers to him or her. The goal of a dual career couple is to maximize research output by choosing a school combination among the ones making them job offers, subject to the condition that both of them have to work in the same city but not necessarily in the same school.

Each school can make job offers in two different ways depending on how they treat dual career couples. First, it can treat a dual career couple as two independent single workers. We call this independent hiring policy. Second, it can treat a dual career couples differently from single workers. We call this couple accommodation policy. We begin with the independent hiring policy and obtain the following results. First, dual career couples are disproportionately more concentrated in large (type 2) cities. Second, rural (type 1H or 1L) schools have lower average faculty ability than the urban (type 2H or type 2L) schools of the same quality. These results are consistent with the empirical findings reported in Costa and Kahn (2000).

Then we allow each school to choose the couple accommodation policy and obtain the following results. First, regardless of school location and quality, it is always optimal for a school to adopt the couple accommodation policy. Second, when every school adopts the couple accommodation policy, some schools get hurt and others get benefited. (Average worker quality in the economy is fixed so not every school can be better off.) We show that high quality urban (type 2H) schools get hurt whereas low quality rural (type 1L) schools (type 1L schools) get benefited. Third, when every school adopts the couple accommodation policy, the couples having dissimilar ability are better off whereas single workers and the couples with similar abilities are worse off. As a corollary, female faculties get more benefit than male faculties since female faculties are more likely to be dual career couples.

This chapter is directly related to the literature on the co-location problem (Costa and

Kahn (2000), Compton and Pollak (2007)). More broadly, this chapter is related to the literature on the labor market matching literature (Helsley and Strange (1990), Acemoglu (1996)). They argue that large cities provide wide variety of jobs and thus workers of different skills are more likely to find jobs that match their skills more closely. What makes this paper differ from the literature is that the matching occurs at couple level rather than individual level. Our model also differs in that the matching leads to the ability sorting across different sized cities, i.e., better ability workers locating in large cities.

The rest of the chapter proceeds as follows. Section 2.2 provides the model. Section 2.3 studies the equilibrium under the independent hiring policy. Section 2.4 studies the equilibrium where schools can choose to use the couple accommodation policy. Section 2.6 concludes.

2.2 Model

There are three types of cities - 1H, 1L, and 2. They differ in two characteristics: the number and the quality of schools they have. A type 1H city has one high quality school and a type 1L city has one low quality school. A type 2 city has two schools: one high quality school and the other low quality school. Each city type (1H, 1L, 2) has one unit measure continuum of cities.

There are four types of schools - 1H (high quality school in type 1H city), 1L, 2H and 2L. They differ in two characteristics: location and quality. Type 1H schools are high quality schools in type 1L cities, type 1L schools are low quality schools in type 1L cities, type 2H schools and type 2L schools are high quality schools and low quality schools respectively in type 2 cities. Each school type has one unit measure continuum of schools in accordance with the number of cities in the economy. The quality of a school affects the research output of its individual faculty member: a high quality (type H) school and a low quality school improve the research output of their individual faculty members by ε_H and ε_L respectively ($\varepsilon_H > \varepsilon_L$). Each school has one unit measure of job openings so there are four unit measures of job openings in the whole economy. The goal of each school is to maximize its average faculty ability by making job offers to workers subject to the constraint that it has to fill up its job openings. Note that the competition for workers occurs within the same type of schools as well as across the different types of schools. Note also that each school is infinitesimal so its unilateral decision does not affect the other schools in the economy.

There are four unit measures of workers. They differ in two characteristics: dual career academic couple status and innate ability. First, workers differ in their dual career academic couple status: $\alpha \in [0,1]$ fraction of workers are dual career academic couple workers and the rest are single workers. Second, workers also differ in their ability: each worker's ability θ is independently drawn from the identical uniform distribution over $\left[\underline{\theta}, \bar{\theta}\right]$ regardless of his or her dual career couple status or spouse ability. The research output of a worker is the sum of his or her individual ability and the productivity gain from the school he or she works in. For example, an ability θ worker at a high quality school produces $\theta + \varepsilon_H$ amount of research. If a worker does not work at a school, we assume for simplicity that its output is negative infinite. The goal of a single worker is to maximize his or her research output by choosing a school among the ones he or she receives a job offer from. The goal of each dual career couple is to maximize the sum of research outputs for the couple, subject to the condition that both of them have to work in the same city but not necessarily in the same school. If workers are indifferent between many schools, they randomly choose the school with equal probability per each school. The implicit assumption behind this equal rationing is that there are other secondary factors affecting workers' school choices and their distribution is independent and identical across different schools.[1] Note that there will not be any unemployment in equilibrium because the total measure of job openings and the total measure of workers are equal.

Each school can make job offers in two different ways depending on how they treat dual career couples. First, it can treat a dual career couple as two independent single workers. We

[1] It is easy to model this explicitly, by adding another i.i.d. random utility component for each school. All the results go through without change if the range of this utility component is small enough not to interfere with the preference over different types of schools.

call this independent hiring policy. Second, it can treat dual career couples differently from single workers. We call this couple accommodation policy. We begin with the independent hiring policy in section 2.3 and then study the couple accommodation policy in section 2.4.

2.3 Independent Hiring Policy

This section characterizes the equilibrium when every school uses the independent hiring policy. We obtain the following two results. First, dual career couple workers are disproportionately more concentrated in large (type 2) cities. Second, large city schools have higher average faculty ability than the small city schools of the same quality. These two results are consistent with empirical findings in Costa and Kahn (2000).

We begin with workers' school choice. A single worker chooses the school maximizing his or her individual research output. Since the individual research output is determined as the sum of their individual ability and school quality and individual ability does not change across schools, the worker's school choice depends solely on school quality. The following describes the workers' preference over the four types of schools.

$$1H \sim 2H \succ 1L \sim 2L. \tag{2.1}$$

Single workers prefer high quality schools to low quality schools but are indifferent among the same quality of schools.

A dual career couple chooses the school combination maximizing the sum of their research output subject to the constraint that both of them have to find jobs in the same city. The following describes their preference over all the feasible school combinations.

$$(1H, 1H) \sim (2H, 2H) \succ (2H, 2L) \sim (2L, 2H) \succ (1L, 1L) \sim (2L, 2L). \tag{2.2}$$

Dual career couples prefer both of them working in high quality schools best, and only one of them working in a high quality school second, and the both of them working in low quality schools third. The feasible school combinations reflect the constraint that both of them have to find jobs in the same city. Note that large (type 2) cities have more feasible school combinations than small (type 1H and 1L) cities: in a large city one worker can work in high quality school and the other in low quality school but this arrangement is not possible in small cities.

We turn to schools' hiring choices. Each school decides to whom to give job offers in order to maximize average faculty ability subject to the constraint that it has to fill up its job openings. A standard argument shows that average ability maximizing school uses a cut-off rule to make job offers.

Lemma 1 *Each school sets a cut-off and makes job offers to all and the only workers whose average abilities are weakly greater than the cut off.*

Proof. Suppose that the cut-off rule is not the optimal policy. This implies that there exist two positive measure groups of workers such that all the workers in one group have lower ability than any worker in the other group and that all the lower ability group workers receive and accepts a job offer from a school and that all the higher ability group workers are willing to accept job offers from the same school but do not receive the offer. The school can improve average ability by switching job offers between the two group workers. ∎

We are ready to define an equilibrium. An equilibrium under the independent hiring policy is the list of cut-offs $\left(\hat{\theta}_{1H}, \hat{\theta}_{1L}, \hat{\theta}_{2H}, \hat{\theta}_{2L}\right)$ satisfying the following four conditions. First, each school of type j makes job offers to all and only the workers whose abilities are weakly greater than $\hat{\theta}_j$ independent of workers' dual career couple status. Second, ability θ single workers choose the school following the order in (2.1) among the schools whose cut-offs $\hat{\theta}$ are weakly lower than θ. Third, the dual career couple of ability (θ_M, θ_F) chooses the school combination following the order in (2.2) among the feasible school combinations whose cut-offs $\left(\hat{\theta}_M, \hat{\theta}_F\right)$ are such that $\theta_M \geq \hat{\theta}_M$ and $\theta_F \geq \hat{\theta}_F$ ($\hat{\theta}_M$ and $\hat{\theta}_F$ are the single worker cut offs of the schools where the male and the female worker in the couple work respectively). Fourth, each school has one unit measure of workers.

We now characterize the equilibrium properties of the cut-offs. First, if there are no dual career couple workers ($\alpha = 0$) the same quality of schools have the same cut offs regardless of their locations. Suppose not. There are two schools of the same quality which have different cut offs. The school with higher cut off will have less number of workers than the other school because single workers are indifferent between the schools of the same quality and are equally likely to choose each one of them. This is a contradiction to the market clearing condition that each school has one unit measure of workers.

Second, if there are dual career couple workers ($\alpha > 0$) large (type 2) city schools have higher cut offs than small (type 1) city schools of the same quality. Suppose not. There are two schools of the same quality such that one is in a small city and the other is in a large city and that the large city school has weakly lower cut off than the small city school. The large city school has at least an equal number of workers for each type of workers the small city school has because it has weakly lower cut off. In addition, the large city school has the type of workers the small city does not have: the dual career couple workers whose spouses work at the other school in the same city. Therefore, the large city school has strictly more number of workers than the small city school and this is a contradiction.

