Baumol and Bowen Cost Effects in Research Universities

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Abstract

We estimate cost models for both public and private research universities and use partial differentials from these models to estimate different cost effects. The results suggest both Baumol's cost disease and Bowen's revenue theory drive cost higher and that Bowen effects are larger than Baumol effects. Tight revenue since 2008 reversed some declines in productivity and accelerated the trend in economizing on the use of tenure track faculty. This behavior under loose and tight revenue constraints is consistent with Bowen's revenue theory.

1. Introduction

Baumol's "cost disease" and Bowen's "revenue theory" are the primary higher education cost theories[1]. Baumol's cost disease is the disproportionate tendency of cost to rise in labor-intensive service industries. The combination of fixed proportions, stagnant productivity, and wages driven higher by productivity increases in the macro-economy leads to higher cost in the service industries (Baumol and Bowen, 1966) (Baumol and Batey-Blackman, 1995). Bowen's revenue theory[2] states universities raise all the money they can and then spend it on an unlimited list of projects that seemingly enhance "quality[3]" (HR Bowen, 1980) (Martin, 2011).

Baumol's cost disease suggests higher cost is imposed on colleges and universities who otherwise judiciously manage costs, while Bowen's revenue theory suggests colleges and universities do not minimize cost; one implies costs are driven by external factors, while the other implies higher cost has an internal origin. 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 cost? Our goal is to deconstruct real cost changes from 1987 to 2005 and from 2008 to 2011 into Baumol effects (outside factors) and Bowen effects (internal decisions).

During any interval part of the change in cost can be attributed to instruction/research output effects, cost saving due to productivity improvements, and input substitution. If total cost per student increased during an interval, then savings from improved productivity and input substitution were spent elsewhere and not passed on through lower cost per student. Hence, the total cost increase to be explained by Baumol and Bowen effects is the recorded increase in cost less the output effects plus the cost savings spent elsewhere.

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[1] Bowen's revenue theory is also known as Bowen's rule. Two additional cost drivers are government mandates and bundling services not previously associated with higher education. Government mandates are an external source of cost increases and bundling is an internal source of cost increases.

[2] The theory 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).

[3] Simple quality maximization is inconsistent with cost minimization.

Baumol cost effects are driven by external wage and benefit costs. Wage and benefit costs per student are average market wages and average market benefits for each labor category. Therefore, the market wage/benefit costs must be separated from staffing decisions which are clearly internal. We consider several scenarios ranging from "all the changes in salaries and benefits are Baumol effects" to less drastic scenarios where some fractions of the changes are attributed to Baumol effects and some fraction attributable to Bowen internal staffing decisions.

Bowen effects include a portion of salaries and benefits, but also includes measures for revenue induced cost, reduced productivity, and governance problems. The central Bowen hypotheses are more revenue induces more spending and agency rents are taken through reduced productivity. The documented increase in administrative staff/student ratios throughout our study period is consistent with the agency rents issue (Greene, 2010) (Ginsberg, 2011) (Desrochers and Kirshstein, 2014). If agent incentives are incompatible with the principal's interests, one has a governance problem. In higher education, there are diverse principals and diverse agent groups. Conceptually, "shared governance" can restrain agent abuse. We estimate governance cost effects in our models.

Our approach then is to deconstruct the change in total cost from 1987 to 2005 and from 2008 to 2011 into components reflecting output effects, cost savings, and changes in salaries and benefits, revenue, productivity, and governance. We estimate a fully specified log-linear total cost equation that can support both Baumol and Bowen theories controlling for university and year fixed-effects. Using the estimates and a robust cluster covariance matrix, we estimate each component's contribution to the change in total cost and provide interval estimates. Next, we obtain estimates and interval estimates of the combined Baumol cost-factors and the combined Bowen cost factors. For Public Universities we conclude that the Bowen effects are larger in both the 1987-2005 and 2008-2011 periods at the 0.1% and 5% levels of significance, respectively. For the Private Universities the same test shows Bowen effects larger in both periods at the 1% and 10% levels, respectively. The reduced significance of the effects in the latter period is consist with Bowen's theory.

2. Cost Minimization and Quality.

Cost Minimization. Let the "strong form" cost disease hypothesis be colleges and universities minimize costs thus all cost increases are driven by external forces[4]. Let the "strong form" revenue theory be these institutions do not minimize costs and all cost increases are driven by available revenues and staffing decisions; cost increases arise internally. If costs are minimized, duality conditions are satisfied and the control variables are output(s) and resource prices (Mas-Colell et al., 1995, 139-143). H R Bowen's revenue theory (1980), Parkinson's Law (1955), bureaucratic entropy (Hutcheson and Prather, 1979), and the theory of bureaucracies (Niskanen, 1994) find bureaucracies do not minimize costs and expenditures are driven by staffing decisions capped by available revenues[5]. The two strong form theories suggest different control variables for higher education cost studies.

Therefore, cost function specification issues depend on the evidence supporting cost minimization in higher education[6]. There is little theoretical, empirical, or anecdotal evidence that supports the assumption that higher education costs are minimized. H R Bowen provided ample evidence that colleges and universities do not minimize costs (1980, 15, 151, 168). Since cost cannot be minimized without output measures, Bowen's empirical conclusions are supported by the absence of reliable output metrics in higher education[7].

The theory of bureaucracy holds that bureaucrats seek to maximize the difference between the budget allocation and the minimum cost of providing the service they produce (Niskanen, 1994, 269-283). Since the discretionary surplus cannot be taken as income, the surplus is spent on additional staff, capital equipment, perquisites, and items of interest to those who approve the bureaucrat's budget. Spending the

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[4] By definition if costs are minimized there are no internal cost inefficiencies.

[5] Under these theories, staffing decisions are not driven by an optimization process with the necessary and sufficient conditions required to solve for optimal staffing ratios, they are the product of negotiated decisions. Each staffing ratio is idiosyncratic to the negotiations at different institutions. Hence, staffing decisions drive costs at different institutions. The only way these theories can be tested is to use staffing ratios as control variables.

[6] Most of the existing higher education cost literature assumes costs are minimized (Cohn, et al., 1989) (Koshal and Koshal, 1999) (Cohn, et al., 2004) (Johnes, et al., 2008) (Johnes, et al., 2009). Or, on a few occasions, assumes costs are not minimized (Newhouse, 1970) (James, 1978) (Brinkman, 1989, 1990) (Clotfelter, et al., 1991) (Ehrenberg, 2000). To our knowledge, this is the first paper to accommodate both theories in the same specification.

[7] The absence if these output metrics is why higher education services are experience goods.

surplus means the minimum cost of providing the service cannot be separated from the total amount spent; in other words, minimum cost is the unobserved floor on total cost for a given output.

Cost minimization is a necessary condition for profit maximization but not for non-profit theory. Failure to minimize cost in a competitive for-profit firm is an existential threat since other cost minimizing firms will drive that firm out of business; the market imposes a rude discipline on such firms. Even among for profit industries the incentive to minimize costs may decline as monopoly power increases (Leibenstein, 1966). There is no corresponding external pressure on non-profits to minimize costs.

Control variables are suggested by the theory tested. A classical test requires a specification consistent with both theories. Not including one set of control variables risks omitted variable bias, while including variables not called for by the correct theory merely adds superfluous variables that will be insignificant if only one theory is correct.

