University Cost Structure in Taiwan *

Tsu-Tan Fu**
Institute of Economics
Academia Sinica
Taipei, Taiwan
Email: tfu@econ.sinica.edu.tw

Cliff J. Huang
Department of Economics
Vanderbilt University
Nashville, TN, USA 37235
Email: cliff.huang@vanderbilt.edu

Flora Tien
Center for Teacher Education
National Taiwan University
Taipei, Taiwan
Email: floratien@ntu.edu.tw

Abstract

In this paper we evaluate empirically the university cost structure in Taiwan. While most empirical studies of higher education show some evidence of scale and scope economies, we demonstrate in this paper that they are elusive because they have failed to account for quality variation among colleges and universities, in particular the endogeneity of congestion in facility utilization. Empirical results show that the private and highly congested universities have consistently underestimated the cost of congestion and are able to decrease the short-run average cost, which results in an upward bias in estimating the economies of scale and scope. Taking into account the quality of outputs in enrollments and the congestion factor, we find that the colleges and universities in Taiwan show increasing returns to scale and the scope economies. The private and the more congested universities have much less scale and scope economies than the public and the less congested institutions. However, more than half of colleges and universities are too big to be scale efficient at the quality level of the top five universities.
1. Introduction

The financial plight and plunging quality of higher education have dominated the current debate about educational reforms in Taiwan. The debate has provided a forum on the issues of the economic behavior of institutions of higher education, including the amalgamation of institutions, in the search for economies of scale, the conglomeration of undergraduate and graduate programs in the search for economies of scope, and the enormous quality disparity between private and public institutions. The paper aims to illuminate the debate by providing an empirical study on the scale and scope economies by estimating a multi-product university cost structure in Taiwan.

The number of colleges and universities in Taiwan has increased rapidly in the last two decades. As of 2003, there were 139 colleges and universities compared to only 26 institutions in 1980. During the same period, the number of college student enrollments increased fivefold, and real educational expenditure per student more than tripled. The variation in unit instructional costs among colleges and universities is substantial. For small institutions, the per-student instruction cost is on average 71 percent higher than in larger institutions, while public, research-oriented institutions’ unit instructional costs are more than twice that of private institutions. The cost differences may be due to the difference in orientation and goals between undergraduate teaching and graduate research. If the larger institutions have lower unit costs, it might be because there are economies of scale and scope. Many empirical studies in the US and in other developed countries have uncovered factors that account for costs in higher education. However, there are no empirical studies investigating the existence or magnitude of economies of scale and scope in Taiwan or the impact of the dual role of higher education in teaching and in research on the university cost structure. Over the last several decades, the universities in Taiwan have essentially been administered at the discretion of the government. The Ministry of Education oversaw every step of university operations, both in public and in private universities, ranging from student admission and enrollment, faculty hiring and promotion, curriculum design and instruction, to budgeting decisions and administrative appointments. In recent years, the government has gradually lessened its rigid control and allowed universities more administrative and financial independence. This policy change has exerted pressure on administrators and policy makers to emphasize productivity, efficiency, and cost-effective management. In this paper, we explore university cost structure by estimating a stochastic frontier cost function. Particular attention is given to the estimation of cost efficiency, and to the effect of quality-adjusted outputs on economies of scale and scope.

While most empirical studies of higher education production in other countries show some evidence of scale and scope economies, we demonstrate in this paper that

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1 Sources: Education Statistical Indicators, Ministry of Education, Taiwan. http://www2.edu.tw/statistics/english/c.htm
2 For the purpose of comparison, small institutions are defined as having enrollment less than the median.
3 Economies of scale and/or scope are generally observed in empirical studies in higher education. For example, the study of American major research universities by de Groot et al. (1991); Hashimoto and Cohn (1997) on Japanese private universities; Lloyd et al. (1993) on Australian universities; Lewis
they are elusive because the studies have failed to account for quality variation among colleges and universities, in particular the endogeneity of congestion in facility utilization. In the short-run, a university can reduce the average cost of enrollment by tolerating more congested dormitory rooms, classrooms, laboratories, libraries, etc. Since the congestion factor is endogenous, that leads to a reduced average cost, and it may give a myopic administrator an incentive to engage, at least in the short-run, in a policy of over-utilizing the university’s fixed capital resource. Congestion thus has an implicit long-run cost in higher education production. While many empirical studies have linked the student-faculty ratio and faculty research activity to the quality of university’s undergraduate and graduate education, these studies generally ignored how the congestion is linked to the estimation of university cost structure, in particular to scale and scope economies. We attempt to bridge these gaps by incorporating the endogeneity of congestion into a higher education production function, and show how to link the congestion factor to the estimation of scale and scope economies, and to the estimation of the shadow price of congestion.

The rest of the paper is organized as follows. In Second 2, we explore how to incorporate the quality dimension of university outputs and the endogenous congestion factor in models of higher education production. For example, the student-faculty ratio is a significant determinant of the quality of undergraduate teaching. Faculty research activities and research funding are important determinants of the quality of graduate teaching and research. Teaching and research quality vary significantly from university to university and have a significant impact on the cost of university operation. Failing to consider such output quality is likely to result in inaccurate or biased estimates of the cost equation and, hence, the measure of economies of scale and scope. Furthermore, we estimate a minimum university cost function that accounts for the endogeneity of congestion. Using this minimum cost function, we compute a shadow price for congestion. We argue that by excluding the congestion factor, most studies of cost functions estimate operating costs rather than university cost in higher education.

Section 3 describes the data set, the summary statistics on the cost structure of the sample universities, and the empirical implementation of estimating a stochastic frontier translog operating cost regression. A stochastic frontier estimates the minimum operating cost function that envelops the observed costs from below. Thus, the deviations of the observed cost from the stochastic frontier are the operating cost efficiency. The estimated operating cost excludes the cost of congestion but the cost is conditioned on the congestion. Since the level of congestion does not necessarily minimize the university cost, Section 4 discusses the linkage between the operating cost and the university cost. The section estimates via the estimated operating cost the implied university cost structure in efficiency, in the quality of university outputs, and the economics of scale and scope. Section 5 provides a summary conclusion.