Third, the lowest cut off is $\underline{\theta}$ because the numbers of workers and job openings are same and thus there is no unemployment. This implies that $\hat{\theta}_{1L} = \hat{\theta}_{2L} = \underline{\theta}$ if $\alpha = 0$ and $\hat{\theta}_{1L} = 0$ if $\alpha > 0$. We can also obtain $\hat{\theta}_{2H} = \hat{\theta}_{1H} = \left(\bar{\theta} + \underline{\theta}\right)/2$ if $\alpha = 0$ since high quality schools have as many job openings as low quality schools in the whole economy.

Lemma 2 *1)* $\hat{\theta}_{2H} > \hat{\theta}_{1H} > \hat{\theta}_{2L} > \hat{\theta}_{1L} = \underline{\theta}$ *if* $\alpha > 0$.
2) $\hat{\theta}_{2H} = \hat{\theta}_{1H} = \left(\bar{\theta} + \underline{\theta}\right)/2 > \hat{\theta}_{2L} = \hat{\theta}_{1L} = \underline{\theta}$ *if* $\alpha = 0$.

Figure 2.1 illustrates an equilibrium when $\alpha > 0$. Figure 2.1.(a) shows single workers' school choices. The workers whose abilities are greater than $\hat{\theta}_{2H}$ receives job offers from all the schools. Since single workers are indifferent between school 1H and school 2H, a half of them choose to go to school 1H and the other half go to school 2H. The single workers between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ all go to school 1H because they do not receive job offers from school

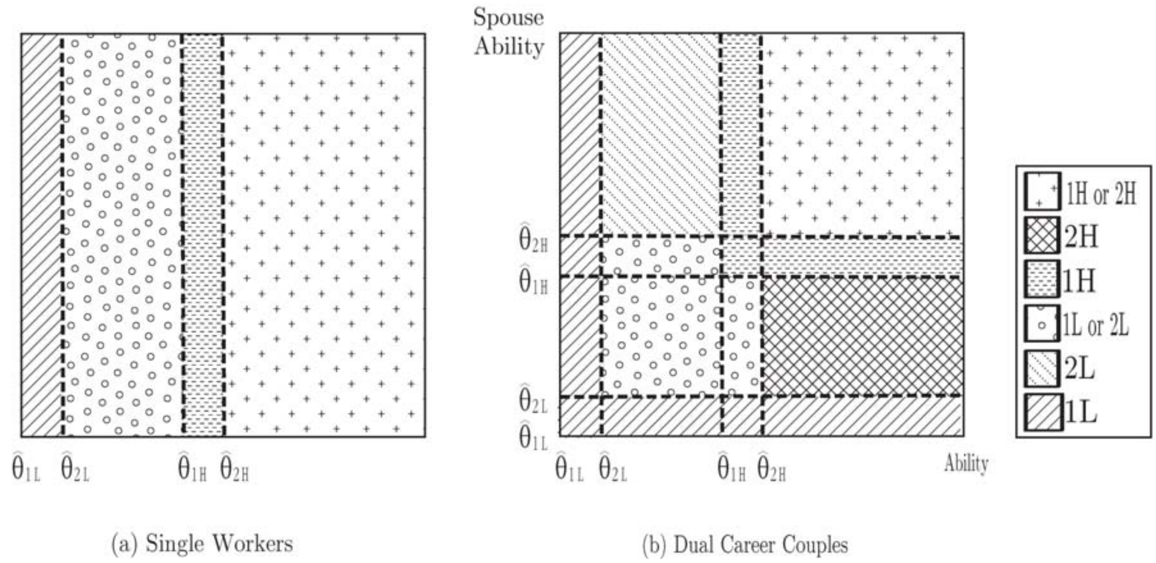


Figure 2.1: Workers' School Choices Under Independent Hiring Policy

2H. By the same reasoning, a half of the single workers between $\hat{\theta}_{2L}$ and $\hat{\theta}_{1H}$ go to school 1L and the other half go to school 2L. The single workers below $\hat{\theta}_{2L}$ all go to school 1L.

Figure 2.1.(b) shows the school choice of a dual career couple worker. The school choice of the worker depends on her spouse ability. For example, when the worker has ability higher than $\hat{\theta}_{2H}$, there are four cases depending on her spouse ability. First, the ones with spouse ability higher than $\hat{\theta}_{2H}$ can go to school 1H or 2H together with her spouse. So a half of them choose school 1H and the other half choose school 2H. Second, the ones with spouse ability between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ cannot go to school 2H together because the husband does not receive a job offer from school 2H. So they all go to school 1H together. Third, the ones with spouse ability between $\hat{\theta}_{2L}$ and $\hat{\theta}_{1H}$ all go to school 2H because their spouses can all go to school 2L. These dual career couples, who benefit from the wider variety of schools in large cities, have to stay in large cities and this raises the cut offs for large city schools. Fourth, the ones with spouse ability below $\hat{\theta}_{2L}$ have to go to school 1L with their spouses.

We can calculate an equilibrium in the following way. Given a set cut offs $\left(\hat{\theta}_{1H}, \hat{\theta}_{1L}, \hat{\theta}_{2H}, \hat{\theta}_{2L}\right)$, we can calculate the number of workers choosing each type of schools using these cut offs. We set the number of workers in each school to be 1 and solve the four equation - four unknown simultaneous equations to obtain the cut offs. Or we can use Lemma 2 to reduce the number of unknowns and equations. We calculate the number of workers for each type of workers by adding up the areas corresponding to each type of schools in Figure 2.1, weighted by the fraction of dual career couple workers and single workers and the probability of going to the type of schools. We report these equations in Appendix.

Now we are ready to prove the main results of this section. First, we show that dual career couples are disproportionately more concentrated in large cities. Suppose that there are positive number of dual career couples (i.e. $\alpha > 0$). Large city schools have higher cut offs than small city schools of the same quality. As can be seen in Figure 2.1.(a), this implies that small city schools have more single workers than large city schools. This in turn implies that large city schools have more dual career couple workers.

Proposition 1 *Dual career couple workers are disproportionately more concentrated in type 2 cities if $\alpha > 0$.*

Second, we show that large city schools have higher average ability than the small city schools of the same quality. Higher cut offs do not necessarily mean higher average abilities because average ability of a school depends not only on its cut off but also on the ability distribution of workers within the school. In fact, it turns out that type 2L schools have lower average ability than school 1L for very high αs even though they always have higher cut offs.

We begin with high quality schools - 1H and 2H. Suppose that $\alpha > 0$. First, average ability of single workers is higher in school 2H. Single workers in school 2H are uniformly distributed between $\hat{\theta}_{2H}$ and $\bar{\theta}$ in terms of their ability. Type 1H Schools have not only these types of workers but also the workers between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ as can be seen in Figure 2.1.(a). These workers between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ lower average ability of school 1H single workers compared to that of school 2H single workers. Second, average ability of dual career couple workers is higher in school 2H. Dual career couple workers in school 2H are uniformly distributed between $\hat{\theta}_{2H}$ and $\bar{\theta}$. On the other hand, dual career couple workers in school 1H can be divided into two intervals in terms of their ability - the one between $\hat{\theta}_{2H}$ and $\bar{\theta}$ and the other one between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ as can be seen in Figure 2.1.(b). The workers between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ lower the average ability of school 1H dual career couple workers compared to that of school 2H dual career couple workers. Before we conclude that school 2H has higher average faculty ability We show that average ability of dual career couple workers in school 2H is higher than average ability of single workers in school 1H because school 2H has bigger share of dual career couple workers (Proposition 1). The ability of dual career workers in school 2H is uniformly distributed between $\hat{\theta}_{2H}$ and $\bar{\theta}$. The ability of single career workers in school 1H consists of not only the ones between $\hat{\theta}_{2H}$ and $\bar{\theta}$ and but also the ones between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$. The ones between $\hat{\theta}_{1H}$ and $\hat{\theta}_{2H}$ make the average of school 1H single workers lower than that of school 2H dual career workers. Now we can conclude that school 2H has higher average ability than school 1H if $\alpha > 0$. Trivially both schools have the same average ability if $\alpha = 0$.

Proposition 2 *Type 2H schools have higher average faculty ability than type 1H schools if $\alpha > 0$.*

Now we compare average ability of school 1L and 2L. Unfortunately we do not have an analytical proof for them. We show by simulation that type 2L schools have higher average ability that type 1L schools for $\alpha < 0.82$. This range of αs should cover the range we expect to see in reality. One nice feature of the model is that the equilibrium cut offs can be expressed as linear functions of $\bar{\theta}$ and $\underline{\theta}$. This leaves α as the only free parameter and makes simulation simple. We have only to check equilibrium outcomes for α ranging from 0 to 1.

