Female Faculty, Tenure, and Student Graduation Success: Efficiency Implications for University Funding

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Abstract
Renewed interest in reforming the funding mechanisms of U.S. public colleges and universities has focused on holding institutions accountable for the academic success of students. Public concern over low graduation rates has stimulated political interest in tying taxpayer financing to university baccalaureate degree completions. Other studies indicate that improvements in student academic success follow from increases in the proportion of female faculty employment. Thus, female faculty could affect the future of university funding. In this paper, stochastic frontier analysis is employed to investigate the potential efficiency gains associated with female faculty employment in producing university student graduation rates. A panel data specification using 199 U.S. publicly owned universities is based on an inefficiency component comprised of percentages of females employed according to different tenure statuses. Results suggest that increased female employment in tenure track positions offer efficiency gains for improving graduation rates. The findings hold for both men and women students. Increases in proportions of tenured females could produce opposing effects, while non-tenure track appointments have unbalanced effects for men compared to women students. The absence of age and student-faculty course specific data suggests caution in the interpretation of the latter results. However, the main findings should be of value to both public policy makers and university administrators.

Key Words: *Female faculty, female tenure, student graduation, university, stochastic frontier*

JEL Classification: *D2, I21, I22, I23, L3, C33*

1. Introduction

The gender composition of faculty employment in public higher education may carry increasingly important implications for the state funding of colleges and universities. That importance derives from the finding that increases in the percentage of female faculty leads to differences in student course selections and majors (Bettinger and Long, 2005) and to improvements in student academic performance and college grades for both men and women students (Sax, 2008). In turn, that can improve student graduation rates which serve as one measure of student outcomes being used by U.S. state governments as a focus for tying university funding to tax appropriated dollars.

The link of public university funding to student graduation success represents a major departure from enrollment based financing. The political driven interest in such restructuring has escalated since the onset of state government budget deficits imposed by the global financial crisis (Harnisch, 2011). For example, in the state of Florida, public university tuition increases beginning in 2013 will be regulated according to measures that include success in graduating students. The state of Michigan planned funding model is based on undergraduate degree completions. At least seventeen other states have used or plan on using performance based financing that relies on some measure of student academic success (Dougherty and Reddy, 2011).

In addition to deficit issues, financial reforms emanate from concerns about low graduation rates simultaneously accompanying public university rising tuition charges. For public institutions, the percent of students completing the bachelor's degree within four years is just above 30% (National Center for Education Statistics, 2012). After six years of enrollment, the graduation rate is 56%. Large variations exist across public institutions and can be due to differences in student college preparation and finances, university admission standards, and higher education funding. In addition, according to the above assertion, university graduation rates can be affected by the gender composition of faculty with higher rates accruing to institutions employing greater proportions of female faculty. However, to date, that contention does not appear to have been subjected to any rigorous empirical testing. That absence serves as the purpose of the present paper.

The approach employs stochastic frontier analysis to evaluate the technical efficiencies of publicly funded universities in producing student academic success. The success is measured by bachelor degree completion rates. A production frontier is estimated using panel data for 199 public colleges and universities engaged in producing undergraduate education and research and carrying a master level Carnegie classification. A university's graduation rate relative to their maximum feasible production frontier defines their level of efficiency. Distance from the frontier determines the level of efficiency or inefficiency and is estimated as being determined by a set of covariates defining the proportions of female faculty employed under different contractual arrangements associated with the tenure system. Thus, the refinement accounts for female employment in the ranks of tenured, tenure track, and non-tenure track positions. While the model controls for the gender composition of student enrollments, robustness is evaluated by estimating the production frontier and inefficiency effects for all students combined and separately for men and women student graduation rates. The next section of the paper provides a brief review of the literature followed by development of the empirical model, the data source, results, and a concluding section.