2. University Production and Cost Functions

Let us consider the university mission of delivering quality education with the primary outputs on undergraduate ($Y_U$) and graduate ($Y_G$) enrollment. Since the quality of instruction varies significantly among universities, these outputs are significant determinants of the quality of undergraduate and graduate education. Faculty research activities and research funding are important determinants of the quality of graduate teaching and research. Teaching and research quality vary significantly from university to university and have a significant impact on the cost of university operation. Failing to consider such output quality is likely to result in inaccurate or biased estimates of the cost equation and, hence, the measure of economies of scale and scope. Furthermore, we estimate a minimum university cost function that accounts for the endogeneity of congestion. Using this minimum cost function, we compute a shadow price for congestion. We argue that by excluding the congestion factor, most studies of cost functions estimate operating costs rather than university cost in higher education.

and Dundar (1995) on Turkish universities; and Glass et al. (1995) on UK universities.
measured in quality-adjusted “undergraduate enrollment” \( (Y_U^*) \) and quality-adjusted “graduate enrollment” \( (Y_G^*) \). The quality indexes are the student-faculty ratio, a proxy for teaching resources in undergraduate education, and sponsored research funding, a proxy for research resources for graduate education. The production technology is represented by the transformation function, \( T(Y_U^*, Y_G^*, L, K, Z) \leq 0 \), where \( L \) and \( K \) are labor and physical capital inputs, respectively; the variable \( Z \) measures students per square meter of building space as a proxy for the congestion in the fixed capital utilization. Let the price of the \( i^{th} \) input be \( W_i \), the university cost of producing the quality-adjusted outputs \( Y_U^* \) and \( Y_G^* \) is given by \( C = (W_L L + W_K K + W_Z Z) \). The price of congestion, \( W_Z \), may be measured per square meter of building cost.\(^4\) If we ignore the cost of congestion, the short-run measure of the operating cost is represented by \( C_P = (W_L L + W_K K) \). Given the quality-adjusted outputs, the minimum operating cost is defined as

\[
C_P(Y_U^*, Y_G^*, W_L, W_K, Z) = \min_{L,K} (W_L L + W_K K)
\]

\[\text{s.t. } T(Y_U^*, Y_G^*, L, K, Z) \leq 0 \text{ and } Z = Z^0.\] (1)

The university’s short-run operating cost excludes the cost of congestion even though the cost is conditioned on the congestion. Thus, the level of congestion does not necessarily minimize cost. It is likely that, given the output level, the university’s average operating cost decreases as students are subjected to a more congested learning environment. The minimum university cost function, on the other hand, is defined on the price of congestion rather than the level of congestion as follows:

\[
C(Y_U^*, Y_G^*, W_L, W_K, W_Z) = \min_{L,K,Z} (W_L L + W_K K + W_Z Z)
\]

\[\text{s.t. } T(Y_U^*, Y_G^*, L, K, Z) \leq 0.\] (2)

Many empirical studies on university cost structure ignore the role of congestion in higher education and the quality aspect of instruction. By omitting \( Z \) and quality adjustment, the following cost function is defined,

\[
C_P(Y_U, Y_G, W_L, W_K) = \min_{L,K} (W_L L + W_K K)
\]

\[\text{s.t. } T(Y_U, Y_G, L, K) \leq 0\] (3)

The differences among the three specifications of a university cost structure are important in the estimation of scale and scope economies, and in policy implications.\(^5\)

\(^4\) Getz and Siegfried (2003) regress the square feet of space per student on the construction price across colleges and universities in the US to determine the sensitivity of capital use to price in higher education.

\(^5\) Hughes, Master, and Moon (2001) addressed the significance of the distinction in the context of the financial bank cost structure and the equity capital. The specifications of the university cost, the operating cost, and misspecified operating cost (3) are a natural extension of the financial bank cost model. The idea and the argument in this section are in most part parallel to the paper.
Equation (3) is misspecified because it does not take into account the quality of instruction and the crowding in facility utilization, in classrooms, in laboratories, in dormitories, and in libraries. Consider two universities that differ only in the congestion factor. The university with the more congested educational facility is substituting facility utilization for capital, and its operating cost will be less than in the less congested university. For not controlling for the congestion factor, the more congested university would appear to be less costly in production. A misguided educational policy would encourage and reward more congestion in higher education.

Most of the concern over economies in higher education is related to the cost effects resulting from an expansion in both the scale and the scope of institutions. The economies of scale (SCALE) of the university cost function (2) are defined as the inverse cost elasticity of the quality-adjusted output,

$$\text{SCALE} = \left( \sum_i \frac{\partial \ln C(Y_U^*, Y_G^*, W_L, W_K, W_Z)}{\partial \ln Y_i^*} \right)^{-1}, \quad i = U, G \quad (4)$$

There exist an economies of scale if \( \text{SCALE} > 1 \), and diseconomies of scale if \( \text{SCALE} < 1 \), and constant economies of scale if \( \text{SCALE} = 1 \).