Lemma 3 *If γ is an equilibrium cut off for a school with $\underline{\theta} = 0$ and $\bar{\theta} = 1$, the equilibrium cut off for the school with parameters $\underline{\theta} = a$ and $\bar{\theta} = b$ is $a + \gamma \cdot (b - a)$.*

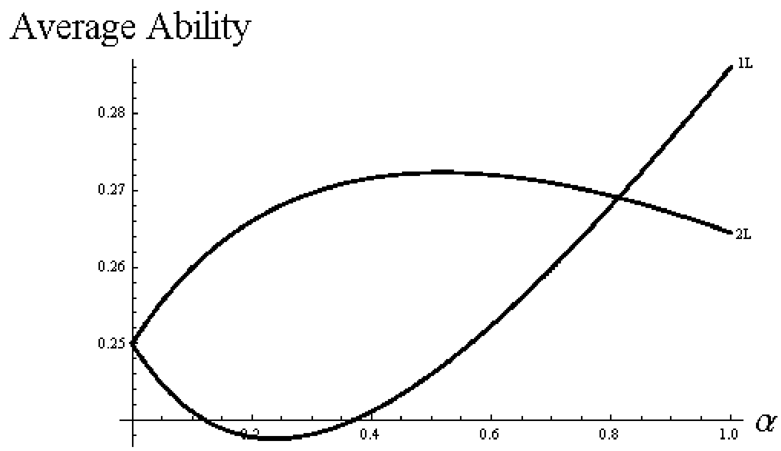


Figure 2.2: Average Ability of School 1L and 2L Under Independent Hiring Policy

Proof. First, consider a model with parameters $\underline{\theta} = a$ and $\bar{\theta} = 1 + a$. The new cut offs can be obtained by adding a to all the original cut offs with $\underline{\theta} = 0$ and $\bar{\theta} = 1$. So the new cut off for the school is $a + \gamma$. Second, consider a model with parameters $\underline{\theta} = 0$ and $\bar{\theta} = b$. The new cut offs can be obtained by multiplying all the original cut offs by b. So the new cut off for the school is $b\gamma$. Therefore, the new cut offs for the model with parameters $\underline{\theta} = a$ and $\bar{\theta} = b$ is $a + (b - a)\gamma$. ■

Figure 2.2 shows the simulation result. The simulation result shows that school 2L has higher average ability than school 1L for $\alpha < 0.82$. It is surprising that school 1L can have higher average ability than school 2L for very higher αs. The intuition behind this result is that school 1L can have very high ability workers having dumb spouses while this can not happen to school 2L because the high ability workers will all go to school 2H leaving their dumb spouses at school 2L.

2.4 Couple Accommodation Policy

In this section, we characterize equilibrium when we allow each school to use the couple accommodation policy, i.e., to treat dual career couples differently from single workers. The main result in this section is that it is a dominant strategy for every school to adopt the couple accommodation policy regardless of its location or quality. This does not mean that every school will be better off when every school implements the couple accommodation policy. We will discuss in the next section who will be the winners and losers when every school uses the policy.

It turns out that schools using a couple accommodation policy would use a cut off rule similar to the one for single workers, but with couples' average ability instead of individual worker's ability.

Lemma 4 *A school using a couple accommodation policy makes a job offer to both workers in a couple if and only if the couple's average ability is weakly greater than the school's single worker cut off.*

Proof. We first show that it is optimal for a school to give job offers to all the couples whose average ability is weakly greater than the single worker cut off. Suppose not. There exist a positive measure of couple workers whose average abilities are strictly greater than a school's single worker cut off, do not receive offers from the school but would accept the offers if they did. The school can raise average faculty ability by swapping job offers between this group (or a subgroup with positive measure) of couples and the same measure of single workers whose abilities are higher than the single worker cut off but sufficiently close. Second, we show that only the couples whose average ability is weakly greater than the single worker cut off receives job offers. Suppose not. There exists a school that has a positive measure of workers whose average abilities are strictly lower than the single workers' cut off. The school can raise its average faculty ability by making job offers to those single workers just below the cut off instead of these couple workers. ■

Lemma 4 allows us to use one cut off for each school, which applies to both couples and single workers. We first study the impact of unilaterally implementing the couple accommodation policy on the cut offs. When a school starts implementing the couple accommodation policy with the other schools' decision fixed, the school's cut off cannot go down because all the currently employed workers would still receive job offers using the independent hiring policy choose the school. Note that the other schools' cut offs do not change because each school is infinitesimally small. In addition to these already employed workers, the school instantly receives the new couple workers who receive job offers through the couple accommodation policy. The measure of these new dual career couples is strictly positive except school 1L. (For school 1L, the couple accommodation policy does not make any difference because their cut off is $\underline{\theta}$ and all the workers in the economy receive job offers even without the couple accommodation policy.) This is a contradiction to the market clearing condition.

Lemma 5 *A school's unilateral implementation of the couple accommodation policy strictly increases its job offer cut-off, except type 1L schools. A type 1L school's unilateral implementation of the policy does not make any difference in equilibrium outcome.*

Now we are ready to show the main result of this section that the unilateral implementation of the couple accommodation policy is optimal for each school regardless of its location or quality. We compare the abilities of those who leave the school due to the policy and the abilities of those new workers who obtain jobs at the school through the policy. When a school implements the couple accommodation policy, its cut off increases according to Lemma 5. First, all the workers leaving the school have lower abilities than the new cut off. Since the school's decision does not affect the other schools' cut offs, all the workers leaving the school are the ones who lose their job offers due to the higher new cut off. Thus, all the workers leaving the school due to the policy have lower abilities than the new cut off.

On the other hand, all the workers who obtain jobs at the school due to the policy are the dual career couple workers whose average abilities are greater than the new cut off. Note that it does not happen that the school will hire only a low ability spouse of a high ability worker whom the school already has. If there are other same type schools implementing the couple accommodation policy, the couple would choose another same type school implementing the couple policy if the school did not hire both of them together. If there is no other same type schools implementing the couple accommodation policy, almost all of the new workers are new dual career couples whose average ability is weakly greater than the new cut off. (Each school is infinitesimally small and almost all new dual career couple workers are the ones who were not employed before implementing the couple policy.)

Proposition 3 *The unilateral implementation of couple averaging policy increases average ability for each school, except for type 1L schools. The policy does not change average ability for type 1L schools.*

The competition among the same type of schools is crucial behind Proposition 3. If there is only one school per each type, each school has a kind of monopoly power over workers. For example, it may not be optimal for the school 2H to implement the couple policy because it may end up employing low ability spouses of high ability workers they already have. This does not happen when there are many type 2H schools and they compete for the same pool of workers.

We redefine an equilibrium to incorporate the couple accommodation policy. An equilibrium when every school implements the couple accommodation policy is the list of cut-offs $\left(\hat{\theta}_{1H}, \hat{\theta}_{1L}, \hat{\theta}_{2H}, \hat{\theta}_{2L}\right)$ satisfying the following four conditions. First, each type j school makes job offers to all the workers whose abilities are weakly greater than $\hat{\theta}_j$ regardless of their dual career couple status and all the dual career couples whose average abilities are weakly greater than $\hat{\theta}_j$. Second, an ability θ single worker chooses the school following the order in (2.1) among the schools whose cut-offs $\hat{\theta}$ are weakly lower than θ. Third, dual career couple of ability (θ_M, θ_F) chooses the school combination following the order in (2.2) among the school combinations whose cut-off $\left(\hat{\theta}_M, \hat{\theta}_F\right)$ are such that $\theta_M \geq \hat{\theta}_M$ and $\theta_F \geq \hat{\theta}_F$ or among the schools whose cut off $\hat{\theta}$ is weakly lower than $(\theta_M + \theta_F)/2$. Fourth, each school has one unit measure of workers.

Figure 2.3 illustrates an equilibrium where every school uses the couple accommodation policy. Some of the cut off lines for dual career couples are now diagonal reflecting the couple accommodation policy. There are also those who still get jobs using the independent

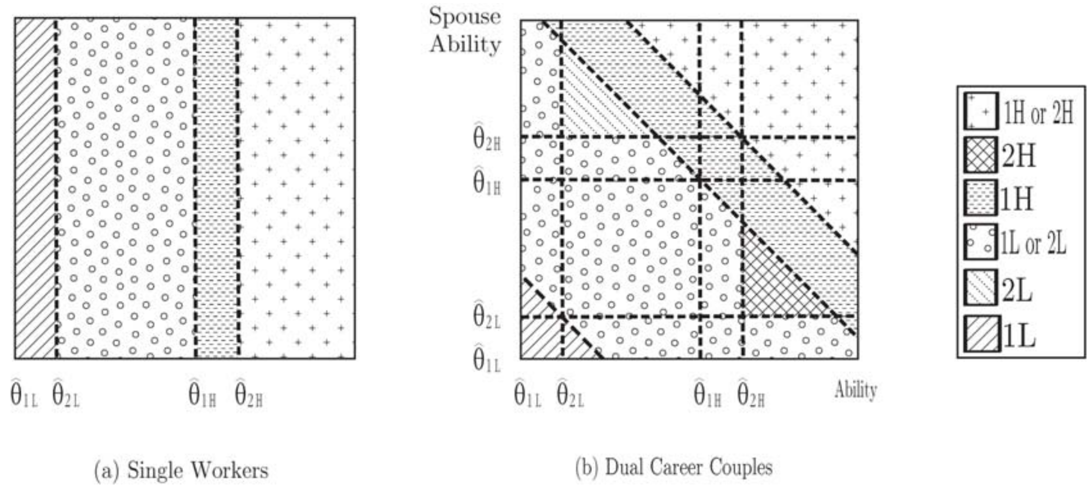


Figure 2.3: Workers' School Choices with Couple Averaging Hiring Rule

hiring policy and the cut off lines are perpendicular for them. These are the couples for whom one of each couple get a job at school 2H and the other at school 2L.

We can calculate the equilibrium outcome when every school uses the couple accommodation policy by solving the market clearing condition for each type of school, as we calculated the independent hiring policy equilibrium. We report the market clearing equations in Appendix.

Proposition 4 *Dual career couples are still disproportionately more concentrated in large cities under the couple accommodation policy.*

2.5 The Winners and Losers of The Couple Accommodation Policy

This section studies what types of schools and workers would benefit or get hurt from the couple accommodation policy. We find that type 2H schools are worse off when every one adopts the couple accommodation policy. We also find that single workers and the couples with similar abilities get worse off while the couples with widely different abilities get better off.