2. LITERATURE REVIEW

The focus of the present paper rests with empirical tests of the relationship between female faculty employment, their contract status and student higher education success as measured by college and university graduation rates. A literature search suggests that a rigorous evaluation of that relationship has yet to be undertaken. That is not to say, however, that gender and diversity effects in higher education have not been studied. The literature is replete with studies linking different educational outcomes to the diversity of both student bodies and faculty employment (e.g.,Gurin, et al., 2002, Hurtado, 2006, and Sax, 2008, and references therein). In addition, a large body of literature exists with respect to how same-gender student-faculty relationships affect student choices and course specific performance. For example, Robb and Robb (1999) find that faculty gender has no impact on male-female differences in economic course performances. On the other hand, Haley, et al. (2007) find that same-gender student-faculty arrangements produce a positive performance effect in statistics courses. Faculty gender effects on student choices are also a matter of interest and concern. That female students tend to avoid majoring in male dominated fields has been thoroughly explored (e.g., Hanson, 1996). In addition, evidence supports the notion that increases in female faculty increase the probability of female student's pursuit of advanced degrees (Rothstein, 1995). Statistical results presented by Bettinger and Long (2005) also support the theory that female faculty serve as role models for female students and positively influence both course selection and choice of major.

In another area of inquiry critical to the current paper, stochastic frontier analysis has been employed to evaluate the managerial and operating efficiencies of universities. While efficiency evaluation using stochastic frontier analysis has been applied to a wide variety of industries and institutions, studies pertaining to higher education have surfaced only recently and are, therefore, relatively new to the literature. Izadi, et al. (2002) provide efficiency estimates for a cross section of 99 British universities, while Stevens (2005) employs panel data for estimates of 80 English and Welsh universities. Johnes and Johnes (2009) do likewise in another English based study. McMillan and Chan (2009) evaluate operating efficiencies of Canadian institutions and Abbott and Doucouliagos (2009) examine both New Zealand and Australian universities. For U.S. higher education, Sav (2012a, 2012b, and 2012c) uses a longitudinal data set in providing stochastic efficiency estimates for doctoral research universities, faith related colleges, and private-for-profit colleges, respectively. The vast differences in data availability for these studies required equal differences in modeling assumptions and empirical specifications. And although the results are not directly comparable, suffice it here to report that technical efficiencies ranged from 0.37 to 0.99, thereby suggesting that universities operated at anywhere from 37% to 99% of potential output when output was measured in terms of either research or teaching but generally captured in institutional enrollments. None of the studies investigated the potential effects of female faculty and their contractual employment status on student academic success or the efficiency aspects of their employment on university graduation rates.

The literature related to the student-faculty gender effects and the literature arising from the efficiency capabilities offered by stochastic frontier analysis appear somewhat disjointed. And although the present paper cannot purport to fuse together these bodies of literature in addressing all of the associated nuances, it does offer an empirical approach and evidence that provide new insights into the effects of female participation and employment in higher education on student academic success. The next section provides the details of that empirical approach and model.

3. EMPIRICAL SPECIFICATION

The empirical model is based on a university production function in which output is the academic success of undergraduate students. The success is measured by their graduation. At the university level, the graduation rate serves as the overall measure of success and depends upon student and university inputs. Inputs include, for example, student academic preparation and finances and university size, support services, faculty, and the allocation of resources devoted to non-undergraduate education production. Given a fixed quantity of inputs, universities are constrained in terms of the graduation rate success that they can produce. Thus, there exits some maximum achievable graduation rate. However, in a given academic year, random shocks, e.g., due to natural disasters or union strikes, can affect university graduation rates. In addition, failure to attain maximum graduation levels can be due to poor managerial decision-making regarding the allocation of university resources or to certain characteristics of university inputs. When measured, this latter effect is regarded as the inefficiency with which universities operate. The present paper evaluates the extent to which these inefficiencies exist and might be attributed to the employment status of faculty with a focus on gender composition and contractual arrangements associated with the academic tenure system, all of which relate to university management.