Quality. Higher costs may also be interpreted as quality investment; this is a plausible point for higher education. Unfortunately, there are few reliable quality metrics in higher education. If high cost is quality investment, the cumulative investment among research universities from 1987 to 2005 would be over one half trillion dollars. There should be evidence of higher quality at these investment levels. Most evidence suggests the quality of undergraduate education is in secular decline; completion rates declined, grade inflation increased, students spend less time studying, adult numeracy/literacy rates declined, and critical thinking skills did not improve[8].

The persistent increase in real revenues from grants at research universities suggests that both the quantity and quality of research output has increased[9]. However, grant activity is largely restricted to academic disciplines with clear paradigms, while money and faculty release time is granted to all faculty regardless of their ability to generate grants.

On balance, college cost models should include output(s), input prices, staffing variables, and revenue variables in order to avoid omitted variable bias in the estimation. Even though staff/student

[8] See (Arum and Josipa, 2011) (Bok, 2005) (Hersch and Merrow, 2005) (Massy, 2003).

[9] Since grant decisions are made by second parties, real grant revenue per student would not persistently increase if they were not getting the return they seek.

ratios are imperfect productivity measures, they are the only metrics available and unravelling the unprecedented high cost of college is a public policy priority.

3. Data

The data are drawn from the National Center for Education Statistics' IPEDS website. For public universities, it covers 137 Carnegie[10] I and II institutions, for the academic years 1987, 1989, 1991, 1999, 2005, 2008, 2010, and 2011. There are 1,122 usable observations in the public university estimating sample[11]. For private universities, the data cover 1987, 1989, 1991, 1999, 2002, 2005, 2008, 2010, and 2011. For each year, there are 60 Carnegie I and II private research universities; due to errors in reporting, not all of these observations are usable. In total, there are 506 observations[12] in the private university estimating sample[13], for an average of 56 each year. All dollar denominated variables are measured in constant 2008 dollars and the average values are weighted by FTE enrollment.

Variables. The cost[14] variable is real total cost per student (*tc*) for each academic year at each institution. All enrollment variables are fall enrollment values for the academic year in question.

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[10] 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.

[11] There are two public university samples in this study. The first is the estimating sample which contains 137 public institutions and 1,122 usable observations for the period studied. This sample is used in the estimation of the public university cost equations. The second sample is the cost analysis sample which contains 133 public institutions. 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 2005 observation. Only 133 public institutions provided usable data in all years.

[12] Given 60 private universities the potential number of observations for nine years is 540; however, the average cost per student at Cal Tech and Rockefeller University was at or above $1 million, while the next highest cost per student from the other 58 universities was approximately $275 thousand. Being about four times as high, costs per student at these two universities are outliers; hence, they were deleted. Within the remaining 58 universities, there were 16 observations with missing values.

[13] There are two private university samples in this analysis. The private university estimating sample contains 506 observations. Since the institutions in the beginning and ending periods for the cost decomposition sample must be the same, there are only 495 observations (55 universities) in the cost decomposition sample.

[14] Between 1987 and 2011 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 2011. Using "total educational and general expenditures

Enrollment is 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 FTE part-time students (*ptstu*). Hence, *ftestu* equals the sum of *ftug*, *ftgrad*, and *ptstu*.

All staff variables are fall values for each academic year. 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 FTE part-time faculty per 100 students (*ptf*), and the number of FTE faculty per 100 students (*ftef*). Hence, *ftef* equals the sum of *tt*, *cf*, and *ptf*. The number of graduate assistants (research and teaching) per 100 students is *ga*.

Nonacademic 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, *ftenap*, is the number of FTE executive, managerial, and professional employees per 100 students. The average number of "reports" per executive is measured by the sum of all FTE professional staff and all FTE nonprofessional staff divided by the number of FTE executives/managers (*staffsize*). Part-time staff employment is measured by the number of FTE part-time nonacademic professional staff per 100 students (*ptnap*) and the number of FTE part-time non-professional staff per 100 students (*ptnpro*).

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*).

All revenue variables are for the immediately preceding academic year; that is, the revenue variables for 2011 come from the revenue reported in 2010. We divide revenue into total revenue (*rev*) and investment income (*invest*) per student, which is the sum of investment income and income from the endowment per student. Further, we separate *rev* into core revenue (*core*), donor revenues (*donor*), hospital revenue (*hosp*), and all other revenue (*other*). Core revenue is net tuition/fees, room/board, and

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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 2011.

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

all government appropriations. Other revenue includes grants and other operating revenue. All revenue variables are real revenue per student.

Data Summaries. The data are split into two intervals: the pre-financial crisis and the post-financial crisis. The pre-crisis data interval is from academic years 1987 through 2005 and the post-crisis interval is from 2008 through 2011. There are two reasons for this partition. First, Bowen identifies periods when revenue constraints were tight and when they were loose; from 1929 to 1950 cost per student declined, from 1950 to 1970 cost per student rose rapidly, and from 1970 to 1980 cost per student declined slowly (Bowen, 1980, 29-47). He hypothesized the degree of revenue constriction is determined by economic conditions and how the public values higher education. The period from 1980 to the financial crisis is known as the "great moderation," when economic conditions were good and, according to surveys, the public placed an ever-higher value on postsecondary education. After the financial crisis, economic conditions became severe and the public was pressed by the cost of higher education, also supported by surveys (Immerwahr and Johnson, 2010). This provides a natural experiment for testing Bowen's revenue theory under "loose" and "tight" revenue constraints[16].

The second reason why we partition the data set is because Chow tests for both public and private universities reveal significant structural changes in the models before and after the crisis; these Chow tests are significant at the 0.001 or better level. Further, we use the before and after cost models to estimate the Baumol and Bowen effects in the cost deconstruction section.

Summaries of changes in the public university estimating sample before and after the financial crisis are contained in Table 1A and the corresponding summaries for private universities are contained in Table 1B. Average values, other than enrollment variables, are weighted[17] by enrollment. All growth rates are measured as average annual growth rates. An important aspect of this data is staff/student ratios are not fixed proportions as is suggested by Baumol's cost disease and staff/student ratios for faculty and nonacademic professional staff increased significantly over the period under study, which is consistent

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[16] This is not a test of the effect of "normal" recessions on higher education, since several short recessions occurred in both the 1950-1970 and the post 1980 intervals, while costs continued to rise.

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

with Bowen's revenue theory. These staffing trends are reported by others (Greene, 2010) (Ginsberg, 2011) (Desrochers and Kirshstein, 2014).

4. Model Specification.

Functional Form. For Total Cost (*tc*) we specify the log-linear regression

$$\ln\left(tc_{it}\right) = \beta' x_{it} + \alpha_i + u_{it}$$

where x_{it} are explanatory variables and where α_i are individual effects, with $i = 1, \ldots, n$ and $t = 1, \ldots, T_i$. The parameters β are estimated using fixed effects and we employ the robust cluster-corrected covariance matrix. The log-linear specification implies the expectation

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

The predicted value should incorporate an estimate of $E\left[\exp\left(u_{it}\right)\right]$. We use the sample average of the fixed effects residuals $N^{-1}\sum_i \sum_t \exp\left(\hat{u}_{it}\right)$, where *N* is the total number of estimation sample observations. We wish to compare outcomes in 1987 to those in 2005, and outcomes in 2008 to those in 2011. For each university *i*, we calculate

$$d(tc_i) = w_i \exp\left(\beta' x_{i,base}\right)\exp\left(\alpha_i\right)E\left[\exp\left(u_{it}\right)\right](\beta' dx_i)$$

where $x_{i,base}$ are regressor values in the base year 1987 or 2008, and $dx_i = x_{i,2011} - x_{i,2008}$ or $dx_i = x_{i,2005} - x_{i,1987}$. The differential is weighted by base year FTE student enrollment $w_i = ftestu_{i,base} \Big/ \left(\sum_{i=1}^{n} ftestu_{i,base}\right)$. Then for the *n* observations available in the common sample, the change in total cost is

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

Since $d(tc) = g\left(\hat{\beta}\right)$ is a nonlinear function of the estimator $\hat{\beta}$ inference uses the delta method. Details are included in the appendix.