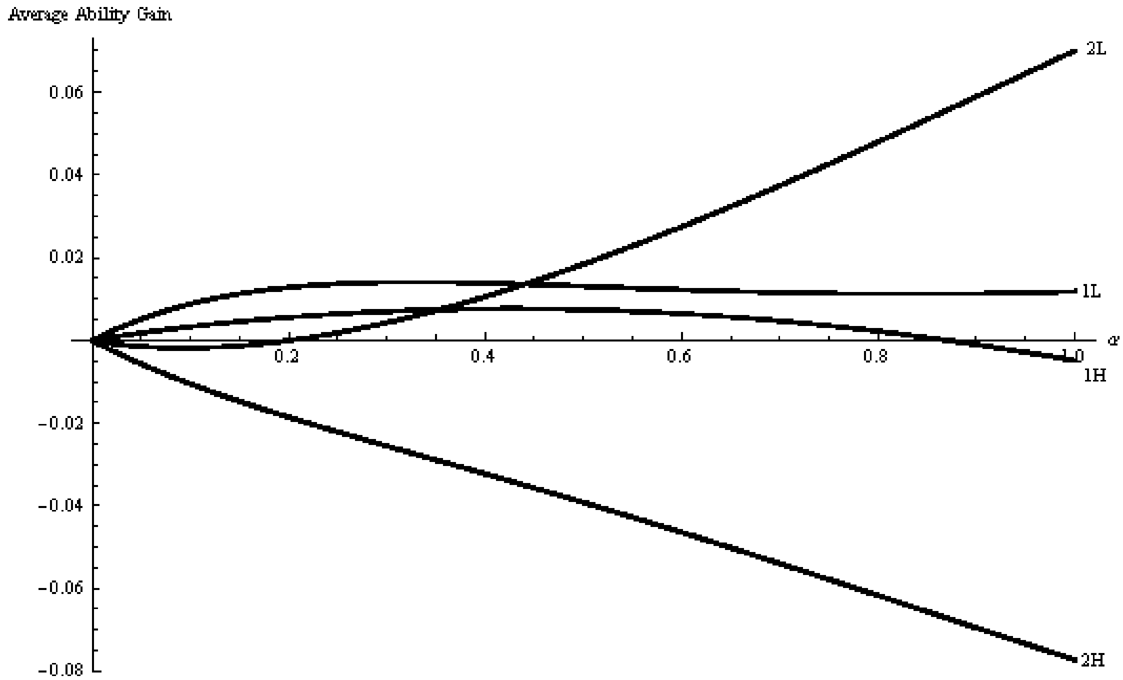


Figure 2.4: Average Ability Gain From Couple Accommodation Policy

2.5.1 Schools

We begin with the impact on schools. We use simulation to show the main result because the cut off equations are complicated. However, we have some analytical results when α is close to 0. (We are still working to get more analytical results.)

Proposition 5 *For sufficiently small $\alpha > 0$, school 2H have lower average faculty ability under the couple accommodation policy and school 1L has higher average ability under the couple accommodation policy.*

Proof. See Appendix. ■

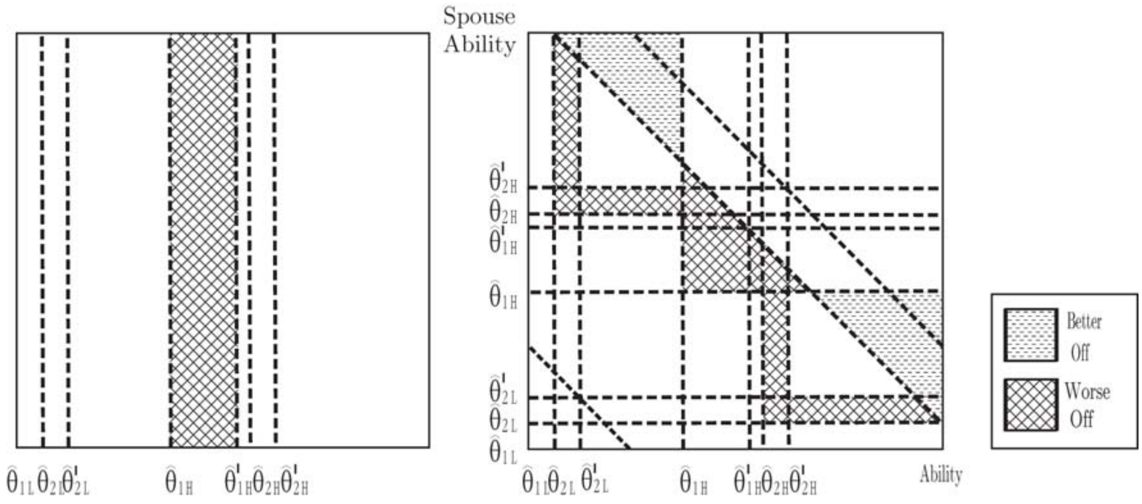
We present the simulation result. Figure 2.4 shows the average ability gain from the independent hiring policy regime to the couple accommodation policy regime where every school uses the couple accommodation policy. The couple accommodation policy hurt school 2H and benefit school 1L for all $\alpha \in [0, 1]$. On the other hand, the impact of the policy on school 1H and 2L depend on α. School 1H get benefit only until α reaches 0.87. School 2L get benefit only after α reaches 0.2.

Type 2H schools are the clear losers of the couple accommodation policy. In the independent hiring regime, it was possible for type 2H schools to employ only high ability spouses of dual career couple workers. In the couple accommodation policy regime, the type 2H schools have to employ low ability spouses together with their high ability spouses and this lowers their average faculty ability. Note that it is still optimal for each type 2H school to use the couple accommodation policy because of the competition with the other schools of the same type.

Type 2L schools are worse off for small αs but better for large αs. Type 2L schools are worse off for small αs because type 1H or 2H schools employ type 2L's relative better dual career couple workers through the couple accommodation policy. These workers taken away from type 2L schools are relatively high ability workers in type 2L schools even though they are relative low ability workers in type 1H or 2H schools. However, type 2L schools are better off for large αs because relatively high workers who lost their jobs at type 1H or 2H schools due to the raised cut offs now move to type 2L or 1L schools.

Type 1H schools are better off for small αs but worse off for very large αs. First, type 1H schools are better off for small αs because they can hire the very high ability workers that they could not hire due to the co-location problem. They also have hired the low ability spouses of these high ability workers but the couples' average abilities are higher than their cut off. What makes type 1H schools different from type 2H schools is that school 2H already had high ability spouses of these couples under the independent hiring policy while school 1H did not.

Type 1L schools are better off for all αs. The cut offs of type 1L do not change because of the couple accommodation policy because they were giving job offers to all the workers in the economy. However, their average faculty ability increase because the cut offs of the other types of schools increase raising the average ability of remaining workers for type 1L schools (and type 2L schools).



(a) Single Workers

(b) Dual Career workers

Figure 2.5: Who Get Benefit From The Couple Accommodation Policy

2.5.2 Workers

Figure 2.5 shows what type of workers get better off or worse off due to the couple accommodation policy. First, single workers and dual career couple workers having similar abilities are worse off because the cut offs for high quality schools increase due to the couple accommodation policy and they do not get the benefit of the couple accommodation policy. Second, the dual career couples with dissimilar abilities are better off because they can both find jobs at school 2H through the couple accommodation policy. Note that the couple accommodation policy did not help the high ability workers having very low ability spouses so that both of them have to work in type 1L schools under the independent hiring policy. Their average couple abilities are not high enough to meet the high quality schools cut offs. They can now work at school 2L due to the couple accommodation policy but this does not improve their utility.

2.6 Conclusion

In this chapter, we study the co-location problem of academic couples and the couple accommodation policy. We find that it is optimal for each school to adopt the couple accommodation policy regardless of its location and quality. However, the impact of the policy when every school implements the policy differs by school location and quality. High quality school in large cities always get worse off and low quality schools in small cities always get better off.

Chapter 3

A General Model and Some Preliminary Numerical Results

3.1 Introduction

Workers in a dual career couple have to find jobs near each other, mostly in the same metropolitan areas. This is called co-location problem. Since it is easier for both of a couple to find jobs in large cities than in small cities, dual career couples are more likely to locate in large cities than single career couples.

This chapter provides a model of the co-location problem and shows that dual career couples are more likely to locate in larger cities as compared to single career couples and that larger cities get higher ability workers. We derive some theoretical results with a general distribution of jobs across cities of different sizes. We also begin some preliminary numerical work, simulating the job choice by couples, and examine the quantitative implications of the co-location problem for the distribution of ability across colleges.

Our model borrows the structure from Holmes (2005) that each worker draws idiosyncratic match quality from each firm. Larger cities have relative more number of firms and thus workers are more likely to find their best matches in larger cities. For single career couples, the chance of finding the best match in a city increases with city size proportionally to the number of firms in the city. For dual career couples, the chance increases faster with city size because they draw two match qualities. This leads to higher concentration of dual career couples in larger cities. In addition, dual career couples' preference for cities, disproportionately increasing with city size, also leads to more supply of workers into larger cities and firms in larger cities can choose relatively higher quality workers than firms in smaller cities.

Costa and Kahn (2000) claim that the co-location problem will lead to the ability sorting and documented that the quality of firms in small cities has been declining as the share of dual career couples has increased. However, they did not provide an explicit model how this can happen. This paper fills the gap.