Stochastic frontier analysis is the standard econometric method for estimating such production inefficiencies and has been widely applied to for-profit firms, non-profit organizations, and government agencies (e.g., see Kumbhakar and Lovell (2003) and Coelli, et al. (2005). Frontier analysis was developed independently by Aigner, et al. (1977) and Meeusen and van den Broeck (1977). Battese and Coelli (1995) advanced the panel data specification for evaluating inefficiencies due to environmental factors, as well as effects attributable to managerial, institutional, and input characteristics. While this inefficiency specification appears in studies of university operating efficiencies in the U.K. (Stevens, 2005) and the U.S. (Sav, 2012a, 2012b), it has not been applied in evaluating possible effects of female faculty and their tenure status on student academic success.

To investigate these inefficiency effects, the commonly used Cobb-Douglas function is proposed for the production frontier. The panel data specification is as follows:

$$\begin{aligned} \ln Graduation_{it} &= \alpha_0 + \alpha_1 \ln Aptitude_{it} + \alpha_2 \ln Retention_{it} + \alpha_3 \ln Grants_{it} \\ &+ \alpha_4 \ln Enrollment_{it} + \alpha_5 \ln Female_{it} + \alpha_6 \ln Services_{it} + \alpha_7 \ln Master_{it} + \alpha_8 \ln Research_{it} \\ &+ \alpha_9 \ln Faculty_{it} + \alpha_{10} \ln Salary_{it} + \alpha_{11} AcademicYear_{it} + (V_{it} - U_{it}) \end{aligned} \tag{1}$$

where for the *i*th university in the *t*th academic year, the baccalaureate graduation rate (Graduation) depends upon

Aptitude=student admission test score
Retention=student fall to fall semester return enrollment
Grants=student financial aid from low income government provided grants
Enrollment=undergraduate total enrollment
Female=proportion of undergraduate female student enrollment
Services=student service expenditures per undergraduate student
Master=graduate program total enrollment
Research=proportion of total expenditures allocated to research
Faculty=total faculty employment
Salary=faculty academic salary
AcademicYear=time trend (Hicks neutral technological change)
V=random variable independently and identically distributed, $N(0, \sigma_V^2)$

The *U* term in the composed error represents the university inefficiency effect in producing student graduations. It is greater than or equal to zero and assumed to be independently distributed as non-negative truncations of $N(m_{it}, \sigma_U^2)$, where *m* is the *Inefficiency* to be determined by a set of faculty employment characteristics as follows (see Coelli, et al., 1999, for a more general formulation):

$$\begin{aligned} Inefficiency_{it} &= \beta_0 + \beta_2 \ln FemaleTenure_{it} + \beta_3 FemaleTrack_{it} \\ &+ \beta_4 FemaleNonTrack_{it} + \beta_5 FemaleAdmin_{it} + \beta_6 AcademicYear_{itit} + Error'_{it} \end{aligned} \tag{2}$$

The inefficiency determinants are defined as

FemaleTenure=female percentage of tenured faculty
FemaleTrack=female percentage of tenure track faculty
FemaleNonTrack=female percentage of non-tenure track faculty
FemaleAdmin=female percentage of administrative faculty
Error'=random variable defined by the truncation of the normal distribution.

Maximum likelihood estimation is used for the full model. The composed error is $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and the proportion of inefficiency in the composed error, $\gamma = \sigma_V^2 / \sigma_U^2$, serves as a test as to whether the inefficiency effect (*U*) should be included in the specification of production. If inefficiency is statistically supported, then the overall technical efficiency score of the university is determined as

$$TechEff_{it} = \exp(-U_{it}) \tag{3}$$

Thus, increases in inefficiency lead to reductions in the overall technical efficiency of universities whereby $0 \le TechEff \le 1$.