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, a partial differential for the incremental effects would involve subsets of the independent variables corresponding to output effects, cost savings, salaries and benefits, productivity, revenue, and governance. These components are described in Section 5.

Independent Variables. All staffing, revenue, and enrollment variables are predetermined control variables. First, staffing and enrollment variables are the fall values for the academic year in question, while the dependent variable is the cost incurred over the following academic year. Further, salary, staff, and admission decisions are made in the spring/summer of the preceding academic year. Finally, the revenue variables are from the immediately preceding academic year. The control variables are temporally independent of the dependent variable[18] (Granger, 1969); hence, the control variables are not simultaneously determined with cost per student; the staffing decisions made in the preceding year drive costs in the current year.

Traditional higher education “outputs” are instruction, research, and public service. As does the existing cost minimization literature, we measure instruction output by the number of FTE students from fall enrollment (*ftestu*). Students enrolled are the countable number of individuals to whom value is to be added by the instruction process; they are inputs and not output per se. Instruction value added and the value of new knowledge created by research are unobservable, so proxy indicators are inevitable. As is the case in the existing cost literature, we do not have controls for public service output. This is a congenital problem with IPED’s data, since there is no breakdown of nonacademic staff assignments by activity or function in the data that would allow one to create proxies.

We use three proxies for research output, the number of tenure track faculty per 100 students, the number of full-time graduate students (*ftgrad*), and the number of graduate assistants (*ga*) per 100 students. This approach reveals university investments in research output, but it does not tell us the actual quantity or quality of research output. Note, we assume all these investments in research are quantity/quality investments in the estimation of Baumol and Bowen effects in the following section.

By definition, FTE faculty (*ftef*) is the sum of tenure track faculty (*tt*), contract faculty (*cf*), and full-time equivalent part time faculty (*ptf*). We include *ftef*, *cf*, and *ptf* as control variables[19]. Thus, holding

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[18] If this were not the case, existing cost studies could not use fall enrollment as a proxy for instruction output.

[19] We choose this specification rather than including *tt*, *cf*, and *ptf* because it represents a substitution of contract faculty or part time faculty for tenure track faculty if *ftef* is held constant while either *cf* or *ptf* increases. Alternatively, if we

cf and *ptf* constant an increase in *ftef* means an increase in the number of tenure track faculty per 100 students[20].

Similarly, *ftestu* is the sum of full-time undergraduates, full time graduate students, and FTE part time students. We include *ftestu*, *ftgrad*, and *ptstu* as independent variables; therefore, holding *ftestu* and *ptstu* constant, an increase in *ftgrad* means the university is "replacing" one full time undergraduate student with one full time graduate student, which reflects an increased emphasis on graduate education[29]. The number of graduate assistants per 100 students is a proxy for the number of PhD programs across departments within the university and the number of graduate students providing research support to each tenure track faculty member.

The relative size of different constituencies can influence the allocation of resources. The groups with the most control over resources are executive/managerial, nonacademic professional staff, and tenure track faculty. Therefore, our staffing strategy is to include staffing ratios for each constituency and choose a proxy for the relative authority over resource allocation between tenure track faculty and the full time nonacademic professional staff.

Each constituency is controlled for by *ftef*, *cf*, *ptf*, *ftenap*, *ptnap*, and *ftenpro*, *ptnpro*, and *staffsize*. The proxy for relative authority is the ratio of tenure track faculty to full time nonacademic professional staff (*ttnap*). If tenure track faculty preferences drive resource allocation, cost per student should be an increasing function of *ttnap.* If full time nonacademic professional staff preferences drive resource allocation, cost per student should be a decreasing function of *ttnap.* If shared governance restrains rent taking by either group, cost per student could be a convex function of *ttnap*. To allow for convexity we include *ttnap* and *ttnap2*, where *ttnap2* is *ttnap* squared.

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exclude *ftef* and include *tt*, *cf*, and *ptf* an increase in any one faculty classification while holding the other two constant represents an increase in FTE faculty.

[20] This interpretation follows directly from partial differentiation. Given enrollment and staffing variables where multiple variables sum to a grand total, all variables plus the total cannot be included in the model without creating perfect co-linearity. One variable must be excluded. By including the grand total variable and omitting one of the variables to be summed, we can interpret the signs of the coefficients for the remaining summed variables as substitution/complimentary effects with respect to the excluded variable. For instance, include *ftestu*, *ftgrad*, and *ptstu*; then, holding *ftestu* and *ptstu* constant and increasing *ftgrad* represents the effect on cost of replacing one full time undergraduate student with one full time graduate student. Or, include *ftef, cf,* and *ptf*; then, hold *ftef* and one of either *cf* or *ptf* constant and an increase in the faculty variable in question is the effect on cost of replacing one tenure track faculty member with either *cf* or *ptf*. Holding the sum variables constant, an increase in the total variable represents an increase in the omitted sum variable.

Bowen's revenue theory argues revenues cap cost so cost per student should be an increasing function of total revenue (*rev*) and investment income (*invest*)[21]. In addition to *rev,* we omit *core* and include *donor*, *hosp*, and *other.* Holding *rev* constant an increase in *donor*, *hosp*, or *other* represents a replacement of $1 in core revenue with $1 from one of those sources. Revenues from different sources have different risk characteristics. We expect core revenues to be the most predictable; hence, the coefficients for *donor, hosp,* and *other* should be negative. The controls for salaries and benefits are *staffsal* and *benstaff*. Year dummies are included.

Estimation Results. The fixed effects parameter estimates for public universities are reported in Table 2A, where there are three models, the pooled model, the pre financial crisis model and the post financial crisis model. The corresponding parameter estimates for private universities are contained in Table 2B. For "deconstructing costs," and the results in Tables 3 and 4 of the paper, the parameters in equation (1) are estimated using fixed effects since the Hausman test rejects the null hypothesis that the control variables and random effects are uncorrelated in each equation.[22] We employ robust cluster-corrected covariance matrix estimates because some residual correlation across time remains even after including year dummies.[23]

[21] These two variables are entered separately because investment income is more volatile than operating revenue; hence, financing recurrent cost with investment income is riskier.

[22] This conclusion was drawn based on 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. Augmenting the regression with the time averages of regressors, Mundlak's (1978) approach, and applying random effects [Greene, 2012, 381; Wooldridge, 2010, 332] offers no meaningful gain in efficiency. The standard form of the more general correlated random effects model of Chamberlain (1982) [Greene, 2012, 383; Wooldridge, 2010, 347-349] does not apply since our panel is unbalanced.

