In “Mathematical College Majors and the Gender Gap in Wages” by Catherine J. Weinberger, the author finds discrepancies between her 1998(a) research and the research of Paglin and Rufolo.[3] Weinberger’s study finds a 9 percent wage gap between white males and white females while the work of Paglin and Rufolo attest that the entirety of the wage differential between white men and white women can be attributed to the different choice of mathematical college majors.[1] Therefore, the question Weinberger tries to examine is “how much of the gender gap in earnings can be explained by the mathematical content of a graduate’s major in a representative sample of college graduates.”[2]

The reasons for the discrepancies between the results of the studies can be attributed to the fact that the samples are not comparable according to Weinberger.[2] Because Paglin and Rofolo conduct their analysis with wage offers reported by the College Placement Council, which are salary offers recruiters present to the best of future graduates, the wages are not representative of all graduates, but those of which who have excelled in their academic studies.[2]

Therefore, Weinberger’s study will use the same dataset from her 1998(a) paper to examine if there is a wage differential between white men and white women. To do this, she restricts her sample to white men and white women no more than 30 years old, not listed as full time students, were employed full time or involuntarily part time, and earn more than a $1 per hour.[2] She restricts the sample in this way in order to prevent events that may bias her results because they would make the groups incomparable. Restricting the sample to only white men and white women remove the potential for differentials in wage due to race, which was established in Weinberger’s 1998(a) paper, from affecting the study. Similarly, age is restricted to no more than 30 years of age so that the effect of previous work experience of graduates cannot cause differences between white men and white women. A person cannot be listed as a full time student because there is the potential that the person is employed as he or she continues his or her education, though potentially not in a job where the assets of their education would reflect their compensation. Additionally, a person must be employed full time or involuntarily part time so that the subjects of the study are not choosing to be employed part time, which is associated with a lower level of compensation than a full time employee is. Finally, the individual must earn more than a $1 per hour to exclude extremely rare cases from the data being analyzed, such as if the person is not paid in monetary compensation and is therefore not equally analyzable in comparison to the rest of the data points.

In order to analyze her results, Weinberger constructs four linear regression models in which she regresses the logarithm of hourly wages onto her white women variable using other variables as controls. The first of these regressions is model 1, which contains no college major control, only the human capital controls, which are predegree work experience, postdegree work experience, college grade-point average, and hours worked per week.[3] The variables predegree work experience, college grade-point average, and hours worked per week are all self-reported in

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[1] Catherine J. Weinberger, "Mathematical College Majors and the Gender Gap in Wages." *Industrial Relations* 38, no. 3 (1999): 407.

[2] Ibid., 408.

[3] Ibid., 409.

the survey. The postdegree work experience is a proxy, using potential work experience, which is the elapsed time in months since graduation.[4]

In her second model, Weinberger continues to use her human capital controls and also controls for a set of 12 different college majors as dummy variables.[5] Model 3 instead accounts for a "mathematical content control."[5] The mathematical control major is constructed to indicate whether an individual has a technical college major, which contain the highest mathematical content among the majors.[5] Weinberger notes that model 3's white women coefficient estimate will most likely be between that of model 1 and 2; the closer model 3 and model 2's coefficients, then mathematical content becomes more important in the explained portion of the gender wage gap.[6]

Finally, a fourth model is constructed which uses the same controls as model 3 and adds another control variable to measure the interaction between technical college majors and white women.[6] The coefficient of the control will be able to measure if there is a difference in the average gender wage gap between white women with technical college majors and white women.[6]

From the regression analysis, Weinberger is able to obtain some insightful conclusions. First and foremost, her controls for models 2, 3, and 4 are able to explain 8 percent of the 17 percent gender wage gap with the inclusion of these controls.[6] Additionally, due to the fact that the resulting coefficient of white women in both model 2 and model 3 explaining 9 percent of the gender wage gap, Weinberger is able to ascertain that mathematical controls can "explain as much of the gender wage gap as the unconstrained college major controls."[6] Finally, women with technical college majors face a smaller wage disadvantage based on the results of the interaction in model 4, but it is unable to be concluded that this measure is not equal to zero since the coefficient is not statistically significant.[6] Therefore, it cannot be rejected that there is no difference between the wage gap of all white women and white women with technical college majors.