In terms of the theoretical literature, the main predecessor of our paper is an early paper by Frank (1978). He provides a model showing that it is easier for dual career couples to find two jobs in large cities. What makes our paper differs is that we model firms' hiring decisions explicitly and obtain the ability sorting effect. Our model also works for more general cases. For example, when comparing two cities, Frank (1978) had to make the assumption that one city size is the multiple of the other. Moreover, he also had to assume that only single career workers would redistribute to small cities if the markets do not clear by voluntary choices.

This chapter has two main parts. The first part develops the theoretical model and derives formal theorems. For this first part of the analysis we make two technical assumptions that we dispense with in our numerical analysis. First, we assume workers are a continuum and use the laws of large numbers. Second, we assume there is no correlation in the ability levels of academic couples. In the second part of the analysis, we simulate a finite number of workers looking for a finite number of jobs. Moreover, we assume perfect assortative matching between the husband and wife in terms of ability. We make this latter assumption purely for technical reasons, as it greatly facilitates our algorithm for calculating the equilibrium. We leave for future work, solving more general cases in both the theoretical section and the quantitative analysis section.

3.2 The Theory

In this section we build a model of couples' location decision. There are cities with different numbers of firms. Firms make job offers to workers with the goal of maximizing the average quality of its workers. All the workers in this economy are couples. These couples are one of the two types - single career couples having only one worker and dual career couples having two workers. Each worker draws random match quality from each firm. Dual career couples maximize the sum of the two random draws by selecting firms that give them offers subject to the condition that couples have to be in the same city (but not necessarily in the same firm.) Single career couples do not face this co-location problem, so just pick the firms and cities which give the highest match quality to the one worker in the couple.

3.2.1 The Environment

There are J cities indexed by the number of firms $n_1 < n_2 < ... < n_J$ ($n_j \in \mathbb{N}$). Let N be the total number of firms $N = \sum_{j=1}^{J} n_j$. Each firm has unit measure of job openings the firm has to fill up. Therefore, in our economy, only measure zero of workers are unemployed, and thus unemployment is not an issue.

There are $M(>= N)$ measure of workers who participate in labor markets. $\alpha \in [0, 1]$ fraction of these workers belong to dual career couple and the other $(1 - \alpha)$ fraction belong to single career couple. Therefore, each worker belongs to one of three groups - M, F, and S. Group M and group F are the groups of males and females respectively in dual career couples, and group S is the group of the workers in single career couples. Note that the measure of group M and group F workers are $\alpha/2$ each, and the measure of group S workers is $1 - \alpha$.

Workers are heterogeneous in their ability θ. Worker's ability is observable to firms, and the distribution for each worker's ability, regardless of his or her group, follows i.i.d.

cumulative distribution function $G\left[\underline{\theta}, \bar{\theta}\right]$.

$$G_M\left(\theta|\theta_F\right) = G_F\left(\theta|\theta_M\right) = G_S\left(\theta\right) = G\left(\theta\right) \text{ for all } \theta_F, \theta_M \in \left[\underline{\theta}, \bar{\theta}\right]$$

where $G_M\left(\theta|\theta_F\right)$ $\left(G_F\left(\theta|\theta_M\right)\right)$ is cumulative distribution function for group M (F) worker ability given his spouse's ability θ_F (θ_M), $G_S\left(\theta\right)$ is cumulative distribution function for group S, and $G\left(\theta\right)$ is the cumulative distribution function for the whole population.

Each worker draws idiosyncratic match quality ε_{ij} from each firm i in city j. This match quality ε is not observable to firms and follows some distribution.

3.2.2 The firms' Problem and Solution Without Couple Standard

Each firm maximizes the average ability of its workers by making job offers subject to the condition that it has to employ one unit measure of workers. Workers' abilities are observable to firms but their match qualities are not. Therefore, each firm's job offer depends only on each worker's ability.

It turns out that firms make job offers using the cut off rule. At first, let's focus on the case that each firm only make jobs based individual ability, not the average ability of a couple. We will discuss about the later case in the later sections.

Each firm's problem is the following. Given other firms' job offer rules, firm i in city j, set its own job offer rules dictated by $\hat{\theta}_{j,i}$ to maximize the average worker ability subject to the condition that it is able to attract unit measure of workers.

3.2.3 Couple's Problem

Single career couples have only one worker in each couple thus picks the firm with the highest match quality among the firms which make a job offer to the worker. Let θ denote the ability of the worker in a single career couple. Given the job offer rules $\hat{\theta}_{j,i}$ for all i and

j, a single career couple solves the following problem.

$$\max_{\{j,i\}} \varepsilon_{j,i}$$

subject to

$$\theta > \hat{\theta}_{j,i}.$$

It is possible that one or two workers of a dual career couple do not get any offer from any firms. In this case, they are unemployed in the academic market.

Here we assume that members of dual career couple strictly prefer academic jobs to other jobs. If one member of the dual career couple doesn't get any offer, then the other member solves the same problem as a single career couple.

If both members of a dual career couple get offers from some cities, then the dual career couple maximizes the sum of match qualities by choosing one combination of the couple's firms subject to the following conditions. First, both husband and wife of each couple have to locate in the same city (but not necessarily in the same firm.) Second, in order to locate in a firm, workers have to get job offers from that firm. Let θ^H and θ^W denote the ability of the husband and the ability of the wife respectively Let i_H and i_W denote the indices of firms where the husband and the wife are located respectively. Let $\varepsilon^H_{j,i}$ and $\varepsilon^W_{j,i}$ denote the job match quality of the husband and the wife with firm i in city j. Given the job offer rules $\hat{\theta}_{j,i}$ for all i and j, a dual career couple a combination of the couple's firms that the following location problem.

$$\max_{\{j,i_{H,}i_W\}} \varepsilon^H_{j,i_H} + \varepsilon^W_{j,i_W}$$

Subject to

$$\theta^H > \hat{\theta}_{j,i_H} \text{ and } \theta^W > \hat{\theta}_{j,i_W}.$$

If there are combinations of the couple's firms that yield the same sum of the couple's match quality, the couple randomly chooses any one of these combinations with equal probability.

3.2.4 Market Clearing Conditions

In our model, there are $M(>= N)$ measure of workers and there are only N measure of job openings. Therefore, in the equilibrium, firms are always able to fill their job openings. $M - N$ measure of workers are unemployed in the academic job markets.

The academic labor markets should clear in every city at the equilibrium. That is, after the all firms set their cut-off ability levels, the job openings are filled by the workers who choose to accept the job offers. In city j, the measure of workers choosing to be in the firms there should be n_j.

3.2.5 Equilibrium

Here, we focus only on symmetric equilibria in which firms in city j set the same cut-off ability level $\hat{\theta}_j$. An equilibrium in the model is a vector of cut-off rules $(\hat{\theta}_1, \hat{\theta}_2, ..., \hat{\theta}_J)$ such that

1. Given the job offers, each couple solves the location problems.
2. Given other firms' cut-off ability levels, $\hat{\theta}_j$ solves the firm's problem for each firm in city j.

3.2.6 Theoretical Implications

Lemma 6 *The chance of a single career household finding the best match in a city is proportional to the number of firms in the city.*

Proof. Random match quality for each firm follows identical probability distribution and each firm has the equal chance of being the best match. Thus, the probability of the best match coming from a city is proportional to the number of firms the city has. ■

Lemma 7 *The chance of a dual career household finding the best match in a city is more than proportional to the number of firms in the city.*

Proof. Suppose there are two cities.

Suppose there are n_1 firms in City 1, and n_2 firms in City 2.

Suppose the couple is restricted to a subset of all possible combinations of the firm the husband can choose and the firm the wife can choose in the large city, and the couple not restricted in the small city. ■

The subset is described as follows.

For $i = 1, ..., n_2$,when the husband goes to firm i, the wife can only go to firm $i, i+1, ..., i+n_1-1$ if $i \leq n_2 - n_1 + 1$, and the wife can only go to firm $i, i+1, ..., i+n_1-1, 1, 2, ..., i+n_1-1-n_2$ if $i > n_2 - n_1 + 1$. We can briefly say that the wife can only go to the n_1 firms behind the husband's firm.

If the couple is restricted to this subset in the large city, the following is also true.

For $i = 1, ..., n_2$,when the wife goes to firm i, the husband can only go to firm $i-(n_1-1), i-(n_1-1)+1, ..., i$ if $i \geq n_1$, and the husband can only go to firm $n_2-(n_1-i)+1, n_2-(n_1-i)+2, ...n_2, 1, 2, ..., i$ if $i < n_1$. We can briefly say that the husband can only go to the n_1 firms before the wife's firm.

Suppose the couple can choose any combination from the above subset in the large city plus all combination of the couple's firm in the small city.

Let i^*_{H2}an i^*_{W2} be one of the combination of the couple's firms in the large city.

Let $\Pr(i^*_{H2}$ and $i^*_{W2})$ be the probability that the couple chooses the above combination.

