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Measuring Baumol and Bowen Effects in Public Research Universities

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Abstract

We estimate three models of cost per student using data from Carnegie I and II public research universities. There are 841 usable observations covering the period from 1987 to 2008. We find that staffing ratios are individually and collectively significant in each model. Further, we find evidence that shared governance lowers cost and that the optimal staffing ratio is approximately three tenure track faculty members for every one full time administrator. Costs are higher if the ratio is higher or lower than three to one. As of 2008 the number of full time administrators is almost double the number of tenure track faculty. Using the differential method and the coefficients estimated in the three models, we deconstruct the real cost changes per student between 1987 and 2008 into Baumol and Bowen effects. This analysis reveals that for every $1 in Baumol cost effects there are over $2 in Bowen cost effects. Taken together, these results suggest two thirds of the real cost changes between 1987 and 2008 are due to weak shared governance and serious agency problems among administrators and boards.

1. Introduction

Over the past three decades, increasing college costs[1], declining undergraduate value added[2], and ballooning student loans[3] became important public policy concerns and these concerns are made more acute by federal/state deficits, looming entitlement deficits, and seriously underfunded public pension obligations. Controlling college cost is now a priority. "Baumol's cost disease[4]" and "Bowen's Rule[5]" are the most prominent theories of higher education cost. Baumol's cost disease argues costs rise due to external macroeconomic forces, while Bowen's rule claims costs increase are due to decisions taken inside higher education.

Baumol's cost disease refers to the disproportionate tendency of costs to rise in labor-intensive service industries. Increasing productivity in the macro-economy raises real wages and those wages draw productive workers from service industries forcing those industries to raise wages even though productivity has not increased. The combination of fixed productivity and higher wages must lead to higher costs. Higher education insiders frequently argue this is the source of higher education's chronic cost problem (Baumol and Batey-Blackman, 1995).

Bowen's rule[6] states colleges raise all the money they can and then spend it on an unlimited list of projects that seemingly enhance "quality." Essentially, the rule says revenues drive costs. The components of Bowen's rule are break-even non-profit budgeting, the peculiar economics of experience goods, and unresolved agency problems. Agency problems imply staff/student ratios are flexible on the upside (declining productivity), rather than fixed as is implied by Baumol's cost disease.

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[1] See Martin (2011) or Massy (2003), among others.

[2] See Bok (2005), Hersch and Merrow (2005) or Arum and Roksa (2011).

[3] See FRBNY (2012) and Parsons and Hennessey (2012).

[4] See Baumol and Bowen, W G, (1966).

[5] See Bowen, H R, (1980).

[6] The rule is derived from Bowen's five laws: 1) "The dominant goals of institutions are educational excellence, prestige, and influence;" 2) "there is virtually no limit to the amount of money an institution could spend for seemingly fruitful educational ends;" 3) "each institution raises all the money it can;" 4) "each institution spends all it raises;" and 5) "the cumulative effect of the preceding four laws is toward ever increasing expenditure" (Bowen, 1980, 19-20).

Furthermore, anything that increases a student's ability to pay (increases in parental wealth, more generous public/private financial aid, more access to credit, etc.) increases revenues and higher revenue increases spending, as there is never a shortage of investments that would make the college "better." Thus, costs will rise whenever more revenue allows it and attempts to promote access by subsidizing students are undone by a higher net cost of attendance[7].

Both theories have sound economic foundations, so we expect each contributes to rising cost. Therefore, the issue is an empirical question: Which theory has the larger impact on higher education costs? Our goal is to deconstruct real cost changes from 1987 to 2008 into Baumol effects (outside factors) and Bowen effects (internal decisions). Since reform depends on the answer to this empirical question, this is an important policy issue.

In the next section we review the traditional estimation of education cost functions and argue cost models without controls for staffing patterns suffer from omitted variable problems; that is, Bowen's theory suggests staffing patterns should be included in higher education cost equations. The data are reviewed in the third section and the governance hypothesis is explained in the fourth section. The governance hypothesis holds that effective shared governance lowers higher education costs, while the withering away of shared governance increases cost[8]. Three models are presented and estimated in sections five and six, where the significance of staffing patterns is demonstrated, the governance hypothesis is tested, and other results are reported. In section seven, we deconstruct the actual changes in cost per student from 1987 to 2008 into Baumol and Bowen effects. We find that Bowen effects are larger than Baumol effects and that for every $1 in increased cost due to Baumol effects there are between $2 and $3 in increased cost associated with Bowen effects.

2. Estimating Higher Education Cost Functions.

Traditionally higher education cost studies assume either costs are minimized (Cohn, et al., 1989) (Cohn, et al., 2004) (Johnes, et al., 2008) (Johnes, et al., 2009) or costs are not minimized (Newhouse, 1970) (James, 1978) (Brinkman, 1989, 1990) (Clotfelter, et al., 1991) (Ehrenberg, 2000). If costs are in fact minimized, the duality conditions allow one to uncover properties of the production function from

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[7] Bennett (1987) Martin and Gillen (2011a).

[8] See Ginsberg (2011).

the estimated parameters and the only data required are cost, output, and input prices (Mas-Colell, Whinston, and Green, 1995, 139-143). Staffing pattern observations would not be needed.

In "for profit" industries, cost minimization is a reasonable assumption, since cost minimization is a necessary condition for profit maximization. In a non-profit environment, however, it does not necessarily follow that costs are minimized.

Bowen's rule is based on break-even budgeting, complex experience goods, shared governance, and unresolved agency problems (Martin, 2011). The break-even constraint leads to competition among agents for a fixed quantity of funds during each budget cycle. If agents collude to maximize rents and then distribute those rents there would be little conceptual difference between profit maximization and rent maximization, costs would be minimized, and the duality conditions would hold[9]. This is not what happens, however; rent seeking behavior in higher education leads agents to take rents in the form of higher expenditures within the areas they control. Therefore, rents are mixed with legitimate expenditures and this makes economic costs indistinguishable from rents[10].

If rents are liberally mixed with economic costs, cost studies cannot reliably reveal characteristics of the underlying production technology. For example, when costs and rents are mixed, returns to scale may not be revealed by the relationship between cost per unit and output. The returns to scale may be there, but the rents obscure the results.

When rents are taken as expenditures, the cost allocation depends on the relative number and importance of the agents in the organization. Costs cannot be unpacked unless one examines staffing patterns. Hence, an empirical cost function that contains only output and input prices has serious omitted variables problems. Specifically, the cost model should control for staffing patterns across different constituencies in the institution. Alternatively, if higher education costs are minimized, the cost function should be independent of staffing patterns. As we find, the staffing variables are individually and collectively significant in the estimated cost functions.

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[9] It would be impossible to pursue such an agency agenda, since rent distribution would leave an obvious audit trail. Mixing legitimate expenditures with rents makes it very difficult for the principal to monitor the agents' behavior.

[10] By contrast, rents are separated from costs by for-profit accounting.

3. Data

The data are drawn from the National Center for Education Statistics' IPEDs website, it covers 137 Carnegie[11] I and II public research universities, for the academic years 1987, 1989, 1991, 1999, 2005, and 2008. There are 841 usable observations in the estimating sample[12]. Our objective is to explain variations in costs between public research universities and across the time period studied; in general, these costs will be driven by decisions taken by each institution regarding academic and overhead staffing patterns, salaries paid, the nature of the undergraduate/graduate programs offered, and the size and composition of the institution's enrollment. Costs are also thought to be influenced by locations, both urban/rural and regional, Carnegie classification, and the emphasis placed on different types of graduate programs.

The cost[13] variables are real total cost per student (*tc*), real academic cost per student (*ac*) and real overhead cost per student (*oh*). Academic costs[14] include instruction, research, and public service; while overhead costs include all costs from academic support, student services, institutional support, plant operation/maintenance, auxiliary activities, hospitals, and independent operations. Enrollment is

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[11] Carnegie I is classified as "very high research activity" and Carnegie II is "high research activity." There are 146 institutions in this classification. However, usable information was available for only 137 institutions.

[12] There are two data samples in this study. The first is the estimating sample which contains 137 institutions and 841 usable observations for the period studied. This sample is used in the estimation of the cost equations. The second sample is the cost analysis sample which contains 134 institutions and 812 usable observations. The cost analysis sample is smaller than the estimating sample because the partial differential method for deconstructing the cost changes requires that for each 1987 observation there must be a matching 2008 observation. Only 134 institutions provided usable data in both years.

[13] Between 1987 and 2008 these institutions adopted significant accounting changes. These changes make it difficult to get consistent time series data on cost. The most consistent total cost series are "total current funds expenditures and transfers total" for 1987 and "total operating expenses – Current year total" for 2008. Using "total educational and general expenditures and transfers total" for 1987 tends to significantly understate the overhead cost in 1987, leading to an overstatement of the total change in overhead spending from 1987 to 2008.

[14] Some researchers claim student service cost should be included in academic costs. Student service staffing expanded rapidly from 1987 to 2008 and student service professionals claim it is their responsibility to take over "instruction outside the classroom." The nature of these activities and the academic qualifications of student service personnel make this notion arguable at least. What is clear is that the inclusion of student service in academic cost will significantly understate the growth in overhead if it is included in academic cost.

measured by FTE students (*ftestu*), the number of full time undergraduate students (*ftug*), the number of full time graduate[15] students (*ftgrad*), and the number of part time students (*ptstu*).

Faculty staffing is measured by the number of tenure track faculty per 100 students (*tt*), the number of contract faculty per 100 students (*cf*), the number of part time faculty per 100 students (*ptf*), the number of FTE faculty per 100 students (*ftef*), the number of teaching assistants per 100 students (*ta*), and the ratio of tenure track faculty to full time non-academic professional employees (*ttad*). FTE staff salaries are the total salaries and wages paid divided by the number of FTE staff employed (*staffsal*). Full time employee benefits are measured by total benefits paid divided by full time staff members (*benstaff*).

Non-instructional staffing is measured by the number of FTE executive/managerial employees per 100 students (*fteex*), the number of other FTE professional employees per 100 students (*ftepro*), and the number of FTE non-professional employees per 100 students (*ftenpro*). The composite variable, *fteadmin*, is the number of FTE executive and professional employees per 100 students. The average number of "reports" per executive is measured by the sum of all FTE professional administrators and all FTE nonprofessional staff divided by the number of FTE executives/managers (*staffsize*). Part time staff employment is measured by the number of part time administrators per 100 students (*ptadmin*), and the number of part time non-professional staff per 100 students (*ptnpro*).