While these models appropriately account for many confounders, the analysis has overlooked one very important confounder: the college attended. Not including the variable in the regression causes a problem of omitted variable bias. This is the failure of the assumption that the model is exogenous because the model now has endogeneity, where the variable white women may vary due to differences in the quality of education received due to college attended. In Weinberger's own 1998(a) paper, in which she analyzed the wage gaps associated with race and sex, she claims:

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[4] Weinberger, Catherine J. "Race and Gender Wage Gaps in the Market for Recent College Graduates." *Industrial Relations* 37, no. 1 (1998): 73.

[5] Weinberger, "Mathematical College Majors," 409.

[6] Ibid., 410.

> College major, college grades, and the college attended represent both exceptionally detailed measures of the type and quality of education attained and an indication of the ability of each graduate to work productively at the broad range of tasks involved in completing college course-work.[7]

Yet in her analysis for this study, she excludes her variable for college attended. The hypothesis for the exclusion of this variable is due to fact that she finds little difference in the wage gaps of particular race and sex groups in comparison to the 12 major controls, which were also used in the study.[8]

However, the quality of college attended is an important confounder that needs to be accounted for in the models when analyzing the wage differential between white men and white women, or even more importantly the wage differentials between white women at different quality colleges attended. In order to justify the inclusion of the quality of college attended in the models, it must first be shown that the variable is in fact a confounder. Therefore, it must be confirmed that the type of college attended is associated with the logarithm of wage, associated with the variable white women, and not redundant, meaning not predicted by the other controls.

A study by the United States Department of Education in 2000 found that "college characteristics to future earnings was statistically significant…for both males and females."[9] These characteristics used to proxy for the quality of the institutions in the study include selectivity, size, faculty contact, governance, and expenditures.[10] Controlling for confounders such as prior achievement, ability, and family background, the study found that the college quality could account for 2 to 3 percent of the variability of men's earnings and 4 to 6 percent of the variability of women's earnings when confounders such as background characteristics, labor market characteristics, and higher educational experiences were taken into account.[11]

This study by the United States Department of Education does not stand alone in its findings that characteristics of the college attended are associated with wage. Rumberger and Thomas find that both males and females receive a premium for attending a selective school.[12] The premiums are estimated to be 3% for men and 4% for women for each 100 point increase in the average SAT score of entering freshman.[12] Important as well is the fact that this study finds no significant difference between the effect of public and private institutions on wage.[13]

In addition to these studies, Zhang uses Barron's ratings, Carnegie classifiers, and mean SAT scores to measure the quality of the institution in his linear regression. The Baccalaureate

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[7] Weinberg, "Race and Gender," 69.

[8] Ibid., 79.

[9] U.S. Department of Education. National Center for Education Statistics. *College Quality and the Earnings of Recent College Graduates*, NCES 2000–043, by Robert A. Fitzgerald. Project Officer: Shelley Burns. Washington, DC: 2000, 30.

[10] Ibid., 11.

[11] Ibid., vi.

[12] Rumberger, Russell W., and Scott L. Thomas. "The Economic Returns to College Major, Quality and Performance: A Multilevel Analysis of Recent Graduates." *Economics of Education Review* 12, no. 1 (1993): 8.

[13] Ibid., 12.

and Beyond longitudinal study is used to construct an OLS model of the logarithm of wage onto demographic factors, similar to Weinberger's 1998(a) study.[14] Barron's ratings, Carnegie classifiers, and mean SAT scores are all statistically significant with Zhang declaring, "the common wisdom that it pays to attend high-quality institutions seems to be quite robust over an array of measures of college quality."[15] However, the one caveat described is that the estimated effects when using a single measure varied because the same institution may move between categories based on what is being measured.[16]

Next, it must be shown that the variable white women is associated with the type of college. With simple examination, the dataset used for Weinberger's analysis, "Recent College Graduates Survey, 1983–1984", was able to show that white men and white women choose to attend different types of institutions.