Empirical estimation proceeds with an evaluation of the inefficiency effects on university graduation rates for all undergraduate students. Recognizing gender differences in graduation rates, the model is then estimated separately for male students and female students. In the separate estimates, it is assumed that there is no difference in the male-female aptitudes or in their financial wherewithal and, therefore, grant recipients. Unfortunately, the data do not permit gender distinctions with regard to retention, so it was necessary to assume that the same holds across male and female students. However, that weakness should not be critical given that part of the effect is captured in male-female graduation rate differentials. Of course, all of the university level production and inefficiency determinants remain intact for both male and female estimations.

4. PANEL DATA

Data pertaining to individual universities are drawn from the U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS). A balanced panel of 199 public universities is used for the four academic years 2005-09. The institutions are all Carnegie classified Master's Colleges and Universities and award at least 50 master's degrees annually. Research and doctoral classified universities are not included because of the complexity presented by their educational heterogeneity, including, for example, medical and professional school education, and the absence of refined data related to such production activities. Even in the present case, a number of institutions were excluded from the sample due to lack of reported data. In other cases, university specific data gaps were filled using cascade routines.

Table 1 presents the variable means and standard deviations along with the year to year annual percentage changes. The variables are the production and inefficiency measures presented in the previous section of the paper.

Table 1. Variable Means, Standard Deviations, and Annual Changes

Variable	*Mean*	*Std. Dev.*	*2006-07*	*2007-08*	*2008-09*
GraduationAll	44.53	12.80	0.62%	0.31%	1.57%
GraduationMen	39.38	13.23	0.53%	1.28%	2.51%
GraduationFemale	48.33	12.83	0.49%	-0.18%	1.02%
Aptitude	894.83	87.71	0.00%	0.44%	0.12%
Retention	72.95	8.15	0.01%	0.09%	1.78%
Grants	33.00	14.43	0.00%	0.00%	-0.49%
Enrollment	8758	5409	1.67%	1.72%	1.78%
Female	59.47	5.83	0.07%	-0.33%	1.05%
Services	1253	538	6.26%	12.69%	3.23%
Master	1593	1365	1.40%	3.12%	3.55%
Research	2.09	2.98	-0.36%	1.48%	-2.32%
Faculty	349	183	2.59%	1.91%	0.20%
Salary	64146	9754	3.73%	3.15%	1.49%
FemaleTenure	37.39	6.15	1.69%	2.06%	1.82%
FemaleTrack	49.24	7.92	0.07%	1.86%	1.36%
FemaleNonTrack	56.90	12.42	0.35%	2.37%	-0.18%
FemaleAdmin	15.51	16.33	1.88%	7.00%	-3.06%

In Table 1, the graduation rate obtained from the IPEDS is the student baccalaureate completion within 150% of the normal time to graduation. As indicated, there is a substantial difference in the male compared to female graduation rates with female rates being nearly ten percentage points higher than males. Male graduation rates, however, do show consistent improvements over the four year period. The student aptitude variable is based on the mathematical Scholastic Aptitude Test (SAT) score. In instances where the ACT was only available, a simple conversion was used to obtain an approximate SAT equivalency. Only slight aptitude improvement is evidenced over the four years. On average, approximately a third of students receive low income government grant aid. University undergraduate enrollments average around 8,700 students with nearly 60% being female. Total enrollments show a steady growth rate that remains somewhat below 2% per annum. The slowdown in public university expenditures on student services can be attributed to budgetary cuts that accompanied the financial crisis. That is also apparent in the university expenditure support for research which serves as an estimate of institutional research output and, therefore, the research focus of universities. The financial crisis also drove fairly large increases in graduate program enrollments as unemployed baccalaureate degree holders returned to higher education in pursuit of master degrees or other graduate training. On average universities employed approximately 350 faculty, but the growth in faculty employment did not keep pace with the growth in graduate program enrollments. For our sample, faculty salaries average just above $64,000 with steady declines in annual increases.