In addition to economies of scale, a multi-product cost function allows the measure of overall economies of scope (SCOPE). Economies of scope exist between outputs if the total cost of joint production is less than the cost of separate production. Economies of scope thus imply the presence of complementarities between the diversified outputs of undergraduate teaching and graduate research. The complementarities may be the result of the sharing and joint utilization of faculty, staff, and equipment. For a university engaging in both undergraduate and graduate programs, the conventional measure of economies of scope compares the costs of separate and joint productions that are evaluated at the quality-adjusted levels \((Y_U^*, Y_G^*)\). More precisely, it is

$$\text{SCOPE} = \left( \sum_i \frac{C(Y_i^*, 0, W_L, W_K, W_Z)}{C(Y_U^*, Y_G^*, W_L, W_K, W_Z)} \right)^{-1}, \quad i \neq j \quad (5)$$

The conventional measure represents the percentage increases in cost of separating the outputs into two specialized universities, an exclusively undergraduate university and an exclusively graduate only university. To estimate the conventional economies of scope, the cost function must be evaluated at zero output levels even if there is no university in the sample engaged in undergraduate-only or graduate-only education. Thus, the measure involves an unrealistic scenario of specialization. An alternative measure of the economies of scope is the within-sample economies of scope (SCOPE),

$$\text{SCOPE} = \left( \sum_i \frac{C(Y_i^* - Y_i^{*m}, Y_j^{*m}, W_L, W_K, W_Z)}{C(Y_U^*, Y_G^*, W_L, W_K, W_Z)} \right)^{-1}, \quad i \neq j \quad (5)$$
where $Y_{i}^{m}$ is the minimum values of $Y_{i}$ in the sample. Economies of scope entail cost complementarities and hence $SCOPE > 0$. Similarly, $SCOPE < 0$ implies diseconomies of scope.

Estimation of the university cost function, $C(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, W_{Z})$, requires observations on the input price of congestion, $W_{Z}$. As will be shown in the following equation, the congestion price and the economies of scale and scope of university cost can be estimated from the operating cost function, $C_{P}(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, Z)$. The operating cost excludes the cost of congestion but accounts for the level of congestion. The level of congestion does not necessarily minimize the university cost. If the level of congestion minimizes the university cost at the price of congestion $W_{Z}$, we have

$$C(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, W_{Z}) = \min_{Z} C_{P}(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, Z) + W_{Z} \Delta Z$$  \hspace{1cm} (6)

The university cost function envelops the operating cost functions. Thus, the minimization condition in (6) requires

$$W_{Z} = -\frac{\partial C_{P}(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, Z)}{\partial Z} = W_{Z}^{*} \hspace{1cm} (7)$$

The right-hand side, $-\frac{\partial C_{P}}{\partial Z} = W_{Z}^{*}$, gives the shadow price of congestion. The university cost function is thus estimated by replacing the unobservable price $W_{Z}$ with the shadow price $W_{Z}^{*}$.

When $W_{Z}$ is replaced by $W_{Z}^{*}$, economies of scale in (6) can be shown to be

$$SCALE = \left(\sum_{i} \frac{\partial \ln C(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, W_{Z}^{*})}{\partial \ln Y_{i}^{*}}\right)^{-1}$$

$$= \left(\sum_{i} \frac{\partial \ln C_{P}(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, Z)}{\partial \ln Y_{i}^{*}}\right)^{-1} \left(1 - \frac{\partial \ln C_{P}(Y_{U}^{*}, Y_{G}^{*}, W_{L}, W_{K}, Z)}{\partial \ln Z}\right) \hspace{1cm} (8)$$

The second equality is obtained by using the conditions that $W_{Z}^{*} = -\frac{\partial C_{P}}{\partial Z}$, and, from (6)

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See Braeutigam and Daughety (1983), and Hughes, Mester, and Moon (2001) for the derivation.
\[ \frac{\partial C(Y^*_U, Y^*_G, W_L, W_K, W_Z^*)}{\partial Y_i^*} = \frac{\partial C_P(Y^*_U, Y^*_G, W_L, W_K, Z)}{\partial Y_i^*} \]

Scale economies of the university cost structure can then be indirectly estimated from the operating cost function.

To compute the scope economies of the university cost function from the operating cost function requires the demand for congestion \( Z \). In applying Shepard’s lemma to \( C(Y^*_U, Y^*_G, W_L, W_K, W_Z^*) \), we have the derived demand for congestion as a function of the quality-adjusted outputs, prices of labor and capital, and the shadow price of congestion,

\[ Z^* = Z^*(Y^*_U, Y^*_G, W_L, W_K, W_Z^*) \quad \text{(9)} \]

The scope economies measure, Eg. (6), is then obtained by using the envelope at the shadow price \( W_Z^* \) and replacing \( Z \) by the demand function \( Z^* \) from (9),

\[ C(Y^*_U, Y^*_G, W_L, W_K, W_Z^*)
= C_P(Y^*_U, Y^*_G, W_L, W_K, Z^*) + W_Z^* Z^* \quad \text{(10)} \]

3. Data and Empirical Implementation

The sample observations in this study were taken from 1999-2001 three-year panel data of 33 four-year colleges and universities in Taiwan. The enrollment for undergraduate and graduate students are two outputs of the university cost function. As indicated previously, such student enrollment variables ignore the quality differential in undergraduate and graduate instruction across colleges and universities. In this study, the student/faculty ratio \( (X_U) \) is used as the quality indicator for undergraduate education to adjust the undergraduate enrollment \( (Y_U) \). Faculty sponsored research projects \( (X_G) \) from the National Science Council serve as the quality indicator to adjust the graduate enrollment \( (Y_G) \) on the assumption that research activity enhances the quality of graduate teaching. Specifically, the quality-adjusted outputs are defined as

\[ \ln Y^*_U = (1 + \delta_U X_U) \ln Y_U \quad \text{(11)} \]
\[ \ln Y^*_G = (1 + \delta_G X_G) \ln Y_G \quad \text{(12)} \]

The coefficient \( \delta_U \) determines how the quality-adjusted undergraduate enrollment changes with increasing the student-faculty ratio. As the student-faculty ratio increases, the undergraduate instructional quality deteriorates. The coefficient \( \delta_U \) is expected to be negative. Similarly, the faculty research activity \( X_G \) indicates the quality of faculty research and graduate teaching. Universities with sizable research

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7 The sample includes only the four-year comprehensive universities having a complete three-year data observations, excluding medical, polytechnic, and normal universities.
programs often provide quality graduate programs in teaching and research. The coefficient $\delta_G$ is expected to be positive.

The total operating cost ($C_P$) consists of labor and capital expenses. The labor expense includes the wages and benefits of both teaching and research faculty and the support staff. It is the dominant component of the total operating cost. The capital expense consists of building and equipment depreciation, expenses on library books, and other related capital expenses. The price of labor is calculated by dividing the total personnel expenses on wage and fringe benefits by the total number of faculty and support staff. The price of capital input is computed by dividing the total capital expenses by total assets. The price of capital is used to normalize the labor input price and the total operating cost in the econometric estimation of the operating cost function.