[23] The data used are not equally spaced through time. We have data from 1987, 1989, 1991, 1999, [2002 for the private universities], 2005, 2008, 2010, and 2011. For each equation, using the fixed effects residuals, we regress the residuals in time t against the residuals in time $t-1$, both with and without other regressors, for each year. 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.

In the public university results in Table 2A[24] and the private university results in Table 2B, coefficient signs among the significant variables are consistent with expectations. The coefficients for *ttnap* and *ttnap2* were significant in the public pooled and pre 2005 models; but not in the private models[25].

Among public universities, before the crisis, the signs for *ttnap* and *ttnap2* suggest total cost is convex in *ttnap* with an estimated turning point at 3.1 with 95% interval estimate [2.6, 3.7]. The elasticities of total cost at the quartiles of *ttnap* are −0.085, −0.109 and −0.131, respectively.[26] These results are consistent with the hypothesis that nonacademic professional staff members have more influence on resource use than tenure track faculty and that shared governance can limit rent seeking by both groups of insiders. After the crisis the coefficients of *ttnap* and *ttnap2* were not significant, individually or jointly, at the 0.05 level.

At both public and private universities, the signs for *ftenap* and *ftenap2* suggest total cost is concave in *ftenap*; total cost per student increases at a decreasing rate as the nonacademic professional staff per 100 student ratio increases. The implied peak values at public universities are 15 and 41 professional administrators per 100 students, before and after the crisis, respectively[27]; that value is within the data experience, as the maximum value is 38 per 100. However, only 4 percent of the 1,122 observations exceeded the 19 peak. The implied peak among private universities is 31 and 48 professional administrators per 100 students.[28] Those values are also within the data experience since the highest value is 76; however, only 6.5 percent of the 506 observations exceed this value. These results are robust to specification and additional data. At public universities, before the crisis, the elasticities of total cost at the quartiles of *ftenap* are 0.082, 0.103, and 0.111, respectively; after the crisis these values increase to 0.242, 0.314 and 0.399, respectively.[29]

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[24] Fixed effects estimates obtained using XTREG, FE in Stata 13.0

[25] The coefficient for *ttnap* was also not significant when entered without *ttnap2*.

[26] The 95% interval estimates are [−0.128, −0.042], [−0.165. −0.053] and [−0.199, −0.064], respectively

[27] 95% interval estimates for publics are [10.14, 19.78] and [10.79, 72.03] before and after the crisis, respectively.

[28] 95% interval estimates are [14.86, 47.82] and [35.71, 59.45] before and after the crisis, respectively.

[29] 95% interval estimates for the before crisis period are [0.014, 0.151], [0.014, 0.192] and [0.001, 0.221]. The interval estimates after the crisis are [0.124, 0.360], [0.169, 0.459] and [0.228, 0.570], respectively.

As anticipated by Bowen's revenue theory, total cost is an increasing function of revenue from the previous year among all universities. The coefficient for revenue is positive and significant at the 1% level in both models. While the coefficients for *donor*, *hosp*, *other*, and *invest* are negative, they are generally not significant at public universities. The coefficients for *donor, hosp, other*, and *invest* are negative and significant at private universities.

5. Cost Analysis

In this section, we deconstruct cost changes into Baumol and Bowen effects for the pre and post financial crisis periods from 1987 to 2005 and from 2008 to 2011. We use partial differentials from the average cost models to make the different estimates. Among the 133 public institutions in the cost analysis sample, total cost per student increased by $11,294 from 1987 to 2005 and by $703 from 2008 to 2011. Among the 55 private institutions in the cost analysis sample, total cost per student increased by $27,181 from 1987 to 2005 and by $4,740 from 2008 to 2011. A weighted average value for the partial differential estimates is created using 1987 enrollment as the weights for the 1987 to 2005 interval and 2008 enrollment as the weights for the 2008 to 2011 interval.

Partial Differentials. The total change in cost for each interval is estimated by partial differentials using subsets of the control variable 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. Output Effects: *ftestu*, *ftgrad*, *ftef*, g*a*
   Instruction: *ftestu*
   Research: *ftgrad, ftef (tt), ga*
2. Cost Savings: *cf*, *ptf*, *ptstu*, *ftenpro*, *ptnpro*
3. Baumol Benefits: decomposed *benstaff*.
4. Baumol Salaries: decomposed *staffsal*.
5. Bowen Productivity: *ftenap*, *ftenap2*, *ptnap*, *staffsize*
6. Bowen Salaries: decomposed *staffsal*.
7. Bowen Benefits: decomposed *benstaff*.
8. Bowen Governance: *ttnap, ttnap2*.

9. Bowen Revenue: *rev*, *invest*, *donor*, *hosp*, *other*.

The constant dollar estimates for all of the within sample forecast estimates for each type of institution can be found in Tables 3A, 3B, 4A, and 4B. Tables 3A and 4A contain the estimates for public and private universities respectively for the loose constraint period and Tables 3B and 4B contain the estimates for the tight constraint period.

Salaries and Benefits. The salary and benefits variables are total salaries paid divided by total FTE staff and total benefits paid divided by total full time staff. The numerators in these ratios are the number of staff members weighted by average salary/benefit compensation per employee type and the denominator is the total number of staff members[30]. The average value can be an accurate reflection of real wages/benefits paid between say 1987 and 2011 only if the staff distribution is constant. A priori, we know the distribution is not constant. The cost disease says the external macro-economy drives wage rates not the staffing pattern chosen by the institution, while the revenue theory says staffing patterns drive cost. Hence, we separate wage/benefit effects from staffing pattern effects.

The impact of changing staffing patterns on both *staffsal* and *benstaff* is measured by correlation analyses between *staffsal/benstaff* and all of the staffing variables. At public universities, correlation analysis reveals that 48 percent of *staffsal* variation and 49 percent of *benstaff* variation is accounted for by changes in staffing variables. Similarly at private universities, correlation analysis reveals that 38 percent of the variation in *staffsal* and *benstaff* is accounted for by variation in staffing variables. Therefore, at public universities we assume the change in Baumol salaries equals 52 percent of the observed change in *staffsal* and 51 percent of the observed change in *benstaff*. At private universities, 62 percent of the observed change in *staffsal* and *benstaff* are Baumol effects.

Output Effects. The instruction output effects for both university types during both constraint periods reduced average cost per student. The average institutions experienced increases in enrollment during both periods. Similarly, research investments increased for both university types during both constraint periods. As is implied by the relative growth in their graduate programs throughout the period, private universities made much larger investments in research than public universities. Since we preclude

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[30] Let w_i be the wage paid to the i^{th} type of FTE employee, e_i be the number of i^{th} type employees, and W be the average salary paid; then, $W = \sum w_i e_i / \sum e_i$. The computation of average benefits paid is similar.

the staffing effects on research investments from either Baumol or Bowen effects, we explicitly assume all higher costs associated with more tenure track faculty, more graduate students, and more graduate assistants are investments in higher research quantity/quality. Potentially, this will understate Bowen effects on cost.

Rising enrollment led to lower average cost per student. Since private university enrollment is around 58 percent of public university enrollment, one would expect the scale effects to be larger at private universities than at public universities, given increasing returns to scale. That is indeed what we observe; the instruction output effect in absolute value is greater at private universities than at public universities during both periods. Both university types substituted contract faculty and/or part time faculty for tenure track faculty throughout the period under study; however, we control for these actions in the cost control section. Hence, the enrollment effects on average cost per student most likely reflect returns to scale in instruction.