With regard to female faculty employment, Table 1 indicates that, on average, 37% of tenured faculty are female. In comparison, that is 20 percentage points below the percentage of university undergraduate female students. With 49% of tenure track faculty being female, that differential narrows to 10 percentage points. Females do dominate the non-track faculty positions and, on average, approach the proportion of female student enrollments. The estimate for female faculty employed in administrative positions is only 15%. Because of data limitation, that percentage is based on tenured female faculty holding twelve month contracts. There does appear to be a fairly steady increase in the proportion of tenured female faculty employed in both the tenured and tenure track statuses and a slight 2008-09 decline in the non-tenure track employment. Annual changes in female administrative employment show much greater variability.

5. RESULTS

Maximum likelihood estimates of the stochastic frontier model are presented in Table 2 and Table 3. Table 2 includes estimates for the production portion of the model while Table 3 provides the estimated inefficiency component. Estimates are provided for all university students and separately for men and women students as explained in the empirical specification section of the paper.

Table 2. University Maximum Likelihood Production Estimates

	Graduation All		Graduation Men		Graduation Female	
Variable	***Coefficient***	***t-value***	***Coefficient***	***t-value***	***Coefficient***	***t-value***
Constant	-2.121	**-2.17	-3.407	*-3.43	-0.759	-0.78
Aptitude	0.212	**2.19	0.471	*4.34	0.042	0.43
Retention	1.299	*18.56	1.317	*16.03	1.257	*18.79
Grants	-0.151	*-7.79	-0.186	*-8.13	-0.128	*-6.78
Enrollment	-0.157	*-6.02	-0.137	*-4.24	-0.166	*-6.23
Female	-0.143	**-2.37	-0.244	*-3.40	-0.207	*-3.32
Services	0.050	*3.51	0.048	*2.84	0.047	*3.39
Master	-0.013	-1.21	-0.015	-1.21	-0.013	-1.23
Research	-0.013	*-3.39	-0.017	*-3.51	-0.011	*-2.72
Faculty	0.177	*5.91	0.163	*4.44	0.177	*5.86
Salary	0.023	0.43	0.004	0.07	0.054	1.01
Year	-0.009	***-1.96	-0.003	-0.48	-0.012	***-1.68
LL	344.20		188.59		359.90	
LR	*138.06		*130.47		*135.32	

Note: significant levels at 1% (*), 5% (**), and 10% (***).

Across all estimates, the log likelihoods (LL) in Table 2 are relatively large and the likelihood ratios (LR) are all statistically significant at the 1% and better level of significance.

In Table 3, each model estimate indicates that gamma is significant at the same 1% and better level and that the proportion of inefficiency in the total variance is at least 0.93 regardless of the model specification. As a result, the stochastic model is statistically preferred over ordinary least squares without inefficiency effects.

Table 3. Maximum Likelihood Inefficiency Estimates

	Graduation All		Graduation Men		Graduation Female	
Variable	***Coefficient***	***t-value***	***Coefficient***	***t-value***	***Coefficient***	***t-value***
Constant	-9.713	*-3.75	-11.566	*-3.58	-9.782	*-3.63
FemaleTenure	2.590	*4.00	2.956	*3.91	2.555	*3.85
FemaleTrack	-0.152	*-2.70	-0.184	*-2.81	-0.105	**-2.04
FemaleNonTrack	-0.040	-0.96	0.127	1.39	-0.085	**-2.20
FemaleAdmin	0.124	*3.84	0.081	*3.05	0.166	*3.99
Year	-0.066	*-2.73	-0.072	**-2.13	-0.057	**-2.14
SigmaSq	0.174	*4.54	0.239	*4.61	0.176	*4.45
Gamma	0.940	*58.74	0.935	*63.54	0.938	*59.38

Note: significant levels at 1% (*), and 5% (**).