Table 1 tabulates the cost structure of the university operating expenditure by types of university. It shows that the average annual university operating expenses are around 1.4 billion NT Dollars in 1999-2001. The private universities have a much larger enrollment than the public universities, and are more concentrated on undergraduate programs. The unit operating cost per student is on average over two hundred thousands NT$ and the unit cost in a public university is twice that of the private counterpart. The share of labor cost in a public university (81%) is much higher than in a private university (70%) while the share of capital cost is higher in a private university. Although the public universities have on average a much larger pool of faculty and staff, the faculty/staff ratios are maintained around 61 percent. Table 1 also indicates that the price of labor in public universities is higher than in private universities. This may be due to fact that, in general, the more established public universities have relatively more senior faculty and have a higher percentage of faculty with a Ph.D. degree, which commands higher compensation. However, the prices of capital seem to be identical. The high utilization rate of building space among the private universities may contribute to the much lower unit operating cost per student than in the public universities.

Output qualities in teaching and in research are much harder to quantify in a service industry, such as higher education, than in the manufacturing sector. However, two ratios – the student/faculty ratio and the grants/faculty ratio – are generally accepted as indicators of a university’s output quality. The average ratio of student to full-time faculty at the sample public universities is about half of that at the private universities. We should note, however, that in general the private universities employed more part-time faculty than the public universities. Due to the lack of data, our student-faculty ratio fails to account for the effect of part-time faculty. The table also shows that the number of NSC-granted research projects per faculty in the public universities is more than twice that of the private universities. The NSC sponsored

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8 At the average exchange rate of NT$32.43/$US during the sample period 1999-2001, the unit operating cost per student is equivalent to US$6,856 for all sample universities.

9 In a study of 115 four-year colleges and universities in the United States, Getz and Siegfried (2003) estimate the average building space per student at 29 square meters, which is much more spacious than the 17 square meters of building space in Taiwan’s colleges and universities.
research funding is another indication that private universities engage more in undergraduate teaching than in research activities.

To analyze the university cost structure, we first estimate the operating cost function, \( C_p(Y^*_U, Y^*_G, W_L, W_K, W_Z) \), we first estimate the operating cost function, \( C_p(Y^*_U, Y^*_G, W_L, W_K, Z) \). The operating cost function is approximated by a translog functional form with the input price of capital \((W_K)\) as the normalization factor to ensure the usual restriction of the linear homogeneity in prices. For the purpose of comparison, the Model \( C_p \) from (3) and the Model \( C_p \) from (1) are both estimated. Model \( C_p \) considers neither the quality of instruction nor the congestion in building space. In this case, the normalized translog operating cost regression is specified as

\[
\ln \left( \frac{C_p}{W_K} \right) = \beta_0 + \sum \beta_i \ln F_i + (1/2) \sum \sum \beta_{ij} \ln F_i \ln F_j + u + v \tag{13}
\]

where \( C_p = (W_L + W_K) \) is the observed operating cost, \( F = (Y_U, Y_G, W^*_L/W_K) \), and \( u \) and \( v \) are two regression error terms to be defined. For Model \( C_p \), the regression includes both the quality-adjusted outputs and the congestion factor even though the cost \( C_p \) is a university’s short-run operating cost that excludes the cost of congestion. In this case, the variables \( F = (Y^*_U, Y^*_G, W^*_L/W^*_K, Z) \) where the quality-adjusted undergraduate \( Y^*_U \) and graduate enrollment \( Y^*_G \) are defined in (11) and (12).

In addition to estimating the translog operating cost equation, we follow the spirit of the stochastic frontier approach to estimate the cost efficiency for each sample university. The random error \( v \) in (13) represents the statistical noise and is assumed to be normally distributed with mean zero and variance \( \sigma^2_v \). The random error \( u \) is a nonnegative that captures cost inefficiency and is truncated from below at zero from a normal distribution with mean zero and variance \( \sigma^2_u \). Since the operating cost regression (13) is in a logarithmic form, the cost efficiency measured as \( e^{-u} \) is bounded between zero and one, \( 0 \leq e^{-u} \leq 1 \). Following the approach of Battese and Coelli (1988), we estimate individual university operating cost efficiency as the conditional mean given the composite error \( \varepsilon = u + v \),

\[
E(e^{-u} | \varepsilon) = \frac{\Phi(\mu*/\sigma_* - \sigma_*)}{\Phi(\mu*/\sigma_*)} \exp \left( -\mu* + \frac{1}{2} \sigma_*^2 \right) \tag{16}
\]

where \( \mu* = \sigma^2_u/\sigma^2_v, \sigma_* = \sigma^2_u/\sigma^2_v, \), and \( \sigma^2 = \sigma^2_u + \sigma^2_v \). The conditional mean is bounded, \( 0 \leq E(e^{-u} | \varepsilon) \leq 1 \). An efficient university will have a high efficiency index \( E(e^{-u} | \varepsilon) \) in minimizing operating cost.

4. **Empirical Results**

An iterative nonlinear seemingly unrelated method is used to estimate simultaneously the translog cost regression (13) and the associated labor share
equation, \( S_L = \frac{\partial \ln C_P}{\partial \ln(W_L/W_K)} \), where \( S_L \) is the labor share of the operating expenses.

The estimated coefficients are presented in Table 2. The overall model fitting for both models, \( C_{P} \) and \( C_P \), are reasonably good with \( R^2 = 0.966 \) and 0.983, respectively, on the cost equation, and \( R^2 = 0.756 \) and 0.747, respectively, on the share equation. The hypothesis that the two models are identical, \( C_{P} = C_P \), is rejected. The asymptotic Chi-square test on the hypothesis that the coefficients, \( \beta_Z, \beta_{ZU}, \beta_{ZG}, \beta_{ZL}, \delta_U, \delta_G \), that are associated with \( Z, X_U, \) and \( X_Z \), are all equal to zero is rejected.\(^{10}\) The congestion factor \( Z \) and the quality-adjustment factor \( X_U \) and \( X_G \) have a significant impact on the operating cost. The misspecified operating cost model \( C_{P} \) is rejected statistically. Thus, the rest of the analysis will concentrate on the estimates of Model \( C_P \).