Given the estimated increases in research investment for both university types and the representative university's FTE enrollment, the representative public university increased its total annual investment in research by $70.3 million from 1987 to 2011 and the representative private university increased its total annual investment in research by $550 million. The private university increase in research investment is approximately 8 times as large as the public university increase in research investment.

Cost Saving. Both university types lowered costs by reducing non-professional staff/student ratios and substituting contract and part-time faculty for tenure track faculty throughout the period under study. In 1987 tenure track faculty accounted for 64 percent of FTE faculty at public universities and 50 percent at private universities, by 2011 those percentages had fallen to 53 percent and 43 percent, respectively. They also lowered costs through declines in the number of part time students. During the loose constraint period, both university types took selective productivity steps that excluded nonacademic professional staff and during the tight constraint period, they adopted across the board productivity improvements; this is the major change in staffing behavior between the loose and tight regimes.

Since total cost increased, it is clear cost savings were spent on other activities. Therefore, the change in cost to be explained is equal to the actual change less the output effects plus the cost that was saved. These are the amounts that must be accounted for by Baumol and Bowen effects. At public universities the estimates for total change in cost per student are $12,126 from 1987 to 2005 and $1,644 from 2008 to 2011 and at private universities the estimates for total change are $37,725 and $6,014 respectively.

Baumol Effects. At public universities, Baumol effects account for 23 percent of total change during the loose constraint period and 32 percent during the tight revenue period. At private universities, Baumol effects account for 20 percent during the loose revenue period and 26 percent during the tight revenue period.

Bowen Effects. During the loose constraint period, the total Bowen effect at public universities was 51 percent of the cost change to be explained. For the same period, the total Bowen effect at private universities was 43 percent of the cost change to be explained. For the tight constraint period, Bowen effects accounted for 29 percent at public universities and 64 percent at private universities.

Overview of Cost Analysis. At the bottom of Tables 3 and 4, we calculate four different Bowen/Baumol ratios: 1) the ratio from the estimated total effects; 2) the ratio assuming all salary and benefits are Baumol effects; 3) an estimate of the lower bound (the total Bowen effect equals its lower bound and the Baumol effect equals its upper bound); and 4) an estimate of the upper bound (the total Bowen effect equals its upper bound and the Baumol effect equals its lower bound).

From Tables 3A and 4A, estimated Bowen/Baumol ratios exceed $2 to $1. The combined effects account for 74 percent of the public university change during the loose revenue period and 63 percent of the private university change for the same period. During the tight revenue constraint, both effects account for 61 percent of the public university change and 90 percent of the private university change. Using a one-tail t-test, we conclude, at the 0.05 level of significance, that the Bowen total cost effect is at least 1.6 times the Baumol effect for both university types during the loose constraint period. During the tight constraint period, we find at the 0.05 level the Bowen total cost effect is significantly larger than the Baumol effect for both university types during the tight constraint period. The forgoing suggests tight revenue constraints tend to moderate Bowen effects as Bowen speculated.

The most favorable case to be made for Baumol effects relative to Bowen effects is to assume that all changes in salaries and benefits are Baumol effects. In this case, for every $1 of increased cost explained by Baumol effects there would be $0.7 in Bowen effects during the loose revenue period and negligible effects during the tight revenue period at public universities. At private universities, the Bowen/Baumol ratio would be $1 to $1 during the loose constraint period and $1.1 to $1 during the tight constraint period.

The lower bound for the Bowen/Baumol ratio is estimated by assuming Bowen effects are at the lower bound while Baumol effects are at the upper bound. The ratio for public universities during the loose constraint period is $1.2 and negligible in the tight constraint period. The ratio for private universities during the loose constraint period is $0.9 and $0.6 in the tight constraint period.

An upper bound for the Bowen/Baumol ratio is implied by assuming the Bowen effect is at the upper bound and the Baumol effect is at the lower bound. In this case, the public university ratio would be $4.2 in the loose constraint period and $4.6 in the tight constraint period. The private university upper bound ratio would be $6.2 in the loose constraint period and $12.5 in the tight constraint period.

The most significant changes between loose constraints and tight constraints are the productivity shifts from reductions in productivity to increases in productivity. The data also reveal all institutions intensified their traditional cost saving behavior after 2005. From this information and the historical record for decreases in cost during the Great Depression and during the 1970's it appears tight revenue lowers agency effects, while loose revenue tends to induce agency effects. This is very intuitive.

6. Conclusions

We estimate average cost functions for public and private research universities using a unified theory of higher education cost. The results demonstrate that staff/student ratios and revenues are collectively and individually significant control variables. As hypothesized by Bowen, revenues tend to drive costs higher in both public and private research universities. Further, the results suggest economies of scale in instruction and external compensation costs drive costs.

The partial differential method is used to estimate cost changes from 1987 to 2005 and from 2008 to 2011 into their component parts. The primary cost categories are output effects, cost saving, Baumol effects, and Bowen effects. We find that both Baumol and Bowen effects drive costs higher; however, Bowen effects tend to be larger than Baumol effects during loose revenue constraints, while Bowen effects tend to moderate during tight revenue constraints. Therefore, most of the increases in cost during this period came from decisions taken inside higher education.

From 1987 to 2011, the number of full time nonacademic professional staff per tenure track faculty member doubled at public universities and increased by 47 percent at private universities. A research university's core missions are teaching and research. The central question is how increasing nonacademic professional staff to tenure track faculty ratios is consistent with increasing the quantity and quality of teaching and research? Tenure track faculty members are essential to both missions, while nonacademic staff members are not. This question deserves more research.

Our model does not account for all possible influences on cost. As much as a third of the historical cost increases remain unexplained. We have not accounted for all possible Baumol or Bowen effects in the models. Likely sources of additional Baumol effects are government mandates, laboratory costs and energy costs for which we have no direct controls. Similarly, we have not accounted for all possible Bowen effects such as reputation competition and the arms race to spend more on physical plant and public service. We include higher tenure track/student ratios as investments in research output and this may overestimate investment in research and under estimate Bowen agency effects, since lower teaching loads spread to most tenure track faculty over this period regardless of individual research output. Our research is the first deconstruction of cost changes into their component parts and that is an important step in learning how to control college costs.

We carried the analysis as far as the existing data will permit. H R Bowen noted that a complete source and use of funds analysis cannot be completed with the existing data (1980, 143). He called for data reform at that time. Without a complete source and use analysis, a definitive higher education cost analysis is not possible.

The most glaring data omissions are salaries/benefits paid to administrators, athletic staff, student services staff, development staff, and other professional staff categories. In addition, the number of employees by this classification are not reported; nor, are there data on gender, race, or ethnicity in these categories. By contrast, the salary/benefits and staffing by gender, race, and ethnicity among faculty has been reported consistently since 1980. It is an anomaly that the data exists for faculty, but not for administrators.