In order to analyze this, the type of institution had to be mapped to each individual's college in the dataset. Since the "Higher Education General Information Survey (HEGIS), 1981–1982: Salaries, Tenure, and Fringe Benefits of Full-Time Faculty" was used as a sampling frame for this dataset, each entry was able to be mapped to its institutional type in the HEGIS dataset through the institution's FICE identification number. The HEGIS dataset contains three types of institutions also in the Recent College Graduates Survey: university, other four-year, and other four-year branch campus of a multi-campus university, which I will refer to as universities, colleges, and branch campuses respectfully.[17] I create an additional category of elite universities from an archive by The Chronicle of Higher Education of 57 institutions that have at some point, and usually fairly consistently, ranked in the top 50 national universities as determined by U.S. News & World Report since the list's inception in 1983.[18]

From this point, the data is added now as a new ordinal variable in the dataset based off the assumptions of previous papers discussed above with 0 corresponding to elite, 1 to universities, 2 to colleges, and 3 to branch campuses. A table is constructed using the replication data from the sample of 5048 white men and white women.

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[14] Zhang, Liang. "Do Measures of College Quality Matter? The Effect of College Quality on Graduates' Earnings." *The Review of Higher Education* 28, no. 4 (2005): 575. doi:10.1353/rhe.2005.0053.

[15] Ibid., 591.

[16] Ibid., 590.

[17] U.S. Dept. of Education, National Center for Education Statistics. HIGHER EDUCATION GENERAL INFORMATION SURVEY (HEGIS), 1981-1982: SALARIES, TENURE, AND FRINGE BENEFITS OF FULL TIME FACULTY [Computer file]. ICPSR version. Washington, DC: U.S. Dept. of Education, National Center for Education Statistics [producer], 1982. Ann Arbor, MI: inter University Consortium for Political and Social Research [distributor], 1999, 18.

[18] "U.S. News Rankings Through the Years." U.S. News Rankings Through the Years. 2007. Accessed December 10, 2015. http://web.archive.org/web/20070905010206/http://chronicle.com/stats/usnews/index.php?category=Universities&orgs=&sort=1983.

Table 1

	MALE (0)	FEMALE (0)	TOTAL
ELITES (0)	327	322	**649**
UNIVERSITIES (1)	684	763	**1447**
COLLEGES (2)	1095	1602	**2697**
BRANCH CAMPUSES (3)	123	132	**255**
TOTAL	**2229**	**2819**	**5048**

Simple calculations provide you with the mean college type for men of 1.455 and women of 1.548. Conducting a 2-sample t-test of sample means provides a t-statistic of statistical significance much larger than that required at the 99 percent level to reject the null hypothesis that there is no difference between the average male institution type and average female institution type. The conclusion now is that men on average attend better universities than women. Therefore, the type of college is associated with the treatment variable white women.

Finally, the quality of the institution cannot be redundant. Though there may be a slight correlation between students at elite universities choosing more technical majors or students attending more elite universities being more hardworking so they achieve higher grade point averages than those at less elite schools, there appears to be no reason why the control for institution type would have near or perfect multicollinearity with any of the other controls or group of controls in the model. The problem, as is here and almost any other researchable question in science, is that there is not enough information. Multicollinearity could only occur if the model attempts to include so much information that the model controls for the same factor more than once. Therefore, the correct assumption is that the control for the quality of the institution is not redundant.

Consequently, the quality of the institution is a confounder. The type of institution, though it will not completely reduce the bias caused by the quality of the institution, works as a respectable proxy for the confounder.

A much better solution that could estimate the bias completely would be a complete list of institution attributes, such as that used in the U.S. Department of Education's study previously described. However, none could be found in which a FICE value could identify the unique institutions.

Another option contemplated was the use of Barron's ratings, Carnegie classifiers, and mean SAT scores for each institution. Though a dataset was found in which the data entries also contained FICE identification values, the data became unusable because it would bias the data for new reasons. This is because Barron's ratings, Carnegie classifiers, and mean SAT scores do not appear to be available for all academic institution of higher learning, or at least were not for the dataset. As a result, the sample size shrunk with how many institutions were available. However, it was not the fact that the sample size shrank that biased the data but how the sample size shrank. Because the ratings, classifiers, and scores were provided for fewer schools, the schools they were provided for were larger institutions and more elite schools. Therefore, the

usage of these variables would have systematically eliminated much more of the observations from colleges and branch campuses than from elite universities and universities. Because of this, the sample would no longer be representative of the desired population, but systematically selected based on the type of institution. Therefore, it was not possible to use Barron's ratings, Carnegie classifiers, or mean SAT scores to attempt to control for the quality of education.