From the operating cost point of view, the performance of universities can be compared only by the effective or quality-equivalent outputs produced. The quality adjustment factors are the student-faculty ratio (\( X_U \)) for the undergraduate enrollment and the grants/faculty ratio (\( X_G \)) for the graduate enrollment. The quality-equivalent enrollments and the ratios to the observed enrollment are

\[
Y_U^* = (Y_U)^{1+\delta_U} X_U ; \quad \frac{Y_U^*}{Y_U} = (Y_U)^{\delta_U} X_U \\
Y_G^* = (Y_G)^{1+\delta_G} X_G ; \quad \frac{Y_G^*}{Y_G} = (Y_G)^{\delta_G} X_G
\]

Since \( \delta_U < 0 \), the high student/faculty ratio (\( X_U \)) devalues the undergraduate education. In this case, the quality-equivalent undergraduate output (\( Y_U^* \)) is adjusted downward. The ratio \( Y_U^*/Y_U < 1 \) serves as the quality indicator of undergraduate education. Similarly, the graduate enrollment (\( Y_G \)) is adjusted by the grants/faculty ratio (\( X_G \)). Since \( \delta_G > 0 \), a university with higher research performance enhances the graduate program and the quality-equivalent graduate output (\( Y_G^* \)) is adjusted upward. The ratio \( Y_G^*/Y_G > 1 \) serves as the quality indicator of the graduate education.

Table 3 estimates the quality indicators for both undergraduate and graduate enrollment. Because of the high student/faculty ratio among the private universities, the quality-adjusted equivalent undergraduate output is only 66.63% of the actual output, versus 82.02% in the case of the public universities. Relatively, the quality of the undergraduate education in the private universities is only about 81% of that of the public universities; and is only 63% for graduate education. The overall disparity in quality between the private and public colleges and universities in Taiwan is significant. The overall quality of the private institutions in enrollments \( Y^*/Y \) is only 58% of the counterpart in the public institutions. These figures should give an

\(^{10}\) The asymptotic \( \chi^2 = 160.6181 \) with 7 degrees of freedom.
alarming signal to the university administrators and policy makers on the quality of higher education at private universities. However, from the management point of view, there is no significant difference in operating cost efficiency among the institutions, even though the range of variation in cost efficiency is smaller in the private universities than in the public universities. This result may be attributed to cost consciousness among administrators in the private universities.

Many empirical studies on the cost structure of the university ignore the role of congestion in higher education. By omitting $Z$, universities with a more congested educational facility will appear to have an operating cost smaller than in the less congested university. For not controlling for the congestion factor, more congested universities will have illusive scale economies. Table 4 reports the scale economies from Model $C^*_P$ and shows scale economies in full sample. Since the congestion factor $Z$, measured by student per square meter of building space, is not taken into consideration, more congested universities (private, and third and fourth quartiles of $Z$) show much higher returns to scale. The returns to scale from Model $C^*_P$ are overestimated, particularly for the private and more congested universities. This overestimation is due either to treating the congestion as a free input in production of higher education or to the shadow price of the congestion being too low and resulting in over-utilization of the facility. Using Eq. (7) and the estimates from Model $C^*_P$, the last column of Table 4 reports the estimated shadow price of the congestion factor $Z$. It shows that the private and highly congested universities significantly undervalue the cost of congestion. The most highly congested universities (the fourth quartile of $Z$) not only treat congestion as a free input, but practically as a windfall gain. This suggests that they have highly over-utilized building space. The universities are able to reduce the short-run average cost with a more cramped university facility and congested learning environment, and hence appear to have economies of scale in operation. This is illusive.

The proper measure of the scale economies of the university cost function is from Eq. (4) which takes into account the quality-adjusted outputs and the congestion factor. The scale economies are to be estimated from the operating cost model $C_P$ from Eq. (8). Table 5 reports the estimates of the scale economies of the university cost function $C(Y_U^*, Y_G^*, W_L, W_K, W_Z)$. The colleges and universities in Taiwan show significant increasing returns to scale. The results are remarkably robust with respect to public and private institutions, and with respect to the congestion factor. This suggests that economies of scale are achievable if the universities produce quality graduate and undergraduate education in classroom, and provide more learning space to relieve congestion.

To illustrate further the significance of the output quality and congestion factor on the scale economies, Figure 1 displays ray average costs for the “average” university and the “top five” university in the sample. The “average” university has the output quality ($X_U, X_G$), the input prices ($W_L, W_K$), and the shadow price of congestion ($W_Z$), all evaluated at the sample means. The “top five” university is the university with the output quality, input prices, and shadow price evaluated at the

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11 These top five universities are: National Tsing Hua University, National Taiwan University, National Cheng Kung University, National Chiao Tung University, and National Central University.
means of the five top universities. The ray expansion is assumed to be proportional
to the ratio of the means of undergraduate ($Y_U$) to graduate ($Y_G$) outputs. The ray
average costs are normalized to 1 at the means of the total sample and the top five
universities, respectively. The ray average costs show the typical U-shape curves.
For the “average” university, the minimum ray average cost is reached at 18,141
student enrollment. When one considers that in comparison to the sample average
enrollment of 11,338, considerable room for expansion is shown, even though there
are 15% of sample universities are near (within 10%) or above the minimum ray
average cost level. However, the least ray average cost scale at the quality level of
the “top five” university is considerably smaller with an enrollment of 10,481. More
than half (55%) the sample universities are beyond this limit. This outcome implies
that to pursue excellence in higher education at the level of the current top five
universities in Taiwan, most universities are too large to be scale efficient.