As indicated in Table 2, the majority of coefficients entering the production frontier is statistically significant at the 1% level and better. In addition, they carry the same sign in all three model estimations and have the expected effects on student graduation successes. That is, increases in student aptitudes (Aptitude) and fall to fall semester enrollment persistence (Retention) improve student graduation rates while increases in student enrollments based on low income federal grants (Grants) are estimated to negatively impact graduation rates. The latter students are more likely to face financial difficulties in educational continuance and may come from poorer secondary school districts that could face greater difficulty in preparing students for higher education success. Institutional size appears to matter in that increases in university total undergraduate enrollments (Enrollment) reduce graduation rates. That supports the conventional wisdom that smaller institutions are associated with smaller class sizes and can provide more individualized education and produce greater academic success. But unexpectedly, the results indicate that increases in the percentage of female undergraduate students (Female) have a negative effect on institutional graduation rates. That negative effect is also estimated to hold in the separate estimates for men and women students. Recalling that the mean female enrollment percentage is approximately 60%, the results might suggest a greater undergraduate gender diversity could improve graduation successes for both men and women students. However, it could be that a greater proportion of low-income grant recipients are female students. Clearly, however, any tests of such hypotheses necessitate a much different study with more refined data at the individual student level.

As expected, universities that spend more money on providing student services (Services) also produce greater rates of graduation success. However, increases in research and graduate education as measured by expenditures (Research) and student enrollments (Master) come at the expense of undergraduate graduation rates. The negative production effect associated with graduate education is, however, weak and can only be considered significant at the unreasonably low 23% level of significance. The estimates do support the notion that increases in faculty employment (Faculty) do improve student graduation rates. Interestingly, faculty salary (Salary) is, however, statistically insignificant. And finally, the negative coefficient for the AcademicYear indicates that graduation rate success has worsened over the four academic years under study. But the decline is only significant for women graduation rates.

The inefficiency results appear in Table 3. In the estimate for all students, four of the five determinants are significant at better than the 1% level. For the separate men estimates, the same four are significant but the AcademicYear coefficient is slightly weaker at the 5% level. For women, all five coefficients are declared significant with three of them falling to the 5% level. With the exception of the female percentage of tenure track faculty (FemaleTrack), the estimates are consistent in that the coefficients carry the same sign across all three models. Positive coefficients for increases in the percentages of females in the tenured ranks (FemaleTenure) and in the administrative category (FemaleAdmin) are associated with increases in production inefficiency. Of course, much caution is in order for the interpretation of the administrative category, i.e., it is based on the measure pertaining to a small group of female administrators that are proxied by those that are tenured and under twelve month contracts. As for the inefficiency effect due to the proportion of tenured females, some might wish to attribute that to productivity declines of older faculty, especially given that the number of professors aged 65 and over has more than doubled from 2000 to 2011 (June, 2012). That, however, would also apply to tenured male faculty. From the theory of the second best, Vogel (2009) argues that compulsory retirement should accompany the tenure system and that the 1994 end of mandatory retirement for tenured professors may have induced inefficiency. However, no empirical evidence has been offered in support of that contention. And in the present study, the absence of age data and quality of teaching or other productivity measures precludes any tests of such hypotheses.

In contrast, efficiency improvements are estimated to occur with the expansion of the proportion of female employment in tenure track positions (FemaleTrack). That efficiency effect is present in all three models and, interestingly, based on the size of the coefficient it is somewhat more powerful in improving the efficiency of producing graduation rates for men as compared to women. The appointment of females to non-tenure track positions (FemaleNonTrack) also improves production efficiency in the estimate for all students but does not reach any reasonable level of statistical significance. In the separate gender model estimates, the non-tenure track proportion of females (FemaleNonTrack) has unbalanced effects. The positive FemaleNonTrack coefficient in the production of graduation rates for men suggests a tendency toward inefficiency, although statistical significance would have to fall to approximately 15%. The opposite is true in the estimate for women; increases in FemaleNonTrack improve graduation rates among women students.