Therefore, the type of institution was selected as the appropriate proxy for the college attended. This is because the colleges and universities in each group contain similarities to each other and differences to colleges and universities in other groups. The elite schools have similarities based on 16 classifications U.S. News & World Report use to rank the institutions every year based on the broad topics of undergraduate academic reputation, graduation and retention rates, faculty resources, student selectivity, financial resources, alumni giving, and graduation rate performance.[19] Universities will be similar in the regards that they typically have a larger number of students, a larger student to faculty ratio, and more money to spend. Typically, colleges will have a smaller student body than universities, less money, but a smaller student to faculty ratio. Finally, students with lower SAT scores are characterized as going to branch campuses of major universities, and these will have less money because the majority of the funds will remain at the main campuses.

Using the replication, models 1 through 4 are constructed using the exact same regressions as Weinberger uses in her own study, but now there is a comparison regression with the type of college dummy control variables included. There is a small, but noticeable difference in models 1 through 3. With more data available, such as for the U.S. Department of Education study, differences between white men and white women in general may be able to be concluded, but the regressions here only seem to account for minute differences in wage.

However, there are much more interesting finding than that of the small changes in the variable white women due to controlling for the type of college. The first of these is contained in model 4. The variable white women with technical college majors was statistically insignificant, but when you control for the type of institution, white women with technical college majors is now statistically significant at the 95 percent level. Additionally, it could be expected that this statistic grow in significance as the model control for each individual factor, such as the Department of Education's study. Now, it can be concluded at the 95 percent confidence level that white women with technical majors do not face the same wage gap as all white women, but a wage gap estimated to be about -.0357, about 3.5 percent.

In model 5, the estimated difference in the wage gap between all women and women at elite universities is measured by the control variable white women at elite universities, which is an interaction between white women and elite schools. The coefficient of this variable is

[19] Mourse, Robert, and Eric Brooks. "Best Colleges Ranking Criteria and Weights." U.S. News & World Report Education. 2015. Accessed December 10, 2015. http://www.usnews.com/education/best-colleges/articles/ranking-criteria-and-weights.

significant at the 99 percent confidence level, which concludes that women at elite colleges face a smaller wage gap of about -.0482, or about 5 percent.

Table 2

	Model 1		Model 2		Model 3		Model 4		Model 5	Model 6	Model 7	Model 8
College Type Control	without	with	without	with	without	with	without	with	witout	without	without	without
Math Content	___	___	___	___	0.0018	0.0018	0.0017	0.0017	0.0018	0.0018	0.0017	0.0017
					(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
White Women	-0.2039	-0.1975	-0.0979	-0.0969	-0.1014	-0.0997	-0.1101	-0.1111	-0.1094	-0.1047	-0.1179	-0.1085
	(0.0115)	(0.0114)	(0.0112)	(0.0112)	(0.0116)	(0.0116)	(0.0133)	(0.0133)	(0.0119)	(0.0118)	(0.0135)	(0.0122)
White women with technical college majors	___	___	___	___	___	___	0.0354	0.0468	___	___	0.0349	___
							(0.0233)	(0.0232)			(0.0232)	
hours	-0.172	-0.0174	-0.0186	-0.0187	-0.0178	-0.018	-0.0178	-0.018	-0.0179	-0.0178	-0.0179	-0.0178
	(0.0012)	(0.0012)	(0.0012)	(0.0012)	(0.0013)	(0.0012)	(0.0013)	(0.0012)	(0.0012)	(0.0013)	(0.0012)	(0.0013)
predegree	0.0139	0.0156	0.0136	0.0149	0.0164	0.0176	0.0165	0.0177	0.0166	0.0165	0.0167	0.0165
	(0.0032)	(0.0032)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0031)
postdegree	0.0489	0.0414	0.0659	0.0593	0.0626	0.0556	0.0634	0.0566	0.0617	0.0629	0.0625	0.0624
	(0.0196)	(0.0195)	(0.0178)	(0.0178)	(0.0182)	(0.0182)	(0.0182)	(0.0182)	(0.0181)	(0.0182)	(0.0012)	(0.0112)
GPA	0.0725	0.0757	0.0683	0.0702	0.0653	0.0681	0.0654	0.0684	0.066	0.0656	0.0661	0.0664
	(0.0120)	(0.0119)	(0.0109)	(0.0108)	(0.0112)	(0.0111)	(0.0111)	(0.0111)	(0.0112)	(0.0112)	(0.0118)	(0.0112)
White women at elite universities	___	___	___	___	___	___	___	___	0.0612	___	0.0610	___
									(0.0215)		(0.0214)	
White women with tech majors at elite schools	___	___	___	___	___	___	___	___	___	0.0853	___	___
										(0.0482)		
White women with tech majors at elite schools or universities	___	___	___	___	___	___	___	___	___	___	___	0.0744
												(0.0294)
12 Major?	No	No	Yes	Yes	No	No	No	No	No	No	No	No
Sample Size	5048	5048	5048	5048	5048	5048	5048	5048	5048	5048	5048	5048
R^2	0.1195	0.1361	0.2953	0.3038	0.2339	0.2422	0.2342	0.2428	0.2352	*0.2343*	0.2433	0.2347