Table 1A
Public Research Universities: Average Values[1]

Year	1987	2005	2008	2011	87/05	08/11
Total Cost	$28,578	$39,51`3	$41,447	$41,896	2.1	0.4
Enrollment:						
FTE Students	16640	20230	21396	22846	1.2	2.3
FT Undergrad	12129	15012	16075	17035	1.3	2.0
FT Grad	2316	3266	3488	3785	2.3	2.8
PT Students	2194	1951	1984	2026	-0.6	0.7
Teaching:						
Contract Faculty	1.9	2.0	2.4	2.7	0.2	4.4
PT Faculty	0.4	0.9	0.7	0.7	6.0	2.8
Grad Assist	1.4	2.5	2.2	2.4	4.4	3.5
Tenure Track	4.3	4.4	4.5	3.9	0.0	-4.0
TT fac/NA ProStaff	1.0	0.6	0.6	0.5	-2.0	-3.1
FTE Faculty	6.7	7.4	7.5	7.4	0.6	-0.7
Administration:						
FTE NA ProStaff	6.6	8.8	9.5	9.1	1.9	-1.4
FTE Exec/Mgr	1.3	1.3	1.4	1.3	-0.1	-2.6
FTE Pro	5.2	7.5	8.1	7.8	2.4	-1.2
FTE Non-Pro	11.2	8.3	7.9	7.4	-1.4	-2.5
Staff Size	14.4	15.9	15.5	15.9	0.6	0.9
Salaries/Benefits:						
Full Prof	$94,247	$108,751	$111,304	$111,358	0.9	0.0
Assistant Prof	$59,205	$67,332	$68,142	$68,347	0.8	0.1
Staff Salary	$53,807	$75,123	$76,020	$79,081	2.2	1.3
Benefits	$12,076	$21,408	$23,616	$26,525	4.3	4.1
Revenue:						
Total Rev	$27,338	$41,312	$40,905	$42,660	2.8	1.4
Core	$18,115	$20,906	$20,956	$20,376	0.9	-0.9
Donor	$1,217	$1,269	$1,256	$1,189	0.2	-1.8
Hospital	$2,521	$4,681	$4,419	$5,488	4.8	8.1
Other	$5,485	$14,456	$14,274	$15,606	9.1	3.1
Invest Income	$245	$2,725	$2,641	$1,574	56.3	-13.5

[1] Enrollment variables are simple averages, and all other variables are weighted by FTE enrollment.

Table 1B
Private Research Universities: Average Values[1]

Year	1987	2005	2008	2011	87/05	08/11
Total Cost	$62,919	$90,229	$95,087	$96,344	2.4	0.4
Enrollment:						
FTE Students	9516	12060	12536	13242	1.5	1.9
FT Undergrad	5512	6893	6986	7300	1.4	1.5
FT Grad	1934	4169	4458	4904	6.4	3.3
PT Students	2070	998	1092	1039	-2.9	-1.6
Teaching:						
Contract Faculty	4.3	4.3	5.7	6.7	0.0	6.1
PT Faculty	1.2	1.2	2.1	1.5	0.2	-8.9
Grad Assist	0.9	2.3	2.3	2.3	8.0	0.4
Tenure Track	5.3	6.6	6.5	6.2	1.4	-1.7
TT fac/NA ProStaff	0.6	0.4	0.4	0.4	-1.6	-1.0
FTE Faculty	10.6	12.0	14.3	14.5	0.8	0.3
Administration:						
FTE NA ProStaff	11.7	17.1	18.4	18.1	2.6	-0.6
FTE Exec/Mgr	3.6	4.4	5.4	5.3	1.3	-0.6
FTE Pro	8.1	12.7	13.0	12.8	3.1	-0.6
FTE Non-Pro	18.8	15.0	14.9	13.5	-1.1	-3.1
Staff Size	10.9	10.7	8.0	7.7	-0.1	-1.2
Salaries/Benefits:						
Full Prof	$108,186	$135,987	$139,377	$143,464	1.4	1.0
Assistant Prof	$63,209	$78,624	$81,059	$84,290	1.4	1.3
Staff Salary	$56,477	$109,540	$83,614	$89,151	5.2	2.2
Benefits	$12,967	$22,870	$23,550	$26,437	4.2	4.1
Revenue:						
Total Rev	$55,602	$83,021	$88,415	$94,692	2.7	2.4
Core	$22,510	$26,821	$28,067	$30,038	1.1	2.3
Donor	$5,363	$11,931	$13,423	$14,056	6.8	1.6
Hospital	$8,738	$13,278	$14,842	$15,172	2.9	0.7
Other	$18,991	$30,991	$32,083	$35,427	3.5	3.5
Invest Income	$3,430	$34,546	$52,851	$44,218	50.4	-5.4

[1] Enrollment variables are simple averages, and all other variables are weighted by FTE enrollment.

Table 1 Continued
Variable Glossary

Variable	Brief Description
tc	real total cost per student
cf	contract faculty per 100 students
ptf	part-time faculty per 100 students
ga	graduate assistants per 100 students
tt	tenure track faculty per 100 students
ftef	FTE faculty per 100 students
ftestu	FTE student enrollment
ftgrad	full-time graduate students including professional students
ptstu	part-time students
ttnap	tenure-track faculty/full-time nonacademic professional employees
ttnap2	ttad squared
staffsal	total salaries and wages paid per FTE staff employed
benstaff	total employee benefits paid per full-time staff member
ftenap	FTE executive and professional employees per 100 students
ftenap2	ftenap squared
ftenpro	FTE non-professional employees per 100 students
ptnap	part-time non-academic professionals per 100 students
ptnpro	part-time nonprofessional staff per 100 students
staffsize	FTE professional/nonprofessional staff per executive
rev	real revenue per student in prior year
donor	real donor revenues per student in prior year
hosp	real hospital revenue per student in prior year
other	real other revenue per student in prior year
invest	real investment income per student in prior year

Table 2A Total Cost equation, Publics: pooled and Pre- and Post-2005

	Pooled 1987-2011	before 1987-2005	after 2008-2011
cf	-0.0399***	-0.0514***	-0.0102
	(0.0083)	(0.0102)	(0.0152)
ptf	-0.0257***	-0.0192	-0.0123
	(0.0091)	(0.0135)	(0.0141)
ga	0.0041	0.0080	0.0017
	(0.0030)	(0.0064)	(0.0014)
ftef	0.0590***	0.0735***	0.0318**
	(0.0090)	(0.0103)	(0.0153)
ftestu	-0.0037	-0.0082*	-0.0030
	(0.0028)	(0.0045)	(0.0021)
ftgrad	0.0155	0.0273**	-0.0002
	(0.0098)	(0.0114)	(0.0102)
ptstu	0.0201***	0.0184**	-0.0270***
	(0.0073)	(0.0084)	(0.0063)
ttnap	-0.1772***	-0.1870***	0.3011*
	(0.0514)	(0.0484)	(0.1683)
ttnap2	0.0309***	0.0299***	-0.0699
	(0.0093)	(0.0084)	(0.0473)
staffsal	0.0048***	0.0067***	0.0023**
	(0.0006)	(0.0008)	(0.0010)
benstaff	0.0005	0.0012	0.0039***
	(0.0013)	(0.0021)	(0.0014)
ftenap	0.0308***	0.0298**	0.0529***
	(0.0089)	(0.0118)	(0.0149)
ftenap2	-0.0008***	-0.0010***	-0.0006
	(0.0003)	(0.0004)	(0.0004)
ftenpro	0.0164***	0.0262***	-0.0005
	(0.0028)	(0.0033)	(0.0011)
ptnap	0.0207	0.0200	-0.0218
	(0.0181)	(0.0184)	(0.0327)
ptnpro	0.0139	-0.0078	0.0362**
	(0.0109)	(0.0084)	(0.0155)
staffsize	0.0008*	0.0015***	0.0007
	(0.0004)	(0.0004)	(0.0008)
rev	0.0099***	0.0058*	0.0073***
	(0.0026)	(0.0030)	(0.0021)
donor	-0.0026	-0.0002	-0.0023
	(0.0081)	(0.0080)	(0.0070)
hosp	-0.0020	0.0013	-0.0041**
	(0.0025)	(0.0026)	(0.0016)
other	-0.0047*	-0.0026	-0.0029*
	(0.0025)	(0.0031)	(0.0017)
invest	-0.0003	-0.0065***	0.0007
	(0.0006)	(0.0017)	(0.0009)
d1989	-0.0264***	-0.0156*	.
	(0.0095)	(0.0092)	.
d1991	-0.0859***	-0.0601***	.
	(0.0169)	(0.0168)	.
d1999	0.0576***	0.0581**	.
	(0.0189)	(0.0227)	.
d2005	0.0586**	0.0665*	.
	(0.0254)	(0.0358)	.
d2008	0.0910***	.	.
	(0.0282)	.	.
d2010	0.0888***	.	0.0023
	(0.0306)	.	(0.0071)
d2011	0.0960***	.	0.0225**
	(0.0312)	.	(0.0107)
Constant	9.0749***	8.9431***	9.2777***
	(0.0901)	(0.1256)	(0.1513)
N	1122	700	422