$\Pr(\varepsilon^H_{2,j^*_{H2}} + \varepsilon^W_{2,j^*_{W2}} > \varepsilon^H_{i,j_H} + \varepsilon^W_{i,j_W}$ for any other allowed combination of j_H and $j_W)$

$= \Pr(\varepsilon^H_{2,j^*_{H2}} > \varepsilon^H_{2,j_H}$for any j_H of the other $n_1 - 1$ firms before the wife's firm j^*_{W2} than j^*_{H2}, $\varepsilon^W_{2,j^*_{W2}} > \varepsilon^W_{2,j_W}$for any j_W of the other $n_1 - 1$ firms behind the husband's firm j^*_{H2} than j^*_{W2}, and $\varepsilon^H_{2,j^*_{H2}} + \varepsilon^W_{2,j^*_{W2}} > \varepsilon^H_{i,j_H} + \varepsilon^W_{i,j_W}$ for any of the other $(n_2 + n_1 - 2) * n_1$ allowed combinations such that $i \neq 2$ or $(j^*_{H2} \neq j_H$ & $j^*_{W2} \neq j_W))$

Similarly, let $j^*_{H1}$and j^*_{W1} be one of the combination of the couple's firms in the small city.

Also, similarly, let $\Pr(j^*_{H1}$ and $j^*_{W1})$ be the probability that the couple chooses the above combination.

$\Pr(\varepsilon^{H}_{1,j^*_{H1}} + \varepsilon^{W}_{1,j^*_{W1}} > \varepsilon^{H}_{i,j_H} + \varepsilon^{W}_{i,j_W}$ for any other allowed combination of j_H and $j_W)$

$= \Pr(\varepsilon^{H}_{1,j^*_{H1}} > \varepsilon^{H}_{1,j_H}$for any j_H of the other $n_1 - 1$ firms than j^*_{H1} in the small city, $\varepsilon^{W}_{1,j^*_{W1}} > \varepsilon^{W}_{1,j_W}$for any j_W of the other $n_1 - 1$ firms than j^*_{W1} in the small city, and $\varepsilon^{H}_{j^*_{H1},1} + \varepsilon^{W}_{j^*_{W1},1} > \varepsilon^{H}_{i,j_H} + \varepsilon^{W}_{i,j_W}$ for any of the other $(n_2 + n_1 - 2) * n_1$ allowed combinations such that $i \neq 1$ or $(j^*_{H1} \neq j_H$ & $j^*_{W1} \neq j_W))$

Obviously, by i.i.d. assumption,

$\Pr(\varepsilon^{H}_{2,j^*_{H2}} + \varepsilon^{W}_{2,j^*_{W2}} > \varepsilon^{H}_{i,j_H} + \varepsilon^{W}_{i,j_W}$ for any other allowed combination of j_H and $j_W) =$ $\Pr(\varepsilon^{H}_{1,j^*_{H1}} + \varepsilon^{W}_{1,j^*_{W1}} > \varepsilon^{H}_{i,j_H} + \varepsilon^{W}_{i,j_W}$ for any other allowed combination of j_H and $j_W)$.

Similarly, for the case where there are several top combinations of firms with equal sum of match qualities, the probability is also equal.

Therefore, $\Pr(j^*_{H2}$ and $j^*_{W2}) = \Pr(j^*_{H1}$ and $j^*_{W1})$.

Let $\Pr(j^*_{H2}$ and $j^*_{W2}) = \Pr(j^*_{H1}$ and $j^*_{W1}) = p$.

Let Pr(subset in the large city) be the probability that the couple chooses one of the combinations in the subset in the large city.

Let Pr(small city) be the probability that the couple chooses one of the combinations of the couple's firms in the small city.

Then,

Pr(subset in the large city)

$= n_2 * n_1 * p$,

and

Pr(small city)

$= n_1 * n_1 * p$.

Therefore,

$\Pr(\text{subset in the large city}) / \Pr(\text{small city}) = \frac{n_2}{n_1}$.

Therefore,

$\Pr(\text{large city}) / \Pr(\text{small city}) > \frac{n_2}{n_1}$.

Proposition 6 *Firms in larger cities have a higher cutoff.*

Proof. Suppose not. In other words, suppose that there exist two cities n_1 and n_2 such that $n_1 < n_2$ and $\hat{\theta}_{n_1} \geq \hat{\theta}_{n_2}$. Lemmas 6 and 7 jointly imply that firms in n_2 will end up employing strictly more workers than firms in n_1. This is a contradiction because each firm has to employ a unit measure of workers. ■

Proposition 7 *Dual career households are more likely to locate in larger cities than single career households.*

Proof. Lemma 6 and Proposition 6 jointly imply that single career households are relatively more concentrated in smaller cities. Thus, dual career households are relatively more concentrated in larger cities. ■

Proposition 8 *Average worker ability increases with city size.*

Proof. *This directly follows from Proposition 6.* ■

3.3 Simulation

In this section, we simulate a calibrated version of our model to get a sense of the impact of the co-location problem on the distribution of quality across locations. We use the NSOPF data on the distribution of jobs as well as the percentage of academic couples to pin down parameters for the simulation.

3.3.1 The Model and the Algorithm

There is a finite set of individuals, male faculties and female faculties. We assume that there are more male faculties than female faculties.

Male faculties are ranked according to their abilities. We assume that the female faculties are randomly placed at the places of the ranking order of the male faculties. Then the male and female faculties would have the same distribution of ability.

We assume perfect assortative matching between male faculties and female faculties, for the technical reason to make the computation tractable. A male faculty ranked at the n-th place among males can only be married to a female placed at the n-th place if there is one such female. A male and a female placed at the same ranking can potentially be a couple, but does not have to be a couple.

We assume that a couple strictly prefers living in the same city over living in separate cities, and then they pick the best random preference draws.

In this setup, the solution is straightforward. The highest ranked faculty among all faculties who have not picks jobs are allowed to pick the jobs they like the most first. We assume that the female pick the job first if a male and a female are ranked at the same place.

3.3.2 Match to the Data

We introduce this parameter λ which will be scaling parameter that measures the thickness of the labor market, or the scarcity of the jobs available to a faculty. If $\lambda = 1$, then all the jobs are available for a faculty to pick. If $\lambda = 1/2$, then only half of the jobs are available for a faculty to pick.

Using the institution level 1998-1999 NSOPF data, we pin down the distribution of jobs over all institutions and all locations. We have $465,292$ jobs in $3,845$ institutions, which are located in $1,012$ cities. Cities are classified as small cities, medium cities and large cities as in Chapter 1. Of all the faculties, there are $293,532$ males and $172,160$ females.

We assume that the number of faculties is equal to the number of jobs in our simulation.

Using the individual level NSOPF data, we find that 16.35% of female faculties are married to academic spouses.

3.3.3 Simulation Results

The female marriage rate α is equal to 16.35%. The only parameter we need to pin down is λ, the labor market thickness parameter. We tried to calibrate λ to the data using the values of couples' same-institution employment. However, we find no value of λ which could produce simulation results close the data. There are several possible reasons behind this problem, and we leave this for future research.

There are $465,692$ postsecondary faculty, $293,532$ males and $172,160$ females. The cdf of the i.i.d. preference draw is given by $F(x) = \exp(-1/x)$ if $x > 0$ and $F(x) = 0$ if $x <= 0$.

We vary λ and α, the fraction of female faculty married to academic spouses, to study the potential magnitude of the impact of co-location problem under various labor market thickness and marriage rate. Since male and female faculty have the same ability distribution and we assume perfect assortative matching between the husband and the wife in terms of ability, any result about male faculty would also be true about female faculty. Hence, in the following simulations, we would only report simulation results about male faculty.

For the first sequence of simulations, we fix the female faculty's marriage rate at 16.35%, and we vary the labor market thickness parameter λ. λ takes value of 1, 0.01, and 0.001. When $\lambda = 1$, then all 465,292 jobs are available for a faculty to pick nationwide at the beginning. When $\lambda = 0.001$, then only about 465 jobs are available for a faculty to pick nationwide at the beginning.

Table 3.1, 3.2, and 3.3 show that as the labor market thickness gets thinner, that is, as λ gets smaller, the impact of co-location problem becomes stronger. As the labor market gets thinner, the gap of faculty ability between large cities and small cities gets larger. For example, when $\lambda = 1$, the top 25 percentile male faculty in large cities and in small cities are ranked top 25.20 percentile and top 24.82 percentile among male faculty nationwide respectively. When $\lambda = 0.001$, the top 25 percentile male faculty in large cities and in small cities are ranked top 26.89 percentile and top 21.98 percentile among male faculty nationwide respectively.

The above observations could also imply that for academic fields where the labor market is thinner the impact of co-location problem is stronger and thus the gap of faculty ability between large cities and small cities is larger.

For the second sequence of simulations, we fix the labor market thickness parameter λ at 0.001, and vary the female faculty marriage rate α. α takes value of 16.35%, 50% and

Top Percentile for Each City Size	Small Cities	Medium Cities	Large Cities
75.00	74.91	74.85	75.14
50.00	49.87	49.77	50.19
25.00	24.82	24.78	25.20

Table 3.1: Top Percentile Male Faculty's Nationwide Ranking for Each City Size, Female Marriage Rate=0.1635, lamda=1

Top Percentile for Each City Size	Small Cities	Medium Cities	Large Cities
75.00	74.43	74.92	75.26
50.00	48.95	49.98	50.37
25.00	23.41	25.04	25.57

Table 3.2: Top Percentile Male Faculty's Nationwide Ranking for Each City Size, Female Marriage Rate=0.1635, lambda=0.01

100%.

Table 3.1, 3.4, and 3.5 show that as the female marriage rate goes up, that is, as α gets larger, the impact of co-location problem becomes stronger. As the female marriage rate gets higher, the gap of faculty ability between large cities and small cities gets larger. For example, when $\alpha = 16.35\%$, the top 25 percentile male faculty in large cities and in small cities are ranked top 25.20 percentile and top 24.82 percentile among male faculty nationwide respectively. When $\alpha = 100\%$, the top 25 percentile male faculty in large cities and in small cities are ranked top 10.93 percentile and top 35.91 percentile among male faculty nationwide respectively.