Carnegie I research institutions are identified by the dichotomous variable *carnegie*, institutions that emphasize the STEM[16] disciplines are identified by *stem*, institutions with medical schools or veterinary schools are identified by *medical*, and institutions that emphasize professional schools are identified by the variable *prof*. The dichotomous variables for different geographic regions are the far west coast (*fwest*), New England[17] (*neweng*), and the Great Lakes (*glakes*).

A summary of the changes in the cost analysis sample[18] between 1987 and 2008 is contained in Table 1. All dollar denominated variables are in real terms. The average values are weighted[19] by

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[15] The number of graduate students includes graduate and professional students as well.

[16] STEM means science, technology, and mathematics.

[17] This variable includes both the New England states and the mid-Eastern states.

[18] See footnote 11.

[19] The weight is the fraction of the institutions share of total enrollment for that year.

enrollment and they reveal that academic cost per student increased by 36 percent from 1987 to 2008, overhead cost per student increased by 57 percent, and total cost increased by 47 percent over the same period. Total cost per student increased by $13,360 and 62 percent of that increase is accounted for by rising overhead costs. Academic activities share of the total budget declined slightly from 49 percent to 48 percent.

Average enrollment increased by 30 percent, the number of full time undergraduate students increased by 27 percent, the number of full time graduate students increased by 40 percent, and the number of part time students declined by 14 percent. Overall, these institutions increased in size, became more graduate intensive and less dependent on part time students.

The number of FTE faculty per 100 students increased by 14 percent, tenure track faculty increased by 3 percent, and part time faculty increased by 60 percent. The contract faculty ratio increased by 25 percent. Since the tenure track ratio was almost constant while the contract faculty ratio and the part time ratio increased substantially, these institutions invested more intensively in contract and part time faculty during this period.

Full professor salaries increased by 18 percent from 1987 to 2008; this represents an average annual rate of increase of 0.9 percent. Similarly, over the same period assistant professor salaries increased at an average annual rate of 0.7 percent. In contrast, average FTE staff salaries increased by 41 percent, an average annual rate of increase of 2 percent and more than double the rate of increase in full professor salaries. Benefit costs (*benstaff*) increased by 96 percent.

For salary comparisons, median household income increased by 6.5 percent from 1987 to 2008. In 1987, the upper income limit for the third quintile in the income distribution was $57,798, less than the average assistant professor salary of $59,343. Assistant professors were in the fourth quintile in 1987 and their salary was equal to 68 percent of the upper bound for the fourth quintile. The average assistant professor salary remained at 68 percent of the upper bound in 2008. The average full professor salary was in the top income quintile in 1987 and was 108 percent of the upper bound for the fourth quintile. In 2008, the average full professor salary was 112 percent of the upper bound for the fourth quintile. The BLS Employment Cost Index (BLS, 2012) for service industries increased by 116 percent from 1987 to 2008, in line with the increase in *benstaff*.

The staffing patterns for non-instructional staff are rather different than the academic staffing patterns. FTE executive/managerial staff per 100 students increased by 9 percent, FTE professional staff per 100 students increased by 57 percent, and FTE non-professional staff per 100 students declined by

28 percent. The staff size variable increased by 6 percent, reflecting an increase in the number of "reports" per executive (each executive's professional staff tended to get larger). Since the number of non-professional staff declined, there was a significant increase in the size of each executive/manager's professional staff.

Part of the decline in non-professional staffing is due to technology that reduced the need for clerical support staff. However, there were also persistent declines in technical, skilled, and service/maintenance staff ratios.

4. The Governance Hypothesis

The foregoing data reveals a persistent investment in overhead activities while resources were withdrawn from non-professional staff activities and the institutions economized on teaching resources by using contract teaching and part time faculty more intensively. Furthermore, the staffing patterns among Carnegie I and II private research universities, private liberal arts colleges, and public masters level universities are remarkably similar to the staffing patterns reported here (Martin, 2012).

Since agency problems always result in costs higher than necessary, higher education's cost record is the agency problem's latent print. The natural constraints on agency abuse in corporations and in politics are the market for corporate control and elections; the shared part of shared governance is the only natural constraint on agency abuse in higher education. Hence, the question is: does the chronic cost problem represent a generic governance failure or is it due to the "shared" part of shared governance?

This suggests two competing *governance hypotheses*. The *anti-shared governance hypothesis* holds that powerful tenure track faculties prevent costs from being controlled. If true, cost and quality would improve as shared governance is replaced by a more hierarchal governance structure. The *pro-shared governance hypothesis* argues the absence of natural checks[20] on agency abuse makes the "shared" part of shared governance an important constraint. Benjamin Ginsberg's (2011) cautionary tale about "the rise of the all-administrative university" is consistent with the pro-shared governance hypothesis.

[20] Beyond the absence of mechanisms similar to markets for control and elections, higher education is subjected to little federal regulation of agency issues, there are no third party groups with a financial interest in monitoring higher education, the press has little appetite for HE agency stories, and the public believes they have charitable motives since they are non-profits.

An implication of the pro-shared governance hypothesis is an imbalance in agent control among tenure track faculty, administrators, or governing boards is revealed by inefficient expenditures in favored activities. The shifts in staffing patterns observed in our sample are consistent with an imbalance towards administrators. An interesting corollary is whether an optimal staffing mix exists, one that minimizes the agency problem? If so, deviations from that optimal would cause costs to rise; that is if shared governance is an effective constraint on agency abuse, costs should be a convex function of the metric for agency control. An imbalance in any direction would lead to costs that are higher than necessary.

Generally, the outcome will depend on the relative size and influence of each constituent group. Since part time employees and non-professional employees have little influence on resource decisions, their preferences are unlikely to be decisive. The most influential agents are tenure track faculty and full time professional administrators. In 1987 the ratio of tenure track faculty to full time administrators stood at 0.96; by 2008 that ratio fell to 0.56 at the public research institutions in our sample. Today tenure track faculty members are significantly outnumbered by administrators. The decline in *ttad* occurred steadily over the period from 1987 to 2008. The ratio of tenure track faculty to full time professional administrators (*ttad*) is a natural metric for the relative bargaining strength between academic interests and overhead interests in the annual budget cycles. Furthermore, if *ttad* is a reliable metric for the efficacy of shared governance, cost should be a convex function of *ttad*; that is, an optimal ratio should exist.

In the following section we estimate three models. The first two are reduced form equations where the dependent variables are academic cost per student (*ac*) and overhead cost per student (*oh*). The third is a single equation model for total cost (*tc*) containing the same variables as the reduced form equations. We test the governance hypothesis in each model. The models reveal costs decrease as *ttad* increases and that costs are convex in *ttad*. The evidence suggests costs are lower the higher is *ttad* until a critical value is reached and costs begin to rise again if *ttad* increases further. These results are robust to specification, estimation method, and hold if the model is run separately on Carnegie I or Carnegie II institutions.

5. Model Specifications

Academic cost per student (*ac*) and overhead cost per student (*oh*) are jointly determined. Assuming ideal data conditions, the number of professional and non-professional employees employed in academic activities and in overhead activities, along with their average salaries, would be identified. Were this the case, identification of *ac* and *oh* would be achieved by excluding the academic staffing ratios and their average salaries from the overhead equation and excluding the overhead staffing ratios and their average salaries from the academic equation. Unfortunately, this level of detail about professional and nonprofessional employees does not exist, so we did not estimate the structural equations.[21]

Our primary objective in this paper is to deconstruct total cost per student into Baumol and Bowen effects for the period from 1987 to 2008. This is equivalent to "forecasting" within the sample experience. Hence, the reduced form equations are the equations of interest for this purpose.

For academic cost (*ac*), overhead cost (*oh*) and total cost (*tc*) we specify the log-linear regressions

$$\ln\left(ac_{it}\right) = \beta'_{ac} x_{ac,it} + \alpha_{ac,i} + u_{ac,it}$$

$$\ln\left(oh_{it}\right) = \beta'_{oh} x_{oh,it} + \alpha_{oh,i} + u_{oh,it}$$

$$\ln\left(tc_{it}\right) = \beta'_{tc} x_{tc,it} + \alpha_{tc,i} + u_{tc,it}$$

where $\alpha_{ac,i}$, $\alpha_{oh,i}$ and $\alpha_{tc,i}$ are fixed effects, with $i = 1,\ldots,n$ and $t = 1,\ldots,T_i$. We estimate these reduced form equations using fixed effects[22] for logarithms of academic costs (*ac*) and overhead costs (*oh*), and the regression for total cost (*tc*). For academic costs, overhead costs, and total cost we then employ the partial differential approach to quantify the Baumol and Bowen effects in the next section.

In the equations, the omitted faculty staffing ratio is the tenure track/student ratio; hence, the interpretation is holding *ftef* constant an increase in *cf* or *ptf* represents a substitution for a corresponding number of tenure track faculty. The expectation is the signs of *cf* and *ptf* should be negative, since they

[21] The data regarding faculty by rank, gender, and race, as well as average salaries by each partition is complete. The data regarding nonacademic staffing is sparse. Academic support staff members are not separated from nonacademic staff and salaries are not reported. A second best strategy is to attempt to identify the system by excluding all the faculty staffing ratios from the overhead equation and excluding all the professional and nonprofessional staffing ratios from the academic equation. Unfortunately tests of the validity of the over identifying restrictions showed the specification to be very delicate with respect to instrument choice.

[22] Using the Hausman contrast test, and the regression based "Mundlak" version, we reject the null hypothesis that the random effects are uncorrelated with the regressor, and conclude that the random effects estimator is inconsistent. See Wooldridge (2010, pp. 328-332).

are a lower cost alternative to tenure track faculty. Similarly, holding *cf* and *ptf* constant an increase in *ftef* represents an increase in tenure track faculty. Therefore, the sign of *ftef* should be positive.

The omitted administrator staffing ratio is the full time administrator/student ratio. Hence, holding *fteadmin* constant, an increase in *ptadmin* represents a substitution of part time employees for full time employees, suggesting the coefficient should be negative since part time employees do not receive benefits. The same interpretation applies to the inclusion of *ftenpro* and *ptnpro*. The coefficient for *ptnpro* should be negative. The variable *staffsize* is a metric for overhead staff sizes, suggesting its coefficient should be positive.

As discussed, the ratio of tenure track faculty to full time administrators, *ttad*, is intended to measure the impact of shared governance on cost. If the anti-shared governance hypothesis is correct, the sign of *ttad* should be positive: more tenure track faculty relative to administrators should drive costs higher. If the pro-shared governance hypothesis is correct, the sign of *ttad* should be negative and if an optimal ratio exists, cost should be a convex function of *ttad*.