Robust standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 2B Total Cost equation, Privates: pooled and Pre- and Post-2005

	Pooled 1987-2011	before 1987-2005	after 2008-2011
cf	-0.0192*	-0.0203	0.0313*
	(0.0114)	(0.0131)	(0.0174)
ptf	-0.0109	-0.0122	0.0269
	(0.0071)	(0.0083)	(0.0168)
ga	-0.0001	-0.0017	0.0154**
	(0.0068)	(0.0066)	(0.0074)
ftef	0.0251**	0.0314**	-0.0156
	(0.0121)	(0.0143)	(0.0150)
ftestu	-0.0909***	-0.1038***	-0.0117
	(0.0317)	(0.0310)	(0.0106)
ftgrad	0.1119***	0.0989**	-0.0001
	(0.0387)	(0.0373)	(0.0207)
ptstu	0.1070***	0.1187***	0.0285*
	(0.0399)	(0.0394)	(0.0146)
ttnap	-0.0738	-0.0481	-0.7598
	(0.0882)	(0.0782)	(0.8231)
ttnap2	0.0130	0.0031	0.7826
	(0.0139)	(0.0141)	(0.6361)
staffsal	0.0031***	0.0028***	0.0043***
	(0.0009)	(0.0010)	(0.0010)
benstaff	0.0017	0.0014	0.0007
	(0.0026)	(0.0030)	(0.0017)
ftenap	0.0155**	0.0125	0.0389***
	(0.0074)	(0.0085)	(0.0125)
ftenap2	-0.0002**	-0.0002	-0.0004***
	(0.0001)	(0.0001)	(0.0001)
ftenpro	0.0113***	0.0081***	0.0144***
	(0.0031)	(0.0029)	(0.0042)
ptnap	-0.0147*	-0.0073	0.0268
	(0.0079)	(0.0106)	(0.0163)
ptnpro	0.0093	0.0093	-0.0060
	(0.0072)	(0.0079)	(0.0157)
staffsize	-0.0001	-0.0007	-0.0043*
	(0.0012)	(0.0016)	(0.0024)
rev	0.0171***	0.0209***	0.0082**
	(0.0055)	(0.0062)	(0.0031)
donor	-0.0128**	-0.0166***	-0.0077**
	(0.0057)	(0.0062)	(0.0033)
hosp	-0.0138**	-0.0175**	-0.0069**
	(0.0062)	(0.0070)	(0.0028)
other	-0.0162**	-0.0192**	-0.0081**
	(0.0065)	(0.0075)	(0.0033)
invest	-0.0001***	-0.0001	-0.0000
	(0.0001)	(0.0003)	(0.0000)
d1989	0.0620***	0.0740***	.
	(0.0225)	(0.0191)	.
d1991	0.0181	0.0450	.
	(0.0292)	(0.0327)	.
d1999	-0.0005	0.0178	.
	(0.0377)	(0.0408)	.
d2002	0.0147	0.0688	.
	(0.0490)	(0.0548)	.
d2005	0.0599	0.1118**	.
	(0.0516)	(0.0512)	.
d2008	0.1003*	.	0.0036
	(0.0579)	.	(0.0145)
d2010	0.1146*	.	0.0062
	(0.0654)	.	(0.0076)
d2011	0.1049	.	.
	(0.0672)	.	.
constant	10.1526***	10.2206***	10.0709***
	(0.2025)	(0.2314)	(0.3860)
N	506	333	173

Robust standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 3A
Public Universities
Loose Revenue Constraint: 1987 to 2005

		Lower[1]	Upper[1]
Actual Change	$11,294		
Cost Saving	-$3,346	-$4,196	-$2,495
Output Effects	$2,514	$1,283	$3,744
Instruction	-$868		
Research	$3,382		
Total Change	$12,126	10812	13439
Baumol Effects:			
Salaries	$2,605	$1,942	$3,268
Benefits	$175	-$445	$795
Subtotal	$2,780	$1,868	$3,691
Bowen Effects:			
Productivity	$877	-$27	$1,781
Salaries	$2,404	$1,792	$3,017
Benefits	$168	-$428	$764
Governance	$953	$464	$1,443
Revenue	$1,787	-$34	$3,608
Subtotal	$6,190	$4,543	$7,837
Explained	$8,970	$6,842	$11,098
B/B Ratios:			
Estimated	2.2		
All Baumol W/B	0.7		
Lower Bound	1.2		
Upper Bound	4.2		

[1] Lower and upper bounds are derived from 95% confidence intervals derived from robust standard errors.

Table 3B
Public Universities
Tight Revenue Constraint: 2008 to 2011

		Lower	Upper
Actual Change	$703		
Cost Saving	-$243	-$853	$368
Output Effects	-$191	-$545	$163
Instruction	-$173		
Research	-$18		
Productivity	-$507	-$728	-$287
Total Change	$1,644	$1,064	$2,224
Baumol Effects:			
Salaries	$189	$24	$353
Benefits	$332	$105	$560
Subtotal	$521	$258	$784
Bowen Effects:			
Salaries	$174	$22	$326
Benefits	$319	$101	$538
Governance	-$366	-$743	$10
Revenue	$357	-$124	$838
Subtotal	$484	-$207	$1,175
Explained	$1,005	$160	$1,849
B/B Ratios:			
Estimated	0.9		
All Baumol W/B	0.0		
Lower Bound	-0.3		
Upper Bound	4.6		

[1] Lower and upper bounds are derived from 95% confidence intervals derived from robust standard errors.

Table 4A
Private Universities
Loose Revenue Constraint: 1987 to 2008

		Lower[1]	Upper[1]
Actual Change	$27,181		
Cost Saving	-$12,384	-$19,432	-$5,336
Output Effects:	$1,839	-$4,190	$7,869
Instruction	-$20,165		
Research	$22,004		
Total Change	$37,725	$29,943	$45,507
Baumol Effects:			
Salaries	$6,905	$2,146	$11,664
Benefits	$561	-$1,870	$2,992
Subtotal	$7,466	$3,678	$11,254
Bowen Effects:			
Productivity	$1,161	-$2,107	$4,430
Salaries	$4,232	$1,315	$7,149
Benefits	$344	-$1,146	$1,834
Governance	$417	-$683	$1,517
Revenue	$10,055	$4,006	$16,104
Subtotal	$16,209	$9,690	$22,729
Explained	$23,675	$15,213	$32,137
B/B Ratios:			
Estimated	2.2		
All Baumol W/B	1.0		
Lower Bound	0.9		
Upper Bound	6.2		

[1] Lower and upper bounds are derived from 95% confidence intervals derived from robust standard errors.