The AcademicYear coefficient is negative across all estimations in Table 3 and indicates that universities have managed to improve the efficiency with which they produce graduation rates over the four year period. In this sense, the overall technical efficiencies of universities are of interest and are summarized in Table 4.

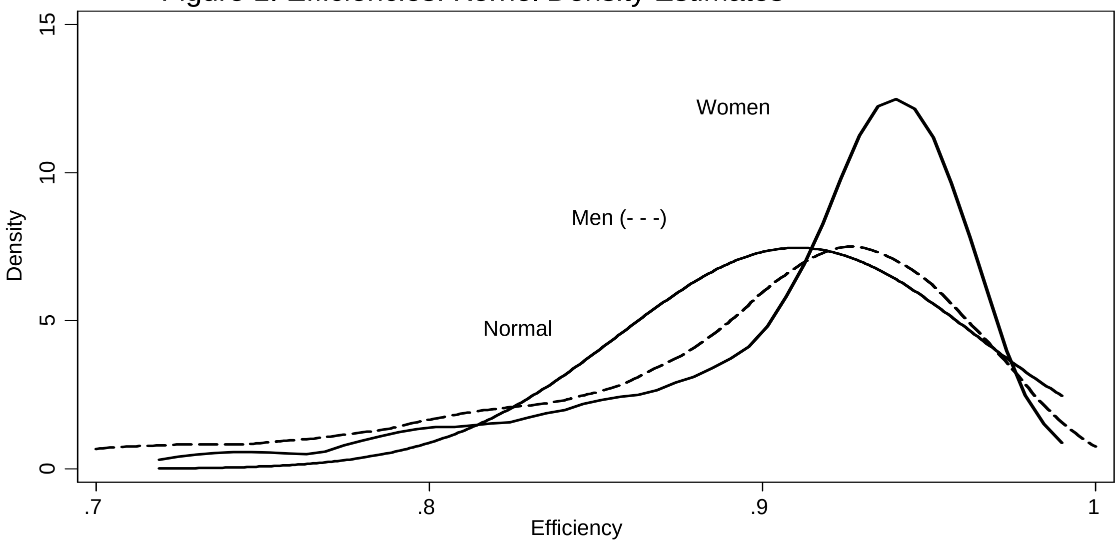
Table 4. University Technical Efficiencies

	All	***Men***	***Women***
Mean	0.880	0.857	0.887
Median	0.912	0.895	0.917
Minimum	0.453	0.264	0.403
Maximum	0.977	0.979	0.977
Std, Dev.	0.091	0.104	0.087
Skewness	-2.13	-1.97	-2.35
Mean Annual Changes			
	2006-07	***2007-08***	***2008-09***
All	0.94%	-0.50%	0.32%
Men	0.33%	-0.47%	1.01%
Women	1.05%	-0.62%	0.13%

As shown in Table 4, the mean efficiency for the production of graduation rates for all students combined indicates that universities are highly efficient in producing at 88% of their maximum, i.e., the production of graduation rates with inefficiency present relative to that which could be achieved in the absence of inefficiency. An approximately 3.5% mean efficiency differential goes in favor of graduating women compared to men students, while the median difference is somewhat less at 2.5%. In addition, the minimum university efficiency score for graduating men is nearly 14 points lower than that for women.

An overall picture of the gender efficiency differences using kernel densities is presented in Figure 1; for expositional purposes the efficiency scores are truncated at 70%. The normal density is presented for comparison. The negative skewness in graduation related efficiencies for both men and women is apparent. Moreover, the greater density in the distribution for graduating women relative to men occurs at about a 0.94 level of efficiency. At lower efficiencies, the density associated with men graduations is marginally greater.