Scale effects are measured by *ftestu.* The mix between undergraduate and graduate programs is controlled for by *ftgrad, ftestu,* and *ptstu;* holding *ftestu* and *ptstu* constant an increase in *ftgrad* represents a substitution of one full time graduate student for one full time undergraduate student. Other things equal an increase in *ftgrad* represents an increase in graduate intensity and it should increase costs. Holding *ftgrad* and *ptstu* constant, an increase in *ftestu* should reduce costs due to both scale effects and program mix effects. The variable *ta* is the number of teaching/research assistants per 100 students; hence, it is a control for the intensity of PhD programs on campus. A large *ta* ratio suggests numerous PhD programs; hence, we expect academic costs to rise as *ta* increases.

6. Estimation Results.

Results using fixed effects estimation for the academic cost equation are contained in the first column of Table 2[23]. The variables *cf, ptf, ftef, ttad, ttad2* (*ttad* squared)*, staffsal*, *ftenpro*, *d1999*, *d2005*, *d2008*, and the constant are significant at the 0.01 level or better. The signs are as anticipated. As expected, *cf* and *ptf* are lower cost substitutes for tenure track faculty and *ftef* is a proxy for more tenure track faculty.

[23] Fixed effects estimates obtained using XTREG, FE in Stata 12.1. Standard errors are based on a cluster corrected covariance matrix, which is used because some significant serial correlation remains even with year dummies. Some details are presented in the Appendix.

Also as expected, academic costs decline as *ftestu and ptstu* increase, although they are not significant. The signs of *ftgrad* and *ta* are positive, but insignificant.

As anticipated, academic costs are a convex function of *ttad.* The coefficient values imply academic costs are minimized at a 2.6 ratio for tenure track to full time administrators. The 95% interval estimate for the minimizing value is [2.02, 3.24]. The elasticity of academic costs with respect to *ttad* at the 25th , 50th, and 75th percentiles of *ttad* are −0.098, with 95% interval estimate [−0.137, −0.060], −0.126, with interval [−0.175, −0.077] and −0.148, with interval [−0.206, −0.089]. As *ttad* gets larger the tenure track faculty's influence on cost progressively offsets the administrative influence on cost, which is exactly what the balance of political influence would suggest. The coefficients of *ttad* and *ttad2* are jointly significant at the 0.01 level. The coefficients of the other staffing variables, *cf*, *ptf*, *ta*, *ftef*, *fteadmin*, *ptadmin*, *ftenpro*, *ptnpro*, and *staffsize*, are also jointly significant at the 0.01 level.

The results for the overhead cost equation are contained in the second column in Table 2. The variables *cf, ftef, ttad, ttad2, staffsal, ftenpro* and *d2008* are significant at the 0.01 or better level. The signs are as anticipated. At the 0.05 or better level, the variables *ptf* and *d1999* are significant. The sign for *ptadmin* is significant at the 0.10 level and contrary to what was anticipated. This suggests part time administrators are not a lower cost substitute for full time administrators. While not significant, the signs of *ftestu*, *ftgrad*, and *ptstu* are as anticipated.

The signs and significance of *ttad* and *ttad2* are consistent with the pro-shared governance hypothesis and inconsistent with the anti-shared governance hypothesis. The coefficient values suggest overhead costs are minimized at a 3.4 ratio of tenure track faculty to full time professional administrators, the 95% interval estimate being [2.62, 4.10]. The elasticity of overhead cost with respect to *ttad* at the 25th, 50th, and 75th percentiles of *ttad* are −0.151, −0.199 and −0.244.[24] Again the joint tests of the staffing variables show them to be significant at the 0.01 level.

The total cost model estimation results are reported in the third column of Table 2. The variables *cf, ptf, ftef, ftestu, ttad, ttad2, staffsal, ftenpro*, *staffsize, d1999, d2005,*and *d2008* are all significant at the 0.01 or better level and have the anticipated signs.

The signs for *ttad* and *ttad2* suggest total cost is convex in *ttad* with estimated turning point at 3.1 with 95% interval estimate [2.73, 3.40]. The implied optimal ratio is consistent with the estimates from models 1 and 2. The elasticity's of total cost at the quintiles of *ttad* are −0.098, −0.126 and −0.148,

[24] The 95% interval estimates are [−0.222, −0.081], [−0.290, −0.107] and [−0.354, −0.134], respectively.

respectively.[25] The anti-shared governance hypothesis is rejected in all models, while the pro-shared governance hypothesis is found to be consistent with the data provided. These results are robust to both the estimation method used and Carnegie classification.[26]

7. Cost Analysis

Among the 134 institutions in the cost analysis sample academic costs increased by $5,049 from 1987 to 2008, while expenditure for overhead increased by $8,311. Total cost per student increased by $13,360. The purpose of this section is to deconstruct these changes into Baumol and Bowen effects. We use the reduced form equations for academic costs and overhead costs, and the single equation model for total cost, along with their partial differentials, to estimate the different types of cost drivers.

The cost deconstruction for different effects is then the partial differential for each of the 134 institutions using the models estimated coefficients, the change in independent variables, and the predicted cost for 1987. A weighted average value for the partial differential estimates is created using 1987 enrollment as the weights. Hence, the estimated cost effects are "forecasts" within the sample experience, since all changes in the independent variables are known and drawn from the sample.

For simplicity denote academic cost (*ac*), overhead cost (*oh*), or total cost (*tc*) by *y*, then the log-linear specification implies the expectation

$$E\left(y_{it}\right)=\exp\left(\beta' x_{it}+\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]=\exp\left(\beta' x_{it}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]$$

The predicted value should incorporate an estimate of $E\left[\exp\left(u_{it}\right)\right]$. We use the sample average of the least squares residuals $N^{-1}\sum_i\sum_t \exp\left(\hat{u}_{it}\right)$ where N = 841 is the total number of sample observations. Thus for each equation the predicted y_{it} is

$$\hat{y}_{it}=\exp\left(\hat{\beta}' x_{it}\right)\exp\left(\hat{\alpha}_i\right)\left\{N^{-1}\sum_i\sum_t \exp\left(\hat{u}_{it}\right)\right\}$$

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[25] The 95% interval estimates are [−0.137, −0.060], [−0.175, −0.077] and [−0.206, −0.089], respectively

[26] The models were estimated using OLS, random effects, and fixed effects; in each case the coefficients were significant and cost was a convex function of *ttad*. These results are reported in the Appendix.

The total differential of $E\left(y_{it}\right)$ is

$$dE\left(y_{it}\right)=\exp\left(\beta' x_{it}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]\left(\beta' dx_{it}\right)$$

For each university *i*, let

$$dy_i=\exp\left(\beta' x_{i,1987}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]\left(\beta' dx_i\right)$$

where $x_{i,1987}$ are regressor values in the base year 1987, and $dx_i = x_{i,2008} - x_{i,1987}$. While our panel is unbalanced we have matching observations for 1987 and 2008.

Rather than the total differential we calculate partial differentials using subsets of the regressor differential dx_i by setting some of its elements to zero. The sum of the (partial) differentials is weighted by 1987 FTE student enrollment. Define

$$w_i = FTESTU_{i,1987} \Big/ \left(\sum_{i=1}^{134} FTESTU_{i,1987}\right)$$

Then

$$dy_i = g\left(\beta\right)=\sum_{i=1}^{n} w_i \exp\left(\beta' x_{i,1987}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]\left(\beta' dx_i\right)$$

$$=\sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,1987}\right)\left(\beta' dx_i\right)$$

where $c_i = w_i \exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]$. The estimator of dy_i is

$$\widehat{dy_i} = g\left(\hat{\beta}\right)=\sum_{i=1}^{n} \hat{c}_i \exp\left(\hat{\beta}' x_{i,1987}\right)\left(\hat{\beta}' dx_i\right)$$

where $\hat{c}_i = w_i \exp(\hat{\alpha}_i)\left\{N^{-1}\sum_i \sum_t \exp(\hat{u}_{it})\right\}$. Since $\widehat{dy} = g(\hat{\beta})$ is a nonlinear function of the estimator $\hat{\beta}$ inference uses the delta method.[27]

Salaries and Benefits The definitions of the salary and benefits variables create special problems as we attempt to assign the impacts of their changes to either Baumol or Bowen effects. As constructed *staffsal* and *benstaff* are not independent of an institution's staffing pattern. For example, *staffsal* equals the sum of all wages and salaries paid by the institution divided by the number of FTE staff members. The size of the numerator in that ratio depends critically on the mix between tenure track faculty, part time faculty, and contract faculty as well as the mix between full time administrators, part time administrators, full time nonprofessional employees, and part time nonprofessional employees.

The data demonstrates these institutions reduced the number of nonprofessional employees relative to professional employees and increased the use of lower cost part time faculty and contract faculty. Holding everything else constant, the former trend would raise the average salary and the latter trend would lower the average salary. Had there been no change in staffing patterns, one could interpret *staffsal* as the average wage paid; but this is not the case, we know staffing patterns changed.

Baumol's cost disease holds that productivity is constant and that salaries are driven by external labor market conditions. Alternatively, declines in staff productivity are consistent with agency problems and Bowen's rule. We measure the impact of changing staffing patterns on both *staffsal* and *benstaff* through correlation analyses between *staffsal/benstaff* and all of the staffing variables. The correlation analyses reveal that 48 percent of the variation in *staffsal* is accounted for by variation in the staffing variables and 49 percent of the variation in *benstaff* is accounted for by variation in the staffing variables. Hence, the change Baumol salaries equals 52 percent of the observed change in salaries and the change in Baumol benefits is 51 percent of the observed change in *benstaff*.

The allocation implies that Baumol salaries increased by 21 percent, or $11,200, from 1987 to 2008. The dollar change in full professor salaries was $16,900 and the change in assistant professor salaries was $8,900. The percent increases were 18 and 15 percent, respectively. Therefore, if professor

[27] These calculations are explained in detail in the Appendix.

salaries are market driven, the Baumol salary increases implied by the model are consistent with Baumol's hypothesis.

The salary model implies that Bowen salaries increased by 19 percent or $10,400 in real terms. This reflects the impact on average FTE salaries due to changes in the composition of the FTE staff, specifically, more professional/executive staff and fewer nonprofessional staff less the net changes in academic staffing.

The total change in benefits per full time staff member was $11,500, or 96 percent. The allocation model implies that $6,000 of that change is due to Baumol effects, while $5,500 is due to Bowen staffing effects. The Baumol benefits effect reflects such externally imposed costs as health care cost per full time employee.