Economies of scope measures the cost savings resulting from joint production of
both undergraduate and graduate programs within a single university, as compared to
separate programs offered by two universities, one specializing in an undergraduate
program with a minimum graduate program and the other in a graduate program with
a minimum undergraduate program. The left panel of Table 6 estimates the
economies of scope from Model $C_P$. It shows the overwhelming scope economies
in the full sample and in both private and public universities. As in the
overestimation of scale economies based on Model $C_P$, scope economies are illusive
since the model treats congestion as a free input in a joint production of undergraduate
and graduate education. Private universities are generally more congested. It is not
surprising that the misspecified Model $C_P$ shows a positive correlation between
scope economies and congestion. Again, the proper measure of scope economies is
to compute the minimum university cost function, Eq. (10), from Model C. The
model accounts for congestion as a factor of production in joint production. The
derived factor demand for congestion and other input demands need to be evaluated at
levels that minimize the costs of joint production and at levels that minimizes the cost
of separate production. We estimate the derived demand for congestion factor as a
function of quality-adjusted outputs, the normalized price of labor input, and the
shadow price of congestion from the following logarithmic regression:

\[
\ln Z = -7.1191 + 0.7046 \ln Y^*_U - 0.2285 \ln Y^*_G - 0.0148 \ln (W/L/W_K)
\]

\[
(-16.0586) \quad (14.2845) \quad (-5.6680) \quad (-0.2689)
\]

\[
-8.35E-8 \left( \frac{W^*_Z}{W_K} \right) + 1.77E-15 \left( \frac{W^*_Z}{W_K} \right)^2 + \varepsilon \quad R^2 = 0.7874
\]

\[
(-3.6343) \quad (3.0504)
\]

\[ \equiv \ln Z^* + \varepsilon \]

where t-values are in parentheses. Using Eq. (10) and the estimated derived demand
$Z^*$ of the congestion, we compute the scope economies of the university cost function,
$C(Y^*_U, Y^*_G, W_L, W_K, W_Z)$. The second panel of Table 6 reports the scope
economies. The estimates of the scope economies are significantly positive at the
5% level. These estimates are much smaller than the estimates obtained from
Model $C_P$. More significantly, the scope economies for the private and more
congested universities are smaller than in the public and less congested
institutions.

5. Summary Conclusion

Considering the quality variation among colleges and universities, this paper develops a model of estimating the cost structure of higher education in Taiwan. Without taking into account quality variation and congestion in facility utilization, we argue and show empirically that the private and highly congested universities have consistently underestimated the cost of congestion and as a result, choose to decrease the short-run average cost. Universities with more congested educational facilities are substituting facility utilization for capital; universities with a higher student/faculty ratio and less research engagement are substituting quality of education for quantity of undergraduate and graduate enrollment. The consequence is an upward bias in estimating economies of scale and scope. We estimate that the overall quality of education in the private universities is only 58% of the counterpart in the public universities. In general, universities in Taiwan are characterized as having economies of scale if they produce quality graduate and undergraduate education in classroom and provide adequate educational facility and resources to relieve the congestion. Furthermore, most private universities are too large to be scale-efficient in pursuing the policy of excellence in higher education, a stated goal in current education reform. Similarly, there are economies of scope in quality-adjusted outputs. Since the private universities are generally more congested and the quality of outputs in undergraduate and graduate programs is lower, the economies of scope are smaller in private than in the public universities.

References


Table 1. Cost Structure of the Sample Universities in Taiwan: 1999-2001*

<table>
<thead>
<tr>
<th>variables</th>
<th>public</th>
<th>private</th>
<th>all sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating Cost (million NT$)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td>1,970(100%)</td>
<td>1,111(100%)</td>
<td>1,449(100%)</td>
</tr>
<tr>
<td>Labor Cost</td>
<td>1,604 (81%)</td>
<td>774 (70%)</td>
<td>1,101 (76%)</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>965 (19%)</td>
<td>336 (30%)</td>
<td>348 (24%)</td>
</tr>
<tr>
<td>Unit Operating Cost †</td>
<td>0.324</td>
<td>0.156</td>
<td>0.223</td>
</tr>
<tr>
<td><strong>Enrollment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Enrollment</td>
<td>9,670 (100%)</td>
<td>12,422 (100%)</td>
<td>11,338 (100%)</td>
</tr>
<tr>
<td>Undergraduate</td>
<td>6,325 (65%)</td>
<td>11,454 (92%)</td>
<td>9,433 (83%)</td>
</tr>
<tr>
<td>Graduate</td>
<td>3,345 (35%)</td>
<td>968 (8%)</td>
<td>1,904 (17%)</td>
</tr>
<tr>
<td><strong>Labor Input</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faculty and Staff</td>
<td>1,007</td>
<td>628</td>
<td>777</td>
</tr>
<tr>
<td>% of Faculty</td>
<td>61%</td>
<td>62%</td>
<td>61%</td>
</tr>
<tr>
<td><strong>Input Price</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price of Labor</td>
<td>1,557</td>
<td>1,230</td>
<td>1,359</td>
</tr>
<tr>
<td>Price of Capital</td>
<td>0.085</td>
<td>0.087</td>
<td>0.086</td>
</tr>
<tr>
<td><strong>Campus Size &amp; Building Space Per Student (square meters)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campus Size</td>
<td>92</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>Building Space</td>
<td>39</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td><strong>NSC Sponsored Research</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projects per Faculty</td>
<td>0.792</td>
<td>0.305</td>
<td>0.498</td>
</tr>
<tr>
<td><strong>Student-Faculty Ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time Faculty</td>
<td>613</td>
<td>386</td>
<td>474</td>
</tr>
<tr>
<td>Student-Faculty Ratio</td>
<td>17.3</td>
<td>33.5</td>
<td>27.1</td>
</tr>
<tr>
<td><strong>Sample Universities</strong></td>
<td>13</td>
<td>20</td>
<td>33</td>
</tr>
</tbody>
</table>