Models 1 through 4 measure the exact same linear regressions as Weinberger's models and contain a comparison of including the dummy variable for the college type control next to it.
Model 5 contains an interaction between white women and elite universities to measure if there is a difference between the wage gap of white women and white women at elite universities.
Model 6 contains an interaction between white women, technical majors, and elite universities to measure the difference between the wage gap of a white woman and a white woman studying a technical field at an elite university.
Model 7 contains two interactions. The first is between white women and technical majors and the second is between white women and elite universities. This was included because jointly the interactions were not significant in Model 6. It can be seen that when separated into two different interactions white women at elite universities is significant but white women with technical college majors is not.
Model 8 contains an interaction between white women with technical majors at elite schools or universities.

Finally, models 6, 7, and 8 together pose a unique discovery about the data. In model 6, the interaction between white women, technical majors, and elite schools is not statistically significant. However, when this is split into two interactions in model 7, it can be seen that white women at elite universities is statistically significant at the 99 percent level while white women with technical majors is not significant at all. However, when you include the elite universities with the universities for the interaction in model 8, the interaction between universities or elite universities, technical majors, and women are statistically significant at the 95 percent level.

This finding seems to show that a similar attribute among elite universities and universities in general must be the driving force behind what makes this interaction significant,

but not significant when just elite universities are included in the interaction. Therefore, some attributes that elite universities have that universities do not have, such as lower acceptance rates, may be working in the opposite direction of a shared attribute between the two, such as larger endowment and therefore more spending per student. It would be interesting to look at how specific attributes of institutions interact with white women and technical majors because some of the effects of each of these may be counteracting as they work in opposite directions.

In summary, college attended is an important confounder missing from Weinberger's model when trying to control for the quality of education received. In the United State Department of Education study, the effects of attending a college for which the characteristics of that institution are one standard deviation above the mean of all institutions "are comparable to the estimated effect of attending an additional year of college."[20]

It was found that simply controlling for the type of institution does relatively little in explaining the wage differential between white men and white women. However, statistically significant interactions were able to explain the different wage gaps women of different backgrounds experience better. For example, white women at elite universities experience an unexplained wage gap of about 5 percent. The wage gap experienced by white women with technical college majors is around 3.5 percent. Finally, women who attend either an elite university or a university who have a technical college major also experience an unexplained wage gap of about 3.5 percent.

Further studies with more accurate measures of individual attributes of institutions are necessary to more accurately control for the college attended and the quality of education received. Studying interactions between specific attributes and white women may help explain what institutional qualities are most important in the workforce and reducing the wage gap between the genders from a policy perspective going forward.

[20] *College Quality and the Earnings*, 31.

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