Scale and Program Effects. The estimated decomposed costs are presented in Tables 3A and 3B. Part of the total change in cost is explained by changes in enrollment scale, program mix between graduate and undergraduate programs, and full time/part time attendance. Hence, changes in *ftestu*, *ftgrad*, *ptstu*, and *ta* represent the scale and program effects. The partial differential estimates for changes in cost per student are −$577 for academic costs and $269 for overhead costs. These estimates for academic cost (model 1) and overhead cost (model 2), along with their confidence intervals (denoted LB and UB) are reported in Table 3A. If nothing else changed between 1987 and 2008, real total cost per student would have gone down by $308. The decline in total cost predicted by model 3 is $301 in Table 3B.

Cost Saving. The public research universities reduced costs by reducing the non-professional staff/student ratio and using contract and part time faculty more intensively. The partial differential estimates using *ftenpro, cf,* and *ptf,* in models 1 and 2 yield cost reductions of $1,534 for academic costs and $3,019 for overhead. Had these cost savings been passed on to students and taxpayers, total cost per student would be $4,553 lower. The total cost savings estimate from model 3 in Table 3B is $4,599.

Since both actual academic and overhead cost increased, it is clear the forgoing cost savings was spent on other activities. Therefore, the real expected changes in academics and overhead are equal to the actual changes plus the cost that was saved. This is the amount that must be accounted for by Baumol and Bowen effects. Models 1 and 2 suggest the total change in cost per student was $18,221, while model 3 suggests the total change was $18,260.

Baumol Effects. The classic Baumol effect is higher real wages and benefits with constant productivity. Implicit in this argument is that real wages and benefits are market driven and have no administrative content (agency effects); further, the pure Baumol effect argues rising service costs are imposed on the service industries by general market effects that are external to the service industries per se.

As discussed above, Baumol salary/benefits effects are separated from Bowen salary/benefits effects based on fixed effects regression models for *staffsal* and *benstaff*. Hence, 52 percent of the change in salaries is considered a Baumol salary effect and 51 percent of the change in benefits is also considered a Baumol benefits effect. The residuals are considered Bowen salary and benefits effects.

The partial differential Baumol salary estimates for academic and overhead costs are $1,135 and $2,150, respectively. The total, $3,285, represents 19 percent of the change in total cost per student. The total Baumol salary effect from model 3 is $3,151 which is 17 percent of the total change in that model.

The partial differential Baumol benefits estimates from models 1 and 2 for academic costs and overhead costs are -$9 and $90, respectively. They appear to have a negligible effect on cost per student. The Baumol benefits effect from model 3 was $124, which is also negligible. The negligible benefits impact was a consistent result, no matter how the model was estimated. Benefits had a significant impact only when we used an alternative metric for benefits. If we used average benefits paid per student, rather than *benstaff*, the benefits impact was a significant dollar amount when we estimated the models with OLS. However, the benefits became insignificant when the new variable replaced *benstaff* in the fixed effects model. Since *benstaff* is the theoretically correct variable, we used it in the final version.

Bowen Effects. The existence of unresolved agency problems in higher education (Martin, 2011, 80-112) implies that while productivity standards may be inflexible on the upside due to fixed proportions, they are flexible on the downside due to agency problems. Reduced productivity can be taken as agent rents. True, reduced productivity may also lead to higher quality, at least on the academic side; but, the critical point is when staff/student ratios go up costs must go up. This is a definitional relationship, hold salaries constant (or increasing) and a rising staff/student ratio must drive costs higher. The increasing expenditures may be purchasing better teaching or better research output; but, the burden of proof is on those who favor this explanation to provide evidence that this is the case. We are aware of no one successfully making that case. In any event, we are dealing with the evident fact that rising staff/student ratios increase costs.

In the presence of unresolved agency problems, one cannot assume that productivity will be maintained and that salaries will not have an administrative component. Contrary to Baumol's cost disease, the data reveals that faculty and staff productivity did not remain constant from 1987 to 2008; nor did administrative staff productivity improve as we would expect from what was happening in the rest of the economy during that period (Jorgenson, et. al, 2008) (Gera and Gu, 2004). On the other hand, these staff changes are consistent with Bowen's rule.

The partial differential estimates from model 1 for the Bowen adverse productivity effect are measured by changes in *ftef*, *fteadmin, ptadmin*, and *ptnpro*. The estimate for academic cost is $1,859 and the estimate for overhead is $2,089. The total is $3,948 and represents 22 percent of the increase in total cost. The productivity effect from model 3 is $4,014, which is also 22 percent of the total.

The partial differential estimates for Bowen salary effects are $1,048 for academic costs and $1,984 for overhead. The total for the reduced form models 1 and 2 is $3,032, which is 17 percent of the total. The Bowen salary effect from model 3 is $3,151 and is 17 percent of the total increase.

The adverse effect of changes in faculty governance is measured by *ttad* in both reduced form models. The partial differential estimates in Table 3A for academic and overhead costs are $693 and $1,026, respectively. The total for the governance effect is $1,719 and it accounts for 9 percent of the total increase in cost. The governance effect estimate from model 3 is $1,883, which is 10 percent of the total.

Overview of Cost Analysis. In total, the models 1 and 2 Baumol effects account for 18 percent of the total increase in cost and the Bowen effects account for 48 percent of the change in cost. The model 3 Baumol effects account for 19 percent of the total increase in cost and the Bowen effects account for 50 percent. The Bowen effect to Baumol effect ratio in dollar terms for models 1 and 2 is $2.6:1 and the similar ratio for model 3 is $2.6:1. In models 1 and 2, Baumol and Bowen effects account for 67 percent of the actual total change in cost and in model 3, these effects account for 70 percent of the total change. Using a one-tail t-test, we conclude, at the 0.001 level of significance, that the Bowen total cost effect is more than twice the Baumol effect.[28]

The most favorable case to be made for Baumol effects relative to Bowen effects would be to assume that all changes in salaries and benefits are Baumol effects. In this case, for every $1 of

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[28] See the econometric appendix, section A.3.

increased cost explained by Baumol effects there would be $.89 in Bowen effects in both model 1&2 and in model 3. Even under this most extreme case (all of the 41 percent increase in FTE staff salaries and the 96 percent increase in benefits are market driven), both Baumol and Bowen effects cause costs to increase and their effects are approximately equal. Another worst case formulation for the significance of Bowen effects is contained in Table 3B; we assume that all Baumol effects are at the upper bound, while all Bowen effects are at the lower bound for their respective 95 percent confidence intervals. Under this assumption, the models 1 and 2 estimate is $1.6:1 and the model 3 estimate is $1.7:1. A realistic allocation of salaries and benefits suggests Bowen effects exceed Baumol effects by at least 2:1.

7. Conclusions

We estimate academic, overhead, and total cost functions for Carnegie I and II public research universities. Some higher education cost studies assume costs are minimized. These studies are consistent with the argument that higher costs are imposed on colleges and universities by the macro-economy (Baumol's cost disease) and not due to internal agency issues. If costs are minimized, duality insures that cost functions can be estimated with input prices and output. Bowen's rule implies costs are not minimized due to unresolved agency problems and the peculiarities of experience goods. Therefore, staff/student ratios are essential control variables for unraveling changes in costs due to decisions taken inside higher education. Our results demonstrate that staff/student ratios are collectively and individually significant in each model; Bowen's rule has a significant impact on cost.

There are two competing hypotheses about the shared governance model unique to higher education. A popular hypothesis is intransigent tenure track faculty prevent costs from being minimized by cost conscious administrators. If this is the case, our shared governance metric (the ratio of tenure track faculty to full time professional administrators) should be positively correlated with cost. The data reveals it is not positively correlated.

The alternative or pro-shared governance hypothesis holds that shared governance is the only natural constraint on agency abuse in higher education. Hence, cost should be convex in the shared governance metric. For each model, costs are convex in the ratio of tenure track faculty to full time administrators and the models suggest costs are lowest when the ratio is approximately three tenure track faculty for every one administrator; if the ratio goes higher or lower costs per student are higher.

The cost models estimated and the partial differentials implied by those cost models are used to deconstruct the change in cost observed in the data from 1987 to 2008 into its component parts. The primary cost categories are scale/program changes, cost saving changes, Baumol effects, and Bowen effects. We find that both Baumol and Bowen effects drive costs higher; however, Bowen effects tend to be over twice as large as Baumol effects. Most of the increases in cost during this period came from decisions taken inside higher education. The partial differential approach developed to deconstruct cost changes within the sample experience allows us to obtain interval estimates and to test hypotheses; this is also a contribution.

The significance of staffing ratios in the cost equations, the shared governance test results and the deconstruction of historical costs are all consistent with Bowen's rule. We take these results as evidence that Bowen's revenue theory of higher education cost is valid.

However, our model does not account for all possible influences on cost. First, we have not accounted for all possible Baumol or Bowen effects in the model. The essence of the Baumol hypothesis is significant costs are imposed on higher education from the general economy within which it is embedded, an undoubtedly true statement. Likely sources of additional Baumol effects are scientific equipment costs and energy cost for which we have no direct controls. Similarly, we have not accounted for all possible Bowen effects such as those due to reputation competition and the arms race to spend more on physical plant, research, and public service. Finally, we have not controlled for bundling activities (the proliferation of new services previously not offered by higher education); nor have we controlled for new government mandates. Our research is the first step in the process of deconstructing real cost changes into their component parts.

Table 1

Public[29] Research Universities:

Weighted[30] Average Values

Cost per Student:	1987	2008	% Change
Academics	$13,912	$18,961	36
Overhead	$14,527	$22,837	57
Total Cost	$28,439	$41,799	47
Enrollment:			
FTE Students	16581	21517	30
FT Undergrad	15422	19541	27
FT Grad	3250	4538	40
PT Student	2582	2229	-14
Staff per 100 Students:			
Tenure track	4.34	4.49	3
FTE Faculty	6.65	7.59	14
Ratio TT to FT Ad	0.96	0.56	-42
Contract Faculty	1.94	2.43	25
PT Faculty	0.42	0.67	60
FTE Admin	6.51	9.57	47
FTE Exec/Mgr	1.32	1.44	9
FTE Pro	5.19	8.13	57
FTE Nonpro	11.24	8.04	-28
Staff size	14.42	15.26	6
PT Admin	0.26	0.36	35
PT Ex	0.01	0.02	42
PT Pro	0.25	0.34	35
PT Nonpro	0.61	0.45	-26
Salaries:			
Full Prof Salary	$94,138	$111,032	18
Assist Prof Salary	$59,210	$68,105	15
FTE Staff Salary	$53,781	$75,654	41
Benefits	$11,965	$23,466	96

[29] 134 institutions.