Figure 1. Efficiencies: Kernel Density Estimates



So as to examine some of the efficiency dynamics, mean annual percentage changes in efficiencies are calculated and shown in the bottom panel of Table 4. As noted, efficiency improvements occurred in 2006-07 and were more than three times stronger for women graduation compared to men. All universities, however, suffered efficiency regress for both men and women graduations in the 2007-08 academic year. That was followed by a 2008-09 substantial efficiency rebound in graduating men students.

6. Conclusions

This paper employed stochastic frontier analysis to evaluate the efficiency effects of increased female faculty employment on student academic success as measured by graduation rates in U.S. publicly owned colleges and universities. The empirical results suggest that there are efficiency gains to be realized by increasing the proportion of female faculty employment in tenure track positions. Those gains were found to apply to the graduation rates for both men and women students. Moreover, the estimates indicate a somewhat more powerful efficiency gain in producing graduation rates for men. The results carry important managerial implications for university hiring decisions as their state governing boards increasingly move to base tax appropriated funding on the graduation successes of their publicly run colleges and universities.

Empirical results for inefficiencies associated with female employment in non-tenure track positions were unbalanced for men and women students. The findings indicate efficiency gains for female student graduations but inefficiencies for men students. Thus, on the one hand, the managerial implications suggest that university administrators reverse current hiring trends and reallocate faculty positions from non-tenure track appointments to tenure track positions. To improve female graduation rate outcomes that reallocation should, according to the present estimates, be focused on decreasing the proportion of female non-tenure track faculty while increasing their percentage employment in tenure track positions. On the other hand, that will produce inefficiencies in attempting to improve male graduation rates. It is likely that the overall efficiency effects would depend upon female employment in specific disciplines. Unfortunately the present data did not permit discipline based efficiency estimates. However, the inefficiency effect uncovered for female tenured professors might raise administrative concerns as new appointments to tenure track positions eventually achieve tenure status. Yet, the analysis offers caution in interpreting those results. Most importantly, the data did not permit any productivity estimates based on faculty ages but reports indicate that professors age 65 and over has doubled in the past decade. In addition, to what extent there has been delayed retirement exacerbated by market forces brought about by the financial crisis is unknown for the present study. Thus, any effects due to those forces could not be incorporated into the present efficiency effects.

Efficiency results are, of course, based on controlling for the inputs directly entering the production frontier for university graduation rates. On that account, the results do support the notion that student aptitudes, academic persistence, and university expenditures on student support services improve graduation rates, while low income student grants and increases in university size as measured by student enrollments tend to adversely affect graduation rates. Evidence also suggested that increases in focusing on research and graduate education can negatively impact undergraduate academic successes, although the later effect was not statistically significant. But the results suggest that some thought might be given to greater specialization in higher education so that all colleges and universities need not attempt to produce all products. Overall, however, the technical efficiencies of universities was found to range between 45% and 98%. And although other stochastic efficiency studies of universities do not evaluate female faculty participation in producing student graduations, that efficiency compares favorably to the 37% to 99% range of efficiencies reported for British (Stevens, 2005), Canadian (McMillan and Chan, 2009), and Australian (Abbott and Doucouliagos, 2009) universities.

It is believed that the paper is the first to evaluate female employment and tenure status effects on university student graduation rates. The results, however, should be interpreted with caution. They are highly dependent on the reporting accuracy of universities. As noted, due to lack of reporting detail, institutions had to be excluded from the analysis. In other cases, it was necessary to contend with some instances of missing data. The quality of the data also comes into play. There is no data at the present level of analysis that allows measures of teaching quality to be incorporated into the effects on student academic successes. In addition, while separate graduation estimates were produced for men vs. women students, the data did not allow for race and ethnicity distinctions. Equally important is the absence of that diversity as it pertains to faculty employment. While data quality issues are not likely to be resolved in the very near future, a valuable path for more immediate research should include a focus on possible effects related to how student-faculty race and ethnicity relationships affect student graduation outcomes. With the increasing diversity of student enrollments, that research should be a matter of importance to both public higher education funding agencies and university management.

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