Table 4B
Private Universities
Tight Revenue Constraint: 2008 to 2011

		Lower[1]	Upper[1]
Actual Change	$4,740		
Cost Saving	$93	-$2,714	$2,900
Output Effects:	-$1,402	-$3,022	$219
Instruction	-$1,126		
Research	-$276		
Productivity	$35	-$735	$805
Total Change	$6,014	$2,446	$9,582
Baumol Effects:			
Salaries	$1,469	$716	$2,222
Benefits	$114	-$471	$699
Subtotal	$1,583	$650	$2,516
Bowen Effects:			
Salaries	$900	$439	$1,362
Benefits	$70	-$288	$428
Governance	$385	-$957	$1,728
Revenue	$2,489	$258	$4,719
Subtotal	$3,845	$1,472	$6,217
Explained	$5,428	$2,740	$8,116
B/B Ratios:			
Estimated	2.4		
All Baumol W/B	1.1		
Lower Bound	0.6		
Upper Bound	12.5		

[1] Lower and upper bounds are derived from 95% confidence intervals derived from robust standard errors.

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Baumol and Bowen Cost Effects in Research Universities: Econometric Appendix

A.1 Model Specification and Estimation

For Total Cost (*tc*) we specify the log-linear regression

$$\ln\left(tc_{it}\right) = \beta' x_{it} + \alpha_i + u_{it} \tag{1}$$

where α_i are individual effects, with $i = 1,\ldots,n$ and $t = 1,\ldots,T_i$. For the purpose of "deconstructing costs," and the results in Tables 3 and 4 of the paper, the parameters β are estimated using fixed effects. Denote the parameter estimates $\hat{\beta}$ and the robust cluster-corrected covariance matrix estimate $\hat{V}$.

A.2 The Partial Differentials

The log-linear specification implies the expectation

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

The predicted value should incorporate an estimate of $E\left[\exp\left(u_{it}\right)\right]$. We use the sample average of the fixed effects residuals $N^{-1}\sum_i \sum_t \exp\left(\hat{u}_{it}\right)$[31], where N is the total number of estimation 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 $\bar{\hat{u}}_{i\cdot} = T_i^{-1}\sum_t \exp\left(\hat{u}_{it}\right)$. Each of these corrections is very small and there were no meaningful differences among them in our calculations. Thus, the predicted tc_{it} is

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

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

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

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

We wish to compare outcomes in 1987 to those in 2005, and outcomes in 2008 to those in 2011. For each university *i*, we calculate

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

where $x_{i,base}$ are regressor values in the base year 1987 or 2008, and $dx_i = x_{i,2011} - x_{i,2008}$ or $dx_i = x_{i,2005} - x_{i,1987}$.[32] The differential is weighted by base year FTE student enrollment. Define

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

Then

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

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

$$d(tc) = \sum_{i=1}^{n} \hat{c}_i \exp\left(\hat{\beta}' x_{i,base}\right)\left(\hat{\beta}' dx_i\right) \tag{8}$$

[32] Our estimation panel is unbalanced. However, we use a common sample to compute the comparison values.

where $\hat{c}_i = w_i \exp(\hat{\alpha}_i)\left\{N^{-1}\sum_i \sum_t \exp(\hat{u}_{it})\right\}$. Since $d(tc) = g(\hat{\beta})$ is a nonlinear function of the estimator $\hat{\beta}$ inference uses the delta method[33]. The asymptotic distribution of the estimator in (8) is

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

where $J = \partial g(\beta)/\partial\beta'$, so that the estimator of the asymptotic variance of $d(tc)$ is $\hat{V}_{d(tc)} = \hat{J}\hat{V}\hat{J}'$, with $\hat{J} = \partial g(\beta)/\partial\beta'\big|_{\beta=\hat{\beta}}$ and $\hat{V}$ is a robust cluster corrected covariance matrix of $\hat{\beta}$.[34]

Given the form of the differential in (8) the Jacobian is

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

A.3 Deconstructions

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, a partial differential for the incremental effects would involve subsets of the independent variables as described in Section 5 of the paper; Output effects, cost savings, etc. To compare the theories of Baumol (*bau*) and Bowen (*bow*) we compute differential estimates for each. The Baumol components are salary and benefits, so

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

[34] Coefficient estimation was carried out using Stata 13.0. Subsequent calculations were carried out in SAS 9.3/IML.

$$d(tc)_{tot}^{bau} = d(tc)_{sal}^{bau} + d(tc)_{ben}^{bau}$$

$$= \sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,base}\right)\left[\beta'\left(dx_{i,sal}^{bau} + dx_{i,ben}^{bau}\right)\right] \qquad (11)$$

$$= \sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,base}\right)\left(\beta' dx_{i,tot}^{bau}\right)$$

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

$$d(tc)_{tot}^{bow} = d(tc)_{prod}^{bow} + d(tc)_{sal}^{bow} + d(tc)_{ben}^{bow} + d(tc)_{rev}^{bow} + d(tc)_{gov}^{bow}$$

$$= \sum_{i=1}^{n} c_i \exp\left(\beta' x_{i,base}\right)\left(\beta' dx_i^{bow}\right) \qquad (12)$$

where

$$dx_i^{bow} = dx_{i,prod}^{bow} + dx_{i,sal}^{bow} + dx_{i,ben}^{bow} + dx_{i,rev}^{bow} + dx_{i,gov}^{bow} \qquad (13)$$

We would like to test the null and alternative hypotheses

$$\begin{aligned} H_0 &: d(tc)_{tot}^{bow} - h \cdot d(tc)_{tot}^{bau} = h(\beta) \leq 0 \\ H_1 &: d(tc)_{tot}^{bow} - h \cdot d(tc)_{tot}^{bau} = h(\beta) > 0 \end{aligned} \qquad (14)$$

The test statistic is

$$t = \hat{h}(\beta) \big/ se\left[\hat{h}(\beta)\right] \qquad (15)$$

The numerator is

$$\hat{h}(\beta) = \sum_{i=1}^{n} c_i \exp\left(\hat{\beta}' x_{i,base}\right)\left(\hat{\beta}' dx_i^{bow}\right) - h \cdot \left[\sum_{i=1}^{n} c_i \exp\left(\hat{\beta}' x_{i,base}\right)\left(\hat{\beta}' dx_i^{bau}\right)\right]$$

$$= \sum_{i=1}^{n} c_i \exp\left(\hat{\beta}' x_{i,base}\right)\left[\hat{\beta}'\left(dx_i^{bow} - h \cdot dx_i^{bau}\right)\right] \qquad (16)$$

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

where $dx_i^h = dx_i^{bow} - h \cdot dx_i^{bau}$. The denominator of the *t*-statistic uses a variance calculation based on the delta method. Note that the form of the differential in (8) and (16) is the same, and thus the Jacobian matrix (10) is of the same form in both cases.

A.4 References

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