[30] Averages are weighted by FTE enrollment.

Table 2: Fixed Effects Estimates

	MODEL 1 AC	MODEL 2 OH	MODEL 3 TC
cf	-0.0582***	-0.0623***	-0.0611***
	(0.0102)	(0.0121)	(0.0094)
ptf	-0.0310***	-0.0391**	-0.0359***
	(0.0116)	(0.0173)	(0.0122)
ta	0.0022	0.0136	0.0072
	(0.0060)	(0.0094)	(0.0056)
ftef	0.0885***	0.0871***	0.0889***
	(0.0095)	(0.0116)	(0.0095)
ftestu	-0.0108**	-0.0079	-0.0089**
	(0.0044)	(0.0054)	(0.0038)
ftgrad	0.0157	0.0442**	0.0277***
	(0.0114)	(0.0178)	(0.0105)
ptstu	0.0216**	0.0298*	0.0231***
	(0.0090)	(0.0156)	(0.0084)
ttad	-0.2359***	-0.3384***	-0.3078***
	(0.0481)	(0.0833)	(0.0517)
ttad2	0.0446***	0.0500***	0.0499***
	(0.0107)	(0.0155)	(0.0094)
tstaffsal	0.0065***	0.0091***	0.0083***
	(0.0009)	(0.0012)	(0.0007)
benstaff	-0.0001	0.0009	0.0007
	(0.0027)	(0.0017)	(0.0017)
fteadmin	0.0061	0.0048	0.0055
	(0.0041)	(0.0066)	(0.0041)
ptadmin	0.0124	0.0424*	0.0321*
	(0.0222)	(0.0252)	(0.0179)
ftenpro	0.0196***	0.0349***	0.0285***
	(0.0041)	(0.0058)	(0.0037)
ptnpro	0.0018	-0.0032	-0.0010
	(0.0080)	(0.0137)	(0.0093)
staffsize	0.0019***	0.0009	0.0013***
	(0.0005)	(0.0007)	(0.0005)
d1989	-0.0178*	-0.0207	-0.0177*
	(0.0100)	(0.0152)	(0.0100)
d1991	-0.0388**	-0.0528***	-0.0413***
	(0.0168)	(0.0195)	(0.0153)
d1999	0.1073***	0.0573*	0.0715***
	(0.0231)	(0.0314)	(0.0203)
d2005	0.1479***	0.0559	0.0848***
	(0.0389)	(0.0465)	(0.0312)
d2008	0.1590***	0.1130**	0.1180***
	(0.0466)	(0.0491)	(0.0339)
constant	8.5555***	8.2547***	9.0830***
	(0.1315)	(0.1259)	(0.1042)
N	841	841	841

Cluster corrected standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 3A
Reduced Form Model 1
Deconstruction of Changes in Cost ($) per Student: 1987 to 2008

	MODEL 1 ACADEMIC			MODEL 2 OVERHEAD		
	Cost	**LB**	**UB**	**COST**	**LB**	**UB**
CHANGE	5049	5049	5049	8311	8311	8311
SAVINGS	-1534	-2087	-981	-3019	-4177	-1861
PROGRAM	-577	-1158	4	269	-431	969
ADJ_CHANGE[31]	7161	6483	7838	11061	9737	12384
BAUMOL:						
SALARIES	1135	794	1476	2150	1428	2871
BENEFITS	-9	-447	430	90	-246	426
SUBTOTAL	1127	537	1716	2240	1524	2955
BOWEN:						
PRODUCTIVITY	1859	1394	2323	2089	1364	2814
SALARIES	1048	733	1363	1984	1318	2650
BENEFITS	-8	-430	413	86	-236	409
GOVERNANCE	693	405	981	1026	572	1479
SUBTOTAL	3591	2629	4554	5185	3756	6614
TOTAL EXPLAINED	4718	3222	6214	7425	5501	9348
PERCENT	66%	50%	79%	67%	56%	76%
BOWEN/BAUMOL RATIO	3.2	4.9	2.7	2.3	2.5	2.2
WORST CASE[32] RATIO			1.5			1.3

[31] Some changes in staffing patterns are designed to reduce cost per student and scale effects from increased enrollment also reduce cost per student; however, these savings were not passed on to the public. Hence, adjusted change equals the actual observed change plus the savings spent elsewhere in the budget.

[32] This is the worst case for the relative importance of Bowen effects relative to Baumol effects; where all Baumol estimates are the upper bound and all Bowen effects are the lower bound.

Table 3B
Total Cost Model 1 and 2
Deconstruction of Changes in Cost per Student: 1987 to 2008

	MODEL 3 TOTAL COST			MODEL 1 & 2 TOTAL COST		
	Cost	**LB**	**UB**	**COST**	**LB**	**UB**
CHANGE	13360	13360	13360	13360	13360	13360
SAVINGS	-4599	-5812	-3386	-4553	-5836	-3270
PROGRAM	-301	-1308	706	-308	-1218	602
ADJ_CHANGE[33]	18260	16925	19595	18221	16735	19708
BAUMOL:						
SALARIES	3413	2700	4127	3285	2486	4083
BENEFITS	124	-470	719	81	-471	634
SUBTOTAL	3538	2644	4432	3366	2439	4293
BOWEN						
PRODUCTIVITY	4014	3095	4934	3948	3086	4809
SALARIES	3151	2493	3809	3032	2295	3769
BENEFITS	119	-451	690	78	-453	609
GOVERNANCE	1883	1276	2489	1719	1181	2256
SUBTOTAL	9167	7470	10865	8776	7053	10499
TOTAL EXPLAINED	12705	9275	16135	12142	10186	14099
PERCENT	70%	55%	82%	67%	61%	72%
BOWEN/BAUMOL RATIO	2.6	2.8	2.5	2.6	2.9	2.4
WORST CASE[34] RATIO			1.7			1.6

[33] Some changes in staffing patterns are designed to reduce cost per student and scale effects from increased enrollment also reduce cost per student; however, these savings were not passed on to the public. Hence, adjusted change equals the actual observed change plus the savings spent elsewhere in the budget.

[34] This is the worst case for the relative importance of Bowen effects relative to Baumol effects; where all Baumol estimates are the upper bound and all Bowen effects are the lower bound.

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Measuring Baumol and Bowen Effects in Public Research Universities: Econometric Appendix

A.1 Model Specification and Estimation

For Academic Cost (*ac*), Overhead Cost (*oh*) and Total Cost (*tc*) we specify the log-linear regressions

$$\ln\left(ac_{it}\right) = \beta'_{ac} x_{ac,it} + \alpha_{ac,i} + u_{ac,it} \tag{1a}$$

$$\ln\left(oh_{it}\right) = \beta'_{oh} x_{oh,it} + \alpha_{oh,i} + u_{oh,it} \tag{1b}$$

$$\ln\left(tc_{it}\right) = \beta'_{tc} x_{tc,it} + \alpha_{tc,i} + u_{tc,it} \tag{1c}$$

Where $\alpha_{ac,i}$ and $\alpha_{oh,i}$ are individual effects, with $i = 1,\ldots,n$ and $t = 1,\ldots,T_i$. The least squares, random effects and fixed effects parameter estimates for each model are reported in Tables A.1, A.2 and A.3. In each of these tables the usual OLS estimates are reported in the first column, random effects estimates[35] in the second column, random effects estimates with robust cluster standard errors in the third column, fixed effects estimates in the fourth column and fixed effects estimates with robust cluster standard errors in the fifth column. For the purpose of "deconstructing costs," and the results in Table 3 of the paper, the parameters β_{ac} and β_{oh} are estimated using fixed effects since the Hausman test rejects the null hypothesis that the regressors and random effects are uncorrelated in each equation.[36] The parameter estimates are denoted $\hat{\beta}_{ac}$, $\hat{\beta}_{oh}$ and $\hat{\beta}_{tc}$. We employ robust cluster-corrected covariance matrix estimates $\hat{V}_{ac}$, $\hat{V}_{oh}$ and $\hat{V}_{tc}$, because some residual correlation across remains even after including year

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[35] All model estimations are carried out in Stata 12.1

[36] This conclusion was drawn on the basis of the usual contrast tests under the assumption of homoscedasticity (no clustering), and also the regression based Hausman test describe in Wooldridge (2010, 332). In this test the averages of the time varying variables are added as regressors in a random effects estimation and their significance jointly tested based on a cluster corrected covariance matrix. Using not only the complete set of time varying variables, but also various subsets of those variables, we reject the null hypothesis that the heterogeneity is not correlated with the time averages.

dummies.[37] The *ac* and *oh* equations are estimated separately. There is a small (0.157) cross-equation residual correlation which is statistically insignificant.[38]

A.2 The Partial Differentials

For simplicity denote academic cost (*ac*) or overhead cost (*oh*) by *y*, then, the log-linear specification implies the expectation

$$E\left(y_{it}\right)=\exp\left(\beta' x_{it}+\alpha_i\right)E\left[\exp\left(u_{it}\right)\right]=\exp\left(\beta' x_{it}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right] \tag{2}$$

The predicted value should incorporate an estimate of $E\left[\exp\left(u_{it}\right)\right]$. We use the sample average of the least squares residuals $N^{-1}\sum_i\sum_t \exp\left(\hat{u}_{it}\right)$[39], where N = 813 is the total number of sample observations. Other variants tried included the usual correction factor for the log-normal model $\exp\left(0.5\sigma^2\right)$, and also a group mean $\bar{\hat{u}}_{i\bullet}=T_i^{-1}\sum_t \exp\left(\hat{u}_{it}\right)$. Each of these corrections is very small and there were no meaningful differences among them in our calculations. Thus for each equation the predicted y_{it} is

$$\hat{y}_{it}=\exp\left(\hat{\beta}' x_{it}\right)\exp\left(\hat{\alpha}_i\right)\left\{N^{-1}\sum_i\sum_t \exp\left(\hat{u}_{it}\right)\right\} \tag{3}$$

The total differential of $E\left(y_{it}\right)$ is

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[37] The data used are not equally spaced through time. We have data from 1987, 1989, 1991, 1999, 2005 and 2008. For each equation, using the fixed effects residuals, we regress the residuals in time t against the residuals in time $t-1$ for each year and also against more prior years using a pooled regression with cluster corrected standard errors. These tests are described in Wooldridge (2010, 310-311). While not every pair of years produced significant evidence of serial correlation, it was significant in more estimations than not. This justifies the use of fixed effects estimation with cluster corrected covariance matrix.