* Figures in the table are the mean value of variables.
† Unit operating cost per student
** The price of labor is in thousands of NT$. The price of capital is a ratio of capital cost over gross fixed capital asset.
Table 2: Estimates of the Translog Operating Cost Functions: $C_{\bar{P}}$ and $C_P$

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>$C_{\bar{P}}$ Function</th>
<th>Variables</th>
<th>Coefficient</th>
<th>$C_P$ Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\beta_0$</td>
<td>3.9462 (2.6805)</td>
<td>Constant</td>
<td>$\beta_0$</td>
<td>3.9932 (8.3777)</td>
</tr>
<tr>
<td>$\ln Y_U$</td>
<td>$\beta_U$</td>
<td>1.1924 (0.5685)</td>
<td>$\ln Y^*_U$</td>
<td>$\beta_U$</td>
<td>1.8297 (1.8452)</td>
</tr>
<tr>
<td>$\ln Y_G$</td>
<td>$\beta_G$</td>
<td>-1.0718 (0.4301)</td>
<td>$\ln Y^*_G$</td>
<td>$\beta_G$</td>
<td>-2.3373 (0.8406)</td>
</tr>
<tr>
<td>$\ln W_L$</td>
<td>$\beta_L$</td>
<td>0.1806 (0.0716)</td>
<td>$\ln W_L$</td>
<td>$\beta_L$</td>
<td>0.5484 (0.1435)</td>
</tr>
<tr>
<td>$(\ln Y_U)^2$</td>
<td>$\beta_{UU}$</td>
<td>-0.1086 (0.0815)</td>
<td>$(\ln Y^*_U)^2$</td>
<td>$\beta_{UU}$</td>
<td>-0.2245 (0.2134)</td>
</tr>
<tr>
<td>$(\ln Y_G)^2$</td>
<td>$\beta_{GG}$</td>
<td>0.2075 (0.0278)</td>
<td>$(\ln Y^*_G)^2$</td>
<td>$\beta_{GG}$</td>
<td>-0.0009 (0.0363)</td>
</tr>
<tr>
<td>$(\ln W_L)^2$</td>
<td>$\beta_{LL}$</td>
<td>0.0856 (0.0082)</td>
<td>$(\ln W_L)^2$</td>
<td>$\beta_{LL}$</td>
<td>0.0771 (0.0086)</td>
</tr>
<tr>
<td>$(\ln Y_U)(\ln Y_G)$</td>
<td>$\beta_{UG}$</td>
<td>0.0073 (0.0458)</td>
<td>$(\ln Y^<em>_U)(\ln Y^</em>_G)$</td>
<td>$\beta_{UG}$</td>
<td>0.2165 (0.0890)</td>
</tr>
<tr>
<td>$(\ln Y_U)(\ln W_L)$</td>
<td>$\beta_{UL}$</td>
<td>0.0144 (0.0076)</td>
<td>$(\ln Y^*_U)(\ln W_L)$</td>
<td>$\beta_{UL}$</td>
<td>-0.0213 (0.0159)</td>
</tr>
<tr>
<td>$(\ln Y_G)(\ln W_L)$</td>
<td>$\beta_{GL}$</td>
<td>0.0214 (0.0077)</td>
<td>$(\ln Y^*_G)(\ln W_L)$</td>
<td>$\beta_{GL}$</td>
<td>0.0344 (0.0090)</td>
</tr>
<tr>
<td>$\ln Z$</td>
<td>$\beta_Z$</td>
<td>-0.3285 (2.0624)</td>
<td>$\ln Z$</td>
<td>$\beta_Z$</td>
<td>0.2247 (0.2450)</td>
</tr>
<tr>
<td>$(\ln Z)^2$</td>
<td>$\beta_{ZZ}$</td>
<td>0.2444 (0.2180)</td>
<td>$(\ln Z)(\ln Y^*_U)$</td>
<td>$\beta_{ZU}$</td>
<td>0.2444 (0.0920)</td>
</tr>
<tr>
<td>$(\ln Z)(\ln Y^*_G)$</td>
<td>$\beta_{ZG}$</td>
<td>-0.0213 (0.0159)</td>
<td>$(\ln Z)(\ln W_L)$</td>
<td>$\beta_{ZL}$</td>
<td>0.0452 (0.0183)</td>
</tr>
<tr>
<td>$X_U$</td>
<td>$\delta_U$</td>
<td>-0.0013 (0.0006)</td>
<td>$X_U$</td>
<td>$\delta_U$</td>
<td>0.1028 (0.0625)</td>
</tr>
<tr>
<td>$\sigma_U$</td>
<td>$S_U$</td>
<td>0.2273</td>
<td>$\sigma_U$</td>
<td>$S_U$</td>
<td>0.1389</td>
</tr>
<tr>
<td>$\sigma_V$</td>
<td>$S_V$</td>
<td>0.2049</td>
<td>$\sigma_V$</td>
<td>$S_V$</td>
<td>0.1248</td>
</tr>
<tr>
<td>Adj $R^2$ in Cost Regression</td>
<td>0.9662</td>
<td>Adj $R^2$ in Cost Regression</td>
<td>0.9832</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj $R^2$ in Share Regression</td>
<td>0.7565</td>
<td>Adj $R^2$ in Share Regression</td>
<td>0.7477</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Output Quality Indicators and Cost Efficiency

<table>
<thead>
<tr>
<th>Quality Indicator</th>
<th>All University</th>
<th>Public University</th>
<th>Private University</th>
<th>Private/Public Ratio$^\dagger$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_U^*/Y_U$</td>
<td>0.7270</td>
<td>0.8202</td>
<td>0.6663</td>
<td>81.23%</td>
</tr>
<tr>
<td>$Y_G^*/Y_G$</td>
<td>1.5286</td>
<td>1.9639</td>
<td>1.2456</td>
<td>63.42%</td>
</tr>
<tr>
<td>$Y^*/Y$</td>
<td>0.9259</td>
<td>1.2381</td>
<td>0.7230</td>
<td>58.40%</td>
</tr>
<tr>
<td>$Y_U^<em>/Y^</em>$</td>
<td>9.1279</td>
<td>1.0302</td>
<td>14.3914</td>
<td></td>
</tr>
</tbody>
</table>

Mean Cost Efficiency $^{††}$: 0.8959, 0.8887, 0.9003

Maximum Cost Efficiency: 0.9618, 0.9618, 0.9418

Minimum Cost Efficiency: 0.7086, 0.7086, 0.8435

St. Deviation of Cost Efficiency: 0.0419, 0.0609, 0.0241

$^\dagger$ Column 4 divides by column 3.