The above observations could also imply that for academic fields where the female faculty marriage rate is higher the impact of co-location problem is stronger and thus the gap of faculty ability between large cities and small cities is larger.

Table 3.1, 3.4, and 3.5 also show that the impact of co-location problem is not very significant under current demographic composition of the USA academic market. But if the female marriage rate of the academic market gets higher in the future, the co-location problem would have very significant impact on ability sorting across cities of different sizes.

Top Percentile for Each City Size	Small Cities	Medium Cities	Large Cities
75.00	73.08	74.50	75.96
50.00	46.75	49.09	51.73
25.00	21.98	23.94	26.89

Table 3.3: Top Percentile Male Faculty's Nationwide Ranking for Each City Size, Female Marriage Rate=0.1635, lambda=0.001

Top Percentile for Each City Size	Small Cities	Medium Cities	Large Cities
75.00	68.38	73.95	77.52
50.00	40.19	47.84	54.65
25.00	16.29	22.68	30.73

Table 3.4: Top Percentile Male Faculty's Nationwide Ranking for Each City Size, Female Marriage Rate=0.5, lambda=0.001

Top Percentile for Each City Size	Small Cities	Medium Cities	Large Cities
75.00	59.14	72.73	79.80
50.00	29.49	46.59	58.83
25.00	10.93	22.63	35.91

Table 3.5: Top Percentile Male Faculty's Nationwide Ranking for Each City Size, Female Marriage Rate=1, lambda=0.001

3.4 Conclusion

In this chapter, we build a probabilistic model of co-location problem of dual career couples. Dual career couples have to find jobs in the same cities and bigger cities provide more chances of good job offers. Therefore, dual career couples are disproportionately concentrated in big cities. The model of Frank (1978) predicts such geographic pattern. In our model, we explicitly model the recruiting behaviors of the firms in cities of different sizes. Since dual career couples are disproportionately concentrated in big cities, firms in big cities set higher cut-off ability levels. Therefore, firm qualities in small cities are lower than in bigger cities. As there are more and more dual career couples, firm qualities deteriorate in small cities and improve in large cities. We simulate our model with finite number of faculties and find some interesting results. The simulation results show that impact of co-location problem is not very significant under current demographic composition of the USA academic market. Our simulations also show that as the labor market gets thinner or the marriage rate gets higher, the impact of co-location problem becomes stronger.

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Appendix A

Appendix for Chapter 1

We give definitions to some geographic terminology, and then we classify the locations of colleges or universities into 3 categories.

A metropolitan statistical area (MSA) is a geographic entity, defined by the Federal Office of Management and Budget (OMB) for use by Federal statistical agencies, based on the concept of a core area with a large population nucleus, plus adjacent communities having a high degree of economic and social integration with that core. Qualification of an MSA requires the presence of a city with 50,000 or more inhabitants, or the presence of an urbanized area and a total population of at least 100,000 (75,000 in New England). The county or counties containing the largest city and surrounding densely settled territory are central counties of the MSA. Additional outlying counties qualify to be included in the MSA by meeting certain other criteria of metropolitan character, such as a specified minimum population density or percentage of the population that is urban. MSAs in New England are defined in terms of cities and towns, following rules concerning commuting and population density.

A consolidated metropolitan statistical area (CMSA) – A geographic entity defined by the Federal OMB for use by Federal statistical agencies. An area becomes a CMSA if it meets the requirements to qualify as a metropolitan statistical area (MSA), has a population of 1,000,000 or more, if component parts are recognized as primary statistical metropolitan areas (PMSAs), and local opinion favors the designation. Whole counties are components of CMSAs outside of New England, where they are composed of cities and towns instead.

A primary metropolitan statistical area (PMSA) is a geographic entity defined by the Federal OMB for use by Federal statistical agencies. If an area meets the requirements to qualify as a metropolitan statistical area (MSA) and has a population of one million or more, two or more PMSAs may be defined within it if statistical criteria are met and local opinion is in favor. A PMSA consists of a large urbanized county, or a cluster of such counties (cities and towns in New England) that have substantial commuting interchange. When one or more PMSAs have been recognized, the balance of the original, larger area becomes an additional PMSA; the larger area of which they are components then is designated a consolidated metropolitan statistical area (CMSA).

A place is a concentration of population either legally bounded as an incorporated place, or identified by the Census Bureau as a Census designated place.

An incorporated Place is recognized legally as in existence under the laws of their respective states as cities, boroughs, towns, and villages, with the following exceptions: the towns in the New England states, New York, and Wisconsin, and the boroughs in New York are recognized as minor civil divisions for census purposes; the boroughs in Alaska are county equivalents.

A census designated place (CDP) is a statistical entity, defined for each decennial census according to Census Bureau guidelines, comprising a densely settled concentration of population that is not within an incorporated place, but is locally identified by a name. CDPs are delineated cooperatively by state and local officials and the Census Bureau, following Census Bureau guidelines. These entities were called unincorporated places for the 1940 through 1970 censuses.

The first category of locations of colleges or universities is called large cities, which includes large cities and the urban fringes of large cities. A large city is a central city of a CMSA or MSA with the city having a population greater than or equal to 250,000. The urban fringe of a large city is any incorporated place, CDP, or non-place territory within a

CMSA or MSA of a Large City and defined as urban by the Census Bureau. This category is called large cities.

The second category is called medium cities, which includes mid-size cities and the urban fringes of the mid-size cities. A mid-size city is a central city of a CMSA or MSA, with the city having a population less than 250,000. The urban fringe of a mid-size City is any incorporated place, CDP, or non-place territory within a CMSA or MSA of a mid-size city and defined as urban by the Census Bureau. This category is called mid-size cities.

The third category is called small cities, which include large towns, small towns, and rural areas. A large town is an incorporated place or CDP with a population greater than or equal to 25,000 and located outside a CMSA or MSA. A small town is an incorporated place or CDP with a population less than 25,000 and greater than or equal to 2,500 and located outside a CMSA or MSA. A rural area is any incorporated place, CDP, or non-place territory designated as rural by the Census Bureau.

Appendix B

Appendix for Chapter 2

B.1 The Cut Off Equations

B.1.1 When every school uses the independent hiring policy

The following are the market clearing conditions for all schools. We can solve for the cut offs $\left(\hat{\theta}_{1H}, \hat{\theta}_{1L}, \hat{\theta}_{2H}, \hat{\theta}_{2L}\right)$ by solving these simultaneous equations. We can drop one or two equations using the condition that $\hat{\theta}_{1L} = \underline{\theta}$ if $\alpha > 0$ and that $\hat{\theta}_{1L} = \hat{\theta}_{2L} = \underline{\theta}$ if $\alpha = 0$.

- School 1H

$$4(1-\alpha)\begin{pmatrix} \int_{\hat{\theta}_{2H}}^{\bar{\theta}} \frac{1}{\bar{\theta}-\underline{\theta}} \frac{1}{2} dx \\ + \int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}} \frac{1}{\bar{\theta}-\underline{\theta}}\, dx \end{pmatrix} + 4\alpha \begin{pmatrix} \int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}} \frac{1}{\bar{\theta}-\underline{\theta}} \left(\frac{\bar{\theta}-\hat{\theta}_{1H}}{\bar{\theta}-\underline{\theta}}\right) dx + \\ \int_{\hat{\theta}_{2H}}^{\bar{\theta}} \frac{1}{\bar{\theta}-\underline{\theta}} \left(\frac{1}{2}\frac{\bar{\theta}-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}} + \frac{\hat{\theta}_{2H}-\hat{\theta}_{1H}}{\bar{\theta}-\underline{\theta}}\right) dx \end{pmatrix} = 1$$

- School 1L

$$4(1-\alpha)\begin{pmatrix} \int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}} \frac{1}{\bar{\theta}-\underline{\theta}}\, dx \\ + \int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}} \frac{1}{2} \frac{1}{\bar{\theta}-\underline{\theta}} dx \end{pmatrix} + 4\alpha \begin{pmatrix} \int_{\underline{\theta}}^{\hat{\theta}_{2L}} \frac{1}{\bar{\theta}-\underline{\theta}}\, dx \\ + \int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}} \frac{1}{\bar{\theta}-\underline{\theta}} \left(\frac{1}{2}\frac{\hat{\theta}_{2H}-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}} + \frac{\hat{\theta}_{2L}-\hat{\theta}_{1L}}{\bar{\theta}-\underline{\theta}}\right) dx + \\ \int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}} \frac{1}{\bar{\theta}-\underline{\theta}} \left(\frac{1}{2}\frac{\hat{\theta}_{1H}-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}} + \frac{\hat{\theta}_{2L}-\hat{\theta}_{1L}}{\bar{\theta}-\underline{\theta}}\right) dx \\ + \int_{\hat{\theta}_{2H}}^{\bar{\theta}} \frac{1}{\bar{\theta}-\underline{\theta}} \frac{\hat{\theta}_{2L}-\hat{\theta}_{1L}}{\bar{\theta}-\underline{\theta}} dx \end{pmatrix} = 1$$

- School 2H

$$4(1-\alpha)\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{\bar{\theta}-\underline{\theta}}\frac{1}{2}dx+4\alpha\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\hat{\theta}_{1H}-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}+\frac{1}{2}\frac{\bar{\theta}-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}\right)dx=1$$

- School 2L

$$4(1-\alpha)\left(\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{\bar{\theta}-\underline{\theta}}\frac{1}{2}dx\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}+\frac{1}{2}\frac{\hat{\theta}_{2H}-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{1}{2}\frac{\hat{\theta}_{1H}-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

B.1.2 When every school chooses to use the couple accommodation policy

The following are the market clearing conditions for all schools. We obtain a bit different geometries depending on α. So we report two cases, $\alpha \geq 0.366$ and $\alpha < 0.366$.