[38] Based on the test statistic $LM = Tr^2 \sim \chi^2_{(1)}$, Judge, Hill, Griffiths, Lütkepohl and Lee (1988, 456). In our case the sample is not balanced and we use the approximation with the average number of time series observations per cross-section unit, $LM = \bar{T}r^2 = 5.8\times 0.1568^2 = 0.1426$. The resulting p-value = 0.706.

[39] Cameron and Trivedi (2010, 108) .

$$dE\left(y_{it}\right) = \exp\left(\beta' x_{it}\right) \exp\left(\alpha_i\right) E\left[\exp\left(u_{it}\right)\right]\left(\beta' dx_{it}\right) \tag{4}$$

For each university *i*, we calculate

$$dy_i = \exp\left(\beta' x_{i,1987}\right) \exp\left(\alpha_i\right) E\left[\exp\left(u_{it}\right)\right]\left(\beta' dx_i\right) \tag{5}$$

where $x_{i,1987}$ are regressor values in the base year 1987, and $dx_i = x_{i,2008} - x_{i,1987}$. While our panel is unbalanced we have matching observations for 1987 and 2008.

Rather than the total differential we consider partial differentials using subsets of the regressor differential dx_i by setting some of its elements to zero. Specifically, the partial differential for the following incremental effects would involve subsets of the independent variables as follows:

1. Program Scale Changes: *ftestu*, *ftgrad*, *ptstu*, *ta*
2. Cost Savings: *cf*, *ptf*, *ftenpro*
3. Baumol Benefits: decomposed *benstaff*. The change in Baumol benefits is 51% of the actual change in *benstaff*.
4. Baumol Salaries: decomposed *tstaffsal*. The change in Baumol salaries is 52% of the actual change in *tstaffsal*.
5. Bowen Productivity: *ftef*, *fteadmin*, *ptadmin*, *ptnpro*, *staffsize*
6. Bowen Salaries: decomposed *tstaffsal*. The change in Bowen salaries is 48% of the actual change in *tstaffsal*.
7. Bowen Benefits: decomposed *benstaff*. The change in Bowen benefits is 49% of the actual change in *benstaff*.
8. Bowen Governance: *ttad*, *ttad2*

The sum of the (partial) differentials is weighted by 1987 FTE student enrollment. Define

$$w_i = FTESTU_{i,1987} \Big/ \left(\sum_{i=1}^{n} FTESTU_{i,1987} \right) \tag{6}$$

Then

$$\begin{aligned} dy = g(\beta) &= \sum_{i=1}^{n} w_i \exp\left(\beta' x_{i,1987}\right) \exp(\alpha_i) E\left[\exp(u_{it})\right](\beta' dx_i) \\ &= \sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,1987}\right)(\beta' dx_i) \end{aligned} \tag{7}$$

where $c_i = w_i \exp(\alpha_i) E\left[\exp(u_{it})\right]$. The estimator of *dy* is

$$\widehat{dy} = g\left(\hat{\beta}\right) = \sum_{i=1}^{n} \hat{c}_i \exp\left(\hat{\beta}' x_{i,1987}\right)\left(\hat{\beta}' dx_i\right) \tag{8}$$

where $\hat{c}_i = w_i \exp(\hat{\alpha}_i) \left\{ N^{-1} \sum_i \sum_t \exp(\hat{u}_{it}) \right\}$. Since $\widehat{dy} = g\left(\hat{\beta}\right)$ is a nonlinear function of the estimator $\hat{\beta}$ inference uses the delta method[40]. The asymptotic distribution of the estimator in (8) is

$$g\left(\hat{\beta}\right) \overset{a}{\sim} N\left[g(\beta), JVJ'\right] \tag{9}$$

where $J = \partial g(\beta) / \partial \beta'$, so that the estimator of the asymptotic variance of $\widehat{dy}$ is $\hat{V}_{dy} = \hat{J}\hat{V}\hat{J}'$, with $\hat{J} = \partial g(\beta) / \partial \beta' \big|_{\beta=\hat{\beta}}$ and $\hat{V}$ is a robust cluster corrected covariance matrix of $\hat{\beta}$.[41]

Given the form of our differential

$$\begin{aligned} J &= \sum_{i=1}^{n} c_i \left[\exp\left(\beta' x_{i,1987}\right)(\beta' dx_i) x'_{i,1987} + \exp\left(\beta' x_{i,1987}\right) dx'_i \right] \\ &= \sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,1987}\right)\left[(\beta' dx_i) x'_{i,1987} + dx'_i\right] \end{aligned} \tag{10}$$

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[40] William Greene (2012, Theorem D.22, 1086).

[41] Coefficient estimation was carried out using Stata 12.1. Subsequent calculations were carried out in SAS 9.3/IML.

A.3 Deconstructions

The differential estimates are computed for subsets of variables reflecting Program Scale changes (*ps*), Cost Savings (*cs*), Benefits (*ben*), Salaries (*sal*), Productivity (*prod*) and Governance (*gov*). To compare the theories of Baumol (*bau*) and Bowen (*bow*) we compute differential estimates for both Academic Cost (*ac*) and Overhead Cost (*oh*). The Baumol components are, for each of *ac* and *oh*,

$$dy_{tot}^{bau} = dy_{sal}^{bau} + dy_{ben}^{bau} \tag{11}$$

For Academic Cost this is

$$\begin{aligned} g_{ac}^{bau}\left(\beta_{ac}\right) &= \sum_{i=1}^{n} c_i^{ac} \exp\left(\beta_{ac}' x_{i,1987}^{ac}\right)\left[\beta_{ac}'\left(dx_{i,sal}^{bau\_ac} + dx_{i,ben}^{bau\_ac}\right)\right] \\ &= \sum_{i=1}^{n} c_i^{ac} \exp\left(\beta_{ac}' x_{i,1987}^{ac}\right)\left(\beta_{ac}' dx_{i,tot}^{bau\_ac}\right) \end{aligned} \tag{12}$$

For Overhead Cost we have

$$\begin{aligned} g_{oh}^{bau}\left(\beta_{oh}\right) &= \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta_{oh}' x_{i,1987}^{oh}\right)\left[\beta_{oh}'\left(dx_{i,sal}^{bau\_oh} + dx_{i,ben}^{bau\_oh}\right)\right] \\ &= \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta_{oh}' x_{i,1987}^{oh}\right)\left(\beta_{oh}' dx_{i,tot}^{bau\_oh}\right) \end{aligned} \tag{13}$$

The Bowen components of cost are productivity, salary, benefits and governance, so

$$g_{ac}^{bow}\left(\beta_{ac}\right) = \sum_{i=1}^{n} c_i^{ac} \exp\left(\beta_{ac}' x_{i,1987}^{ac}\right)\left(\beta_{ac}' dx_i^{bow\_ac}\right) \tag{14}$$

where

$$dx_i^{bow\_ac} = dx_{i,prod}^{bow\_ac} + dx_{i,sal}^{bow\_ac} + dx_{i,ben}^{bow\_ac} + dx_{i,gov}^{bow\_ac} \tag{15}$$

and

$$g_{oh}^{bow}\left(\beta_{oh}\right) = \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta_{oh}' x_{i,1987}^{oh}\right)\left(\beta_{oh}' dx_i^{bow\_oh}\right) \tag{16}$$

where

$$dx_i^{bow\_oh} = dx_{i,prod}^{bow\_oh} + dx_{i,sal}^{bow\_oh} + dx_{i,ben}^{bow\_oh} + dx_{i,gov}^{bow\_oh} \tag{17}$$

The total of the Bowen components is

$$dy_{tot}^{bow} = dy_{prod}^{bow} + dy_{sal}^{bow} + dy_{ben}^{bow} + dy_{gov}^{bow} \tag{18}$$

We would like to test the null and alternative hypotheses

$$\begin{aligned} H_0 &: dy_{tot}^{bow} - h \cdot dy_{tot}^{bau} = h(\beta_{ac}, \beta_{oh}) \le 0 \\ H_1 &: dy_{tot}^{bow} - h \cdot dy_{tot}^{bau} = h(\beta_{ac}, \beta_{oh}) > 0 \end{aligned} \tag{19}$$

The test statistic is

$$t = \hat{h}(\beta_{ac}, \beta_{oh}) \Big/ se\left[\hat{h}(\beta_{ac}, \beta_{oh})\right] \tag{20}$$

The numerator is

$$\begin{aligned} \hat{h}(\beta_{ac}, \beta_{oh}) &= \sum_{i=1}^{n} c_i^{ac} \exp\left(\hat{\beta}'_{ac} x_{i,1987}^{ac}\right)\left(\hat{\beta}'_{ac} dx_i^{bow\_ac}\right) + \sum_{i=1}^{n} c_i^{oh} \exp\left(\hat{\beta}'_{oh} x_{i,1987}^{oh}\right)\left(\hat{\beta}'_{oh} dx_i^{bow\_oh}\right) \\ &\quad - h \cdot \left[\sum_{i=1}^{n} c_i^{ac} \exp\left(\hat{\beta}'_{ac} x_{i,1987}^{ac}\right)\left(\hat{\beta}'_{ac} dx_i^{bau\_ac}\right) + \sum_{i=1}^{n} c_i^{oh} \exp\left(\hat{\beta}'_{oh} x_{i,1987}^{oh}\right)\left(\hat{\beta}'_{oh} dx_i^{bau\_oh}\right)\right] \\ &= \sum_{i=1}^{n} c_i^{ac} \exp\left(\hat{\beta}'_{ac} x_{i,1987}^{ac}\right)\left[\hat{\beta}'_{ac}\left(dx_i^{bow\_ac} - h \cdot dx_i^{bau\_ac}\right)\right] \\ &\quad + \sum_{i=1}^{n} c_i^{oh} \exp\left(\hat{\beta}'_{oh} x_{i,1987}^{oh}\right)\left[\hat{\beta}'_{oh}\left(dx_i^{bow\_oh} - h \cdot dx_i^{bau\_oh}\right)\right] \\ &= \sum_{i=1}^{n} c_i^{ac} \exp\left(\hat{\beta}'_{ac} x_{i,1987}^{ac}\right)\hat{\beta}'_{ac} dx_{ac} + \sum_{i=1}^{n} c_i^{oh} \exp\left(\hat{\beta}'_{oh} x_{i,1987}^{oh}\right)\hat{\beta}'_{oh} dx_{oh} \end{aligned} \tag{21}$$

Note that the form of the various differentials in (8), (12), (13), (14) and (16) is the same, and thus the Jacobian matrix (10) is of the same form in each case. The numerator of the test statistic in (21) is the sum of differentials, so that if we assume $\text{cov}\left(\hat{\beta}_{ac}, \hat{\beta}_{oh}\right) = 0$, the standard error in the denominator of (20) is obtained from a sum of two standard errors.