$^{††}$ Cost efficiency = $E(e^{-u} | \varepsilon)$
Table 4: Estimated Scale Economies from Model $C_p^*$

<table>
<thead>
<tr>
<th>Congestion Factor $Z$ **</th>
<th>Mean</th>
<th>Std</th>
<th>T-Statistic $\neq 1$</th>
<th>$W_Z^*$ = Shadow Price of $Z$ #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>1.3451 †</td>
<td>0.0866</td>
<td>3.9844</td>
<td>36,189</td>
</tr>
<tr>
<td>Public University</td>
<td>0.9512 ††</td>
<td>0.0260</td>
<td>−1.8734</td>
<td>85,862</td>
</tr>
<tr>
<td>Private University</td>
<td>1.6054 †</td>
<td>0.1327</td>
<td>4.5619</td>
<td>3,902</td>
</tr>
<tr>
<td>First Quartile $Z$</td>
<td>0.9602</td>
<td>0.0341</td>
<td>−1.1680</td>
<td>91,445</td>
</tr>
<tr>
<td>Second Quartile $Z$</td>
<td>1.0484</td>
<td>0.0414</td>
<td>1.1695</td>
<td>53,810</td>
</tr>
<tr>
<td>Third Quartile $Z$</td>
<td>1.3886 †</td>
<td>0.0540</td>
<td>7.1974</td>
<td>2,128</td>
</tr>
<tr>
<td>Fourth Quartile $Z$</td>
<td>2.0054 †</td>
<td>0.3061</td>
<td>3.2850</td>
<td>−2,064</td>
</tr>
</tbody>
</table>

* Scale economies = $\left( \sum_i \frac{\partial \ln C_{p\hat{}}} {\partial \ln Y_i} \right)^{-1}$

** Congestion factor $Z$ = student per square feet of building space

# Shadow price $W_Z^*$ (thousands of NT$) is computed from Eq. (8) using Model $C_p$.

† Significantly larger than one at the 5% level

†† Significantly less than one at the 5% level
Table 5: University Scale Economies*

<table>
<thead>
<tr>
<th>Congestion Factor</th>
<th>Mean</th>
<th>Std</th>
<th>T-Statistic ≠ 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full Sample</strong></td>
<td>1.4453 †</td>
<td>0.0586</td>
<td>7.5995</td>
</tr>
<tr>
<td>Public University</td>
<td>1.4894  †</td>
<td>0.0494</td>
<td>9.9107</td>
</tr>
<tr>
<td>Private University</td>
<td>1.4167  †</td>
<td>0.0914</td>
<td>4.5570</td>
</tr>
<tr>
<td>First Quartile Z</td>
<td>1.6319  †</td>
<td>0.0723</td>
<td>8.7390</td>
</tr>
<tr>
<td>Second Quartile Z</td>
<td>1.5534  †</td>
<td>0.0799</td>
<td>6.9310</td>
</tr>
<tr>
<td>Third Quartile Z</td>
<td>1.2864  †</td>
<td>0.0659</td>
<td>4.3460</td>
</tr>
<tr>
<td>Fourth Quartile Z</td>
<td>1.3100</td>
<td>0.1918</td>
<td>1.6167</td>
</tr>
</tbody>
</table>

* Scale economies = \( \left( \sum_i \frac{\partial \ln C}{\partial \ln Y_i^*} \right)^{-1} \)

** Congestion factor Z = student per square feet of building space

† Significantly larger than one at the 5% level
Table 6: Estimated Scope Economies from Model $C_P$ and Model C

<table>
<thead>
<tr>
<th>Congestion Factor Z **</th>
<th>Model $C_P$</th>
<th></th>
<th>Model C</th>
<th></th>
<th>T-Statistic &gt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std</td>
<td>Mean</td>
<td>Std</td>
<td></td>
</tr>
<tr>
<td>Full Sample</td>
<td>3.4915 †</td>
<td>0.2462</td>
<td>0.7208 †</td>
<td>0.0431</td>
<td>16.7242</td>
</tr>
<tr>
<td>Public University</td>
<td>1.9110 †</td>
<td>0.3757</td>
<td>1.1372 †</td>
<td>0.0378</td>
<td>30.0852</td>
</tr>
<tr>
<td>Private University</td>
<td>4.5362 †</td>
<td>0.2449</td>
<td>0.4408 †</td>
<td>0.0341</td>
<td>12.9271</td>
</tr>
<tr>
<td>First Quartile Z</td>
<td>2.2141 †</td>
<td>0.4645</td>
<td>1.1823 †</td>
<td>0.0398</td>
<td>29.7052</td>
</tr>
<tr>
<td>Second Quartile Z</td>
<td>2.9567 †</td>
<td>0.5429</td>
<td>0.9812 †</td>
<td>0.0553</td>
<td>17.7438</td>
</tr>
<tr>
<td>Third Quartile Z</td>
<td>4.0906 †</td>
<td>0.3674</td>
<td>0.4265 †</td>
<td>0.0312</td>
<td>13.6694</td>
</tr>
<tr>
<td>Fourth Quartile Z</td>
<td>4.7549 †</td>
<td>0.4562</td>
<td>0.3000 †</td>
<td>0.0443</td>
<td>6.7726</td>
</tr>
</tbody>
</table>

* Congestion factor $Z = \text{student per square feet of building space}$
† Significantly larger than one at the 5% level
Figure 1: Ray Average Costs