If $\alpha \geq 0.366$

- School 1H

$$4(1-\alpha)\left(\begin{array}{c}\int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\end{array}\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}+(\hat{\theta}_{2H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{2H}+(\hat{\theta}_{2H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 1L

$$4(1-\alpha)\left(\begin{array}{c}\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\end{array}\right)+4\alpha\left(\begin{array}{c}\int_{\underline{\theta}}^{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}+\hat{\theta}_{2L}-\underline{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{2L}+(\hat{\theta}_{2L}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2L}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 2H

$$4(1-\alpha)\left(\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{2H}+(\hat{\theta}_{2H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{2H}+(\hat{\theta}_{2H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{2H}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2L}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 2L

$$4(1-\alpha)\left(\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\right)+4\alpha\left(\begin{array}{c}\int_{\underline{\theta}}^{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\underline{\theta}}^{\hat{\theta}_{2L}+\hat{\theta}_{2L}-\underline{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{2L}+(\hat{\theta}_{2L}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2L}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

If $\alpha < 0.366$

- School 1H

$$4(1-\alpha)\left(\begin{array}{c}\int_{\hat{\theta}_{1H}}^{\hat{\theta}_{2H}}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\end{array}\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}+(\hat{\theta}_{2H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{2H}+(\hat{\theta}_{2H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 1L

$$4(1-\alpha)\left(\begin{array}{c}\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\end{array}\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx+\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{1}{2}\frac{\hat{\theta}_{2H}-\hat{\theta}_{1L}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}+\hat{\theta}_{2L}-\underline{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{2L}+(\hat{\theta}_{2L}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 2H

$$4(1-\alpha)\left(\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{2H}+(\hat{\theta}_{2H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{\bar{\theta}-(\hat{\theta}_{2H}+(\hat{\theta}_{2H}-x))}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{2H}}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2L}}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

- School 2L

$$4(1-\alpha)\left(\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\right)+4\alpha\left(\begin{array}{c}\int_{\hat{\theta}_{1L}}^{\hat{\theta}_{2L}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}dx\\+\int_{\hat{\theta}_{2L}}^{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}\left(\frac{\bar{\theta}-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}+\frac{1}{2}\frac{\hat{\theta}_{2H}-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\underline{\theta}}^{\hat{\theta}_{2L}+\hat{\theta}_{2L}-\underline{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{2L}+(\hat{\theta}_{2L}-x))-\underline{\theta}}{\bar{\theta}-\underline{\theta}}\right)dx\\+\int_{\hat{\theta}_{1H}+(\hat{\theta}_{1H}-\bar{\theta})}^{\hat{\theta}_{1H}+\hat{\theta}_{1H}-\hat{\theta}_{2H}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2H}}{\bar{\theta}-\underline{\theta}}\right)dx\\-\int_{\hat{\theta}_{2H}}^{\bar{\theta}}\frac{1}{2}\frac{1}{\bar{\theta}-\underline{\theta}}\left(\frac{(\hat{\theta}_{1H}+(\hat{\theta}_{1H}-x))-\hat{\theta}_{2L}}{\bar{\theta}-\underline{\theta}}\right)dx\end{array}\right)=1$$

B.2 The Proof of Proposition 5

The average ability of a school can be expressed as follows.

$$\omega(\alpha)\,d(\alpha)+(1-\omega(\alpha))\,s(\alpha) \tag{B.1}$$

where $\omega(\alpha)$ is the share of dual career couple workers in the school, $d(\alpha)$ is the average ability of dual career couple workers in the school, $s(\alpha)$ is the average ability of single workers in the school. When $\alpha = 0$, the couple accommodation policy does not matter at all so the average abilities are same whether the school uses the couple accommodation policy or not. In order to compare average abilities when α is close to 0, we compare the derivative of average ability functions under the two hiring policies.

$$g(\alpha)\equiv\{\omega_1(\alpha)\,d_1(\alpha)+(1-\omega_1(\alpha))\,s_1(\alpha)\}-\{\omega_0(\alpha)\,d_0(\alpha)+(1-\omega_0(\alpha))\,s_0(\alpha)\} \tag{B.2}$$

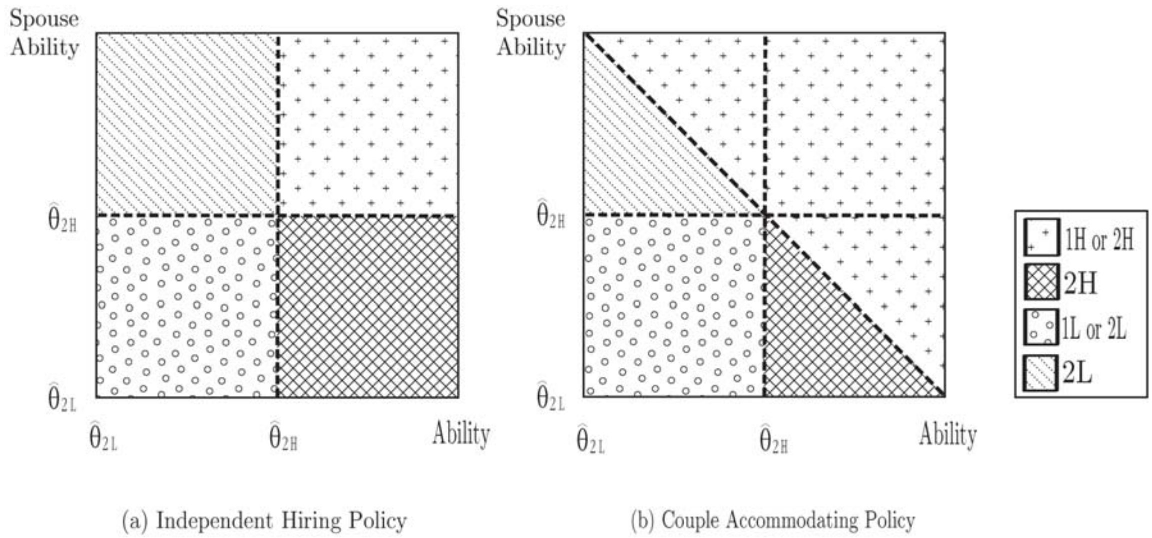

Figure B.1: The limiting distribution of dual career couples' school choices as $\alpha \to 0$

where $d_1(\alpha)$ and $s_1(\alpha)$ indicate the average abilities of dual career couples and single workers respectively under the couple accommodation policy and $d_0(\alpha)$ and $s_0(\alpha)$ indicate the average abilities of them under independent hiring policy.

Taking derivative of $(B.1)$ with respect to α and plugging in $\alpha = 0$, $\omega_0(0) = \omega_1(0) = 0$ and $s_1(0) = s_0(0)$ we obtain

$$g'(0) = \left(s_1'(0) - s_0'(0)\right) + \omega_1'(0)\left(d_1(0) - s_0(0)\right) - \omega_0'(0)\left(d_0(0) - s_0(0)\right). \tag{B.3}$$

School 2H get hurt by the couple accommodation policy. Consider infinitesimal increase in α by $\triangle\alpha$. We show that $\omega_1'(0) = \omega_0'(0)$, $s_1'(0) = s_0'(0)$, and $d_1(0) < d_0(0)$. Figure B.1 shows the limiting school choice distribution for dual career couples under the two policies. The measure of dual career couple workers going to school 2H are equal under the two policies. This implies that the dual career couple percentage in the school change at the same rate under the two policies at $\alpha = 0$ ($\omega_1'(0) = \omega_0'(0)$). This also implies that the cut off for single workers would change at the same rate under the two policies. Since school 2H get a half of the single workers above the cut off, this implies that the average ability of single workers would change at the same rate ($s_1'(0) = s_0'(0)$). On the other hand, the average ability of dual career couples is lower under the couple accommodation policy ($d_1(0) < d_0(0)$). With the couple accommodation policy, school 2H loses a half of the triangular area above $\hat{\theta}_{2H}$ and gains a half of the triangular below $\hat{\theta}_{2H}$. Combining these three, we conclude that $g'(0) < 0$ and school 2H has lower average abilities for sufficiently small $\alpha > 0$.

School 1L gets benefit from the couple accommodation policy. The measure of dual career couple workers going to school 1L is equal under the two policies. The ability distribution of dual career couple workers going to school 1L are same under the two policies ($d_1(0) = d_0(0)$). By the same reasoning with school 2H, we can also obtain $\omega_1'(0) = \omega_0'(0)$ and that the cut off changes at the same rate under the two policies (in fact its cut off does not change at all at $\underline{\theta}$ under either policy.) What differs from school 2H case is that the average ability of school 1L depends not only on its cut off but also on the cut off of the other schools. The cut off of school 2H does not change, the cut off of school 1H increases and the cut off of school 2L decreases by the same amount as the school 1H cut off increase (This is to meet the market clearing condition for school 1L). Combining these, we can infer that average ability of single workers increase more under the couple accommodation policy ($s_1'(0) < s_1'(0)$). Therefore, the average ability of school 1L increases with the couple accommodation policy.