A.3.1 Variance Calculation: Baumol Total

The Jacobian for the Baumol academic cost is

$$J_{ac}^{bau} = \sum_{i=1}^{n} c_i^{ac} \exp\left(\beta'_{ac} x_{i,1987}\right)\left[\left(\beta'_{ac} dx_i^{bau\_ac}\right) x'_{i,1987} + dx_i'^{bau\_ac}\right]$$

where $dx_i^{bau\_ac} = dx_{i,sal}^{bau\_ac} + dx_{i,ben}^{bau\_ac}$, and $V_{ac}^{bau} = J_{ac}^{bau} \cdot V_{ac} \cdot \left(J_{ac}^{bau}\right)'$

Similarly, the Jacobian for the Baumol overhead cost is

$$J_{oh}^{bau} = \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta'_{oh} x_{i,1987}\right)\left[\left(\beta'_{ac} dx_i^{bau\_oh}\right) x'_{i,1987} + dx_i'^{bau\_oh}\right]$$

where $dx_i^{bau\_oh} = dx_{i,sal}^{bau\_oh} + dx_{i,ben}^{bau\_oh}$, so $V_{oh}^{bau} = J_{oh}^{bau} \cdot V_{oh} \cdot \left(J_{oh}^{bau}\right)'$

Then, the variance of the total cost, assuming that the academic cost and overhead cost equation errors are uncorrelated with each other, is

$$V_{tot}^{bau} = J_{ac}^{bau} \cdot V_{ac} \cdot \left(J_{ac}^{bau}\right)' + J_{oh}^{bau} \cdot V_{oh} \cdot \left(J_{oh}^{bau}\right)' = V_{ac}^{bau} + V_{oh}^{bau}$$

A.3.2 Variance Calculation: Bowen Total

The Jacobian of the Bowen academic cost

$$J_{ac}^{bow} = \sum_{i=1}^{n} c_i^{ac} \exp\left(\beta'_{ac} x_{i,1987}\right)\left[\left(\beta'_{ac} dx_i^{bow\_ac}\right) x'_{i,1987} + dx_i'^{bow\_ac}\right]$$

where $dx_i^{bow\_ac} = dx_{i,prod}^{bow\_ac} + dx,_{i,sal}^{bow\_ac} + dx_{i,ben}^{bow\_ac} + dx_{i,gov}^{bow\_ac}$, so $V_{ac}^{bow} = J_{ac}^{bow} \cdot V_{ac} \cdot \left(J_{ac}^{bow}\right)'$

Similarly for the Bowen overhead cost component

$$J_{oh}^{bow} = \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta'_{oh} x_{i,1987}\right)\left[\left(\beta'_{ac} dx_i^{bow\_oh}\right) x'_{i,1987} + dx_i'^{bow\_oh}\right]$$

Where $dx_i^{bow\_oh} = dx_{i,prod}^{bow\_oh} + dx_{i,sal}^{bow\_oh} + dx_{i,ben}^{bow\_oh} + dx_{i,gov}^{bow\_oh}$, so $V_{oh}^{bow} = J_{oh}^{bow} \cdot V_{oh} \cdot \left(J_{oh}^{bow}\right)'$

Then

$$V_{tot}^{bow} = J_{ac}^{bow} \cdot V_{ac} \cdot \left(J_{ac}^{bow}\right)' + J_{oh}^{bow} \cdot V_{oh} \cdot \left(J_{oh}^{bow}\right)' = V_{ac}^{bow} + V_{oh}^{bow}$$

A.3.3 Variance Calculation for t-statistic

The denominator of the *t*-statistic (20) is

$$V\left[\hat{h}\left(\beta_{ac},\beta_{oh}\right)\right] = V\left[\hat{h}\left(\beta_{ac}\right)\right] + V\left[\hat{h}\left(\beta_{oh}\right)\right]$$

where

$$V\left[\hat{h}\left(\beta_{ac}\right)\right] = V\left[\sum_{i=1}^{n} c_i^{ac} \exp\left(\hat{\beta}'_{ac} x_{i,1987}^{ac}\right)\left(\hat{\beta}'_{ac} dx_{ac}\right)\right] = J_{ac}^{h} \cdot V_{ac} \cdot \left(J_{ac}^{h}\right)'$$

The Jacobian is

$$J_{ac}^{h} = \sum_{i=1}^{n} c_i^{ac} \exp\left(x_{i,1987}^{\prime ac} \beta_{ac}\right)\left[\left(dx'_{ac}\beta_{ac}\right) x_{i,1987}^{\prime ac} + dx'_{ac}\right]$$

Where $dx_{ac} = dx_i^{bow\_ac} - h \cdot dx_i^{bau\_ac}$. Similarly

$$V\left[\hat{h}\left(\beta_{oh}\right)\right] = V\left[\sum_{i=1}^{n} c_i^{oh} \exp\left(\hat{\beta}'_{oh} x_{i,1987}^{oh}\right)\left(\hat{\beta}'_{oh} dx_{oh}\right)\right] = J_{oh}^{h} \cdot V_{oh} \cdot \left(J_{oh}^{h}\right)'$$

with $J_{oh}^{h} = \sum_{i=1}^{n} c_i^{oh} \exp\left(\beta'_{oh} x_{i,1987}^{oh}\right)\left[\left(\beta'_{oh} dx_{oh}\right) x_{i,1987}^{\prime oh} + dx'_{oh}\right]$ where $dx_{oh} = dx_i^{bow\_oh} - h \cdot dx_i^{bau\_oh}$

A.4 References

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Table A.1 Overhead Cost equation

	OH_OLS	OH_RE	OH_RE_ROB	OH_FE	OH_FE_ROB
cf	-0.0380**	-0.0596***	-0.0596***	-0.0623***	-0.0623***
	(0.0179)	(0.0085)	(0.0117)	(0.0086)	(0.0121)
ptf	0.0038	-0.0345***	-0.0345**	-0.0391***	-0.0391**
	(0.0207)	(0.0130)	(0.0166)	(0.0130)	(0.0173)
ta	-0.0097	0.0087	0.0087	0.0136*	0.0136
	(0.0120)	(0.0071)	(0.0083)	(0.0074)	(0.0094)
ftef	0.0690***	0.0860***	0.0860***	0.0871***	0.0871***
	(0.0171)	(0.0073)	(0.0115)	(0.0074)	(0.0116)
ftestu	0.0007	-0.0041	-0.0041	-0.0079**	-0.0079
	(0.0046)	(0.0027)	(0.0042)	(0.0037)	(0.0054)
ftgrad	0.0093	0.0294***	0.0294**	0.0442***	0.0442**
	(0.0180)	(0.0103)	(0.0149)	(0.0135)	(0.0178)
ptstu	0.0023	0.0177**	0.0177	0.0298***	0.0298*
	(0.0130)	(0.0081)	(0.0132)	(0.0103)	(0.0156)
ttad	-0.3204***	-0.3391***	-0.3391***	-0.3384***	-0.3384***
	(0.1010)	(0.0519)	(0.0751)	(0.0536)	(0.0833)
ttad2	0.0553***	0.0504***	0.0504***	0.0500***	0.0500***
	(0.0206)	(0.0128)	(0.0148)	(0.0129)	(0.0155)
city	-0.0837**	-0.0980***	-0.0980**	.	.
	(0.0383)	(0.0362)	(0.0402)	.	.
rural	-0.0727	-0.0955*	-0.0955**	.	.
	(0.0443)	(0.0525)	(0.0484)	.	.
carnegie	-0.0625	-0.0467	-0.0467	.	.
	(0.0448)	(0.0417)	(0.0510)	.	.
fwest	0.0421	0.0468	0.0468	.	.
	(0.0466)	(0.0486)	(0.0482)	.	.
glakes	0.1294***	0.1340***	0.1340***	.	.
	(0.0386)	(0.0420)	(0.0445)	.	.
neweng	0.1507***	0.1499***	0.1499***	.	.
	(0.0418)	(0.0456)	(0.0558)	.	.
stem	-0.0513	-0.0260	-0.0260	.	.
	(0.0420)	(0.0464)	(0.0459)	.	.
medical	0.0307	0.0691*	0.0691	.	.
	(0.0403)	(0.0416)	(0.0460)	.	.
prof	-0.0027	0.0039	0.0039	.	.
	(0.0449)	(0.0508)	(0.0548)	.	.
tstaffsal	0.0086***	0.0095***	0.0095***	0.0091***	0.0091***
	(0.0013)	(0.0006)	(0.0010)	(0.0007)	(0.0012)
benstaff	0.0028	0.0013	0.0013	0.0009	0.0009
	(0.0025)	(0.0014)	(0.0015)	(0.0015)	(0.0017)
fteadmin	0.0228***	0.0097**	0.0097	0.0048	0.0048
	(0.0079)	(0.0040)	(0.0062)	(0.0042)	(0.0066)
ptadmin	0.0566	0.0446**	0.0446*	0.0424*	0.0424*
	(0.0354)	(0.0206)	(0.0245)	(0.0218)	(0.0252)
ftenpro	0.0435***	0.0391***	0.0391***	0.0349***	0.0349***
	(0.0064)	(0.0031)	(0.0050)	(0.0035)	(0.0058)
ptnpro	-0.0501**	-0.0103	-0.0103	-0.0032	-0.0032
	(0.0213)	(0.0114)	(0.0122)	(0.0116)	(0.0137)
staffsize	0.0023**	0.0013*	0.0013*	0.0009	0.0009
	(0.0011)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
d1989	-0.0399*	-0.0225	-0.0225	-0.0207	-0.0207
	(0.0216)	(0.0186)	(0.0158)	(0.0184)	(0.0152)
d1991	-0.0459**	-0.0426**	-0.0426**	-0.0528***	-0.0528***
	(0.0208)	(0.0189)	(0.0182)	(0.0190)	(0.0195)
d1999	0.0382	0.0464**	0.0464	0.0573**	0.0573*
	(0.0363)	(0.0216)	(0.0282)	(0.0224)	(0.0314)
d2005	0.0323	0.0419	0.0419	0.0559*	0.0559
	(0.0518)	(0.0287)	(0.0405)	(0.0311)	(0.0465)
d2008	0.0735	0.0938***	0.0938**	0.1130***	0.1130**
	(0.0591)	(0.0309)	(0.0433)	(0.0338)	(0.0491)
constant	8.1627***	8.1803***	8.1803***	8.2547***	8.2547***
	(0.1028)	(0.0762)	(0.0947)	(0.0888)	(0.1259)
N	841	841	841	841	841

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table A.2 Academic Cost equation

	AC_OLS	AC_RE	AC_RE_ROB	AC_FE	AC_FE_ROB
cf	-0.0938***	-0.0663***	-0.0663***	-0.0582***	-0.0582***
	(0.0160)	(0.0068)	(0.0105)	(0.0068)	(0.0102)
ptf	-0.0660***	-0.0369***	-0.0369***	-0.0310***	-0.0310***
	(0.0196)	(0.0104)	(0.0116)	(0.0103)	(0.0116)
ta	0.0408***	0.0110*	0.0110*	0.0022	0.0022
	(0.0132)	(0.0057)	(0.0061)	(0.0059)	(0.0060)
ftef	0.1319***	0.0956***	0.0956***	0.0885***	0.0885***
	(0.0122)	(0.0059)	(0.0089)	(0.0059)	(0.0095)
ftestu	-0.0012	-0.0067***	-0.0067**	-0.0108***	-0.0108**
	(0.0028)	(0.0023)	(0.0026)	(0.0029)	(0.0044)
ftgrad	0.0153	0.0214**	0.0214**	0.0157	0.0157
	(0.0118)	(0.0087)	(0.0090)	(0.0107)	(0.0114)
ptstu	0.0024	0.0164**	0.0164**	0.0216***	0.0216**
	(0.0098)	(0.0068)	(0.0065)	(0.0082)	(0.0090)
ttad	-0.4741***	-0.2877***	-0.2877***	-0.2359***	-0.2359***
	(0.0865)	(0.0418)	(0.0510)	(0.0424)	(0.0481)
ttad2	0.0875***	0.0519***	0.0519***	0.0446***	0.0446***
	(0.0177)	(0.0103)	(0.0107)	(0.0102)	(0.0107)
city	-0.0633*	-0.0825**	-0.0825**	.	.
	(0.0363)	(0.0329)	(0.0369)	.	.
rural	0.0306	0.0323	0.0323	.	.
	(0.0450)	(0.0480)	(0.0523)	.	.
carnegie	0.0884**	0.1923***	0.1923***	.	.
	(0.0406)	(0.0375)	(0.0485)	.	.
fwest	0.0410	0.0704	0.0704	.	.
	(0.0543)	(0.0442)	(0.0538)	.	.
glakes	-0.0389	-0.0147	-0.0147	.	.
	(0.0341)	(0.0383)	(0.0361)	.	.
neweng	0.0167	0.0586	0.0586	.	.
	(0.0414)	(0.0415)	(0.0408)	.	.
stem	0.1240**	0.1135***	0.1135**	.	.
	(0.0478)	(0.0423)	(0.0548)	.	.
medical	0.1017**	0.1193***	0.1193***	.	.
	(0.0415)	(0.0378)	(0.0453)	.	.
prof	-0.0804*	-0.1153**	-0.1153**	.	.
	(0.0420)	(0.0463)	(0.0468)	.	.
tstaffsal	0.0077***	0.0070***	0.0070***	0.0065***	0.0065***
	(0.0011)	(0.0005)	(0.0008)	(0.0005)	(0.0009)
benstaff	0.0028	0.0004	0.0004	-0.0001	-0.0001
	(0.0041)	(0.0012)	(0.0029)	(0.0012)	(0.0027)
fteadmin	0.0023	0.0065**	0.0065*	0.0061*	0.0061
	(0.0068)	(0.0032)	(0.0039)	(0.0033)	(0.0041)
ptadmin	-0.0023	0.0065	0.0065	0.0124	0.0124
	(0.0323)	(0.0167)	(0.0219)	(0.0172)	(0.0222)
ftenpro	0.0184***	0.0220***	0.0220***	0.0196***	0.0196***
	(0.0052)	(0.0025)	(0.0039)	(0.0028)	(0.0041)
ptnpro	0.0080	0.0022	0.0022	0.0018	0.0018
	(0.0166)	(0.0091)	(0.0086)	(0.0092)	(0.0080)
staffsize	0.0029***	0.0021***	0.0021***	0.0019***	0.0019***
	(0.0011)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
d1989	-0.0049	-0.0141	-0.0141	-0.0178	-0.0178*
	(0.0139)	(0.0148)	(0.0102)	(0.0146)	(0.0100)
d1991	-0.0105	-0.0343**	-0.0343**	-0.0388**	-0.0388**
	(0.0182)	(0.0151)	(0.0158)	(0.0150)	(0.0168)
d1999	0.0230	0.0793***	0.0793***	0.1073***	0.1073***
	(0.0278)	(0.0173)	(0.0218)	(0.0177)	(0.0231)
d2005	-0.0344	0.0925***	0.0925**	0.1479***	0.1479***
	(0.0492)	(0.0232)	(0.0364)	(0.0246)	(0.0389)
d2008	-0.0405	0.0980***	0.0980**	0.1590***	0.1590***
	(0.0563)	(0.0250)	(0.0438)	(0.0267)	(0.0466)
constant	8.2319***	8.3245***	8.3245***	8.5555***	8.5555***
	(0.1262)	(0.0643)	(0.0998)	(0.0703)	(0.1315)
N	841	841	841	841	841

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table A.3 Total Cost equation

	TC_OLS	TC_RE	TC_RE_ROB	TC_FE	TC_FE_ROB
cf	-0.0649***	-0.0649***	-0.0649***	-0.0611***	-0.0611***
	(0.0120)	(0.0058)	(0.0096)	(0.0061)	(0.0094)
ptf	-0.0317**	-0.0370***	-0.0370***	-0.0359***	-0.0359***
	(0.0135)	(0.0090)	(0.0120)	(0.0092)	(0.0122)
ta	0.0130*	0.0102**	0.0102**	0.0072	0.0072
	(0.0073)	(0.0048)	(0.0048)	(0.0052)	(0.0056)
ftef	0.0995***	0.0937***	0.0937***	0.0889***	0.0889***
	(0.0103)	(0.0050)	(0.0089)	(0.0052)	(0.0095)
ftestu	-0.0002	-0.0038**	-0.0038	-0.0089***	-0.0089**
	(0.0024)	(0.0017)	(0.0026)	(0.0026)	(0.0038)
ftgrad	0.0122	0.0219***	0.0219***	0.0277***	0.0277***
	(0.0088)	(0.0066)	(0.0084)	(0.0095)	(0.0105)
ptstu	0.0004	0.0114**	0.0114	0.0231***	0.0231***
	(0.0085)	(0.0052)	(0.0082)	(0.0073)	(0.0084)
ttad	-0.3965***	-0.3441***	-0.3441***	-0.3078***	-0.3078***
	(0.0712)	(0.0356)	(0.0508)	(0.0377)	(0.0517)
ttad2	0.0694***	0.0555***	0.0555***	0.0499***	0.0499***
	(0.0140)	(0.0088)	(0.0096)	(0.0091)	(0.0094)
city	-0.0735***	-0.0864***	-0.0864***	.	.
	(0.0208)	(0.0209)	(0.0222)	.	.
rural	-0.0278	-0.0363	-0.0363	.	.
	(0.0230)	(0.0299)	(0.0259)	.	.
carnegie	0.0079	0.0460*	0.0460	.	.
	(0.0277)	(0.0244)	(0.0328)	.	.
fwest	0.0275	0.0407	0.0407	.	.
	(0.0264)	(0.0280)	(0.0261)	.	.
glakes	0.0472**	0.0566**	0.0566**	.	.
	(0.0227)	(0.0242)	(0.0253)	.	.
neweng	0.0729***	0.0914***	0.0914***	.	.
	(0.0258)	(0.0264)	(0.0309)	.	.
stem	0.0374	0.0439*	0.0439	.	.
	(0.0262)	(0.0267)	(0.0298)	.	.
medical	0.0728***	0.0949***	0.0949***	.	.
	(0.0264)	(0.0239)	(0.0273)	.	.
prof	-0.0329	-0.0407	-0.0407	.	.
	(0.0288)	(0.0291)	(0.0336)	.	.
tstaffsal	0.0086***	0.0089***	0.0089***	0.0083***	0.0083***
	(0.0008)	(0.0004)	(0.0006)	(0.0005)	(0.0007)
benstaff	0.0033*	0.0015	0.0015	0.0007	0.0007
	(0.0017)	(0.0010)	(0.0016)	(0.0010)	(0.0017)
fteadmin	0.0126**	0.0089***	0.0089**	0.0055*	0.0055
	(0.0050)	(0.0027)	(0.0038)	(0.0029)	(0.0041)
ptadmin	0.0336**	0.0301**	0.0301**	0.0321**	0.0321*
	(0.0146)	(0.0140)	(0.0152)	(0.0153)	(0.0179)
ftenpro	0.0329***	0.0326***	0.0326***	0.0285***	0.0285***
	(0.0042)	(0.0021)	(0.0037)	(0.0025)	(0.0037)
ptnpro	-0.0262**	-0.0072	-0.0072	-0.0010	-0.0010
	(0.0115)	(0.0078)	(0.0081)	(0.0081)	(0.0093)
staffsize	0.0027***	0.0018***	0.0018***	0.0013***	0.0013***
	(0.0005)	(0.0004)	(0.0004)	(0.0005)	(0.0005)
d1989	-0.0200	-0.0162	-0.0162	-0.0177	-0.0177*
	(0.0150)	(0.0130)	(0.0114)	(0.0129)	(0.0100)
d1991	-0.0248*	-0.0315**	-0.0315**	-0.0413***	-0.0413***
	(0.0145)	(0.0132)	(0.0140)	(0.0134)	(0.0153)
d1999	0.0247	0.0457***	0.0457**	0.0715***	0.0715***
	(0.0213)	(0.0149)	(0.0186)	(0.0157)	(0.0203)
d2005	-0.0112	0.0370*	0.0370	0.0848***	0.0848***
	(0.0312)	(0.0196)	(0.0272)	(0.0219)	(0.0312)
d2008	0.0054	0.0627***	0.0627**	0.1180***	0.1180***
	(0.0349)	(0.0210)	(0.0302)	(0.0238)	(0.0339)
_cons	8.8717***	8.9083***	8.9083***	9.0830***	9.0830***
	(0.0856)	(0.0490)	(0.0775)	(0.0625)	(0.1042)
N	841	841	841	841	841

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01