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The Cost Structure of Higher Education in Further Education Colleges in England.

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Abstract.

This paper examines the cost of the increased provision of higher education courses within further education colleges in England. We believe this to be the first attempt to fit a cost function specifically to the further education sector. Cost functions for a sample of 96 colleges over a two-year period, from 2000 to 2002, are fitted using a panel data methodology as well as stochastic frontier analysis. We compare and contrast our findings with a sample of 959 US colleges. Our findings indicate that most further education colleges are able to benefit from economies of scale. Results from both methodologies suggest the presence of product-specific economies of scale, substantial ray economies of scale and indicate that higher education classroom-based courses, such as business studies, as well as vocational courses display substantial economies of scope.

JEL classification: C21; C23; I21
Keywords: costs; educational economics; economies of scale

1. Introduction

In the United Kingdom, the provision of degree-level education traditionally provided by universities and higher education colleges (HE colleges), has been supplemented by programmes at further education colleges (FE colleges). FE colleges, the focus of this paper, are complex structures many of whose origins began in providing vocational courses, for example joinery and mechanical skills. Over time, they have added to their portfolio of courses a wide range of academic and vocational qualifications: in the first place access courses, which provide students with a 'second chance' option to retake examinations failed in school[1], but in addition vocational and degree programmes: the Higher Education Funding Council for England (2006) state that currently 71% of students participating in access courses progress to degree programmes. FE colleges have strong links with local businesses, are able to respond to changes in local employers' needs for skills, and reach out to all socio-economic groups within the community. By contrast with traditional higher education institutions where the proportion of students from low-income backgrounds in the UK is low (at around 14% from socioeconomic groups III, IV and V between 1980 and 2001; Greenaway & Haynes 2003) FE colleges are much more socially inclusive, with some 29 percent of their students coming from relatively disadvantaged areas (Foster 2005); the rate of educational progression especially for individuals from lower socio-economic groups between the ages of 16 and 18 years has been found to be greater in FE colleges than in other institutions (Lenton 2006). It appears therefore that FE colleges offer a major alternative strategy for progressing towards the UK government objective of broadening access to post-18 education for disadvantaged socio-economic groups.

This paper analyses, for the first time, the cost structure of UK further education colleges. The need for an analysis of the cost structure of higher education provision within FE colleges in the UK was highlighted in a recent DfES report (Johnes *et al* 2005), and the present study addresses this need by applying the methodology used by Johnes *et al* to a new dataset of English FE colleges**.** We estimate cost functions for a panel of 96 FE colleges in England over a two-year period and compare the results from two estimation methods, random effects modelling and stochastic frontier analysis, to explore the robustness of our findings. This analysis is then replicated for a comparison group of 959 US tertiary-level institutions. Our data covers the two academic years 2000-01 and 2001-02. The data are constructed from several sources supplied by the UK Learning and Skills Council and include the staff information records, individualised student records and qualification records. The following section provides an overview of the literature of cost functions within higher education. Section 3 discusses the data and the methodology. In section 4 we present our results and we draw our conclusions in section 5.

2. The estimation of cost functions within higher education

In common with much of the literature on tertiary education (Cohn *et al*, 1989; Dundar & Lewis, 1995) we characterise the higher education institution as a multi-product firm. We define three types of economies of scale:

- *product-specific economies of scale* (S_i)

$$S_i(y) = AIC(y_i)/C_i(y) \qquad (1)$$

If the value $S_i(y)$ is greater than unity, product-specific economies of scale for output *y* of type *i* exist.

- *ray economies of scale* where expansion of *all* outputs leads to economies of scale:

$$S_R = \frac{C(y)}{\sum_i y_i C_i(y)} \qquad (2)$$

where $C_i(y) = \partial C(y)/\partial y_i$ represents the difference in total cost given the difference in output of product *i* alone, i.e. the marginal cost of producing the *i*th output.

- finally, *economies of scope,* identify the existence of synergies between outputs:

$$SC_i = \left[C(y_i, 0, 0) + C(0, y_j, y_k) - C(y_i, y_j, y_k)\right] / C(y_i, y_j, y_k) \qquad (3)$$

Global economies of scope exist if economies exist for producing the outputs jointly in one firm rather than separately:

$$S_G = \left[\sum_i C(y_i) - C(y)\right] \Big/ C(y) \qquad (4)$$

where C(y_i) is the cost of producing a given output type *i* in isolation and

C(y) is the cost of producing all output jointly

If the value for S_G is greater than zero, then global economies of scope exist.

Previous estimations of cost functions in higher education (Verry and Layard (1975; Glass et al 1995) have used ordinary least-squares (OLS) analysis, which assumes that production is efficient. In order for such analysis to be meaningful it must be assumed that FE colleges seek to minimize their costs; however, in a non-profit sector, this assumption is questionable in the UK context, albeit the sector has become much more competitive in recent years. If efficient production cannot be assumed, then an approach such as stochastic frontier analysis (SFA) (Johnes *et al* 2005), which provides a means of estimating the parameters of the cost function of a technically inefficient producer, may be appropriate, and in this study the technique is used as a complement to OLS analysis.

3. The data and methodology

The UK data used in the present study come from a sample of 96 FE colleges, for the years 2000-01 and 2001-02, within the Learning and Skills Council's (LSC) datasets.[2] Total operating costs, as in the vast majority of empirical analyses of costs in higher education, are treated as the dependent variable: Table 1 shows descriptive statistics for total operating costs, higher education and further education outputs. Our measure of outputs, following normal practice (e.g. Koshal & Koshal 1999) is based on full-time equivalent (FTE) student numbers.[3] It is also imperative to distinguish between course types: we are able to separate higher education students by broad course type that groups science subjects, classroom based subjects and vocational subjects.[4] Table 1 clearly shows us that some of the outputs take a value of zero, hence a quadratic model is appropriate here. We estimate both linear and quadratic models and compare the results. Estimation of the quadratic cost function is as follows:

$$y = \alpha + \sum_{1-7} \beta_i x_{ik} + \sum_{1-5} \gamma_i x_i x_j + \sum_{\substack{i,j=1 \\ i \neq j}}^{5} \delta_{ij} x_i x_j + \varepsilon \qquad (5)$$

where:

y represents total operating costs (£000 *per annum*)

x_1 through x_7 represent full-time equivalent (FTE) student numbers in higher education sciences; FTE student numbers in higher education vocational ; FTE student numbers in higher education classroom; FTE student numbers in further education 'high'; FTE student numbers in further education 'low'; a vector reflecting teaching quality ; a vector reflecting the quality of the student intake.

It has been argued that any measure of the outputs of higher education should reflect the quality of teaching (Getz *et al* 1991), and also that the quality of the student intake must be considered (Koshal & Koshal 1999). We have attempted to capture the quality of teaching in several ways; firstly, by the estimation of a cost function which includes the staff-to-student ratio, secondly, by including the proportion of teachers who hold a degree; thirdly, by including a measure of the proportion of teaching staff to total staff.[5]; and finally, by estimating a model which includes as an input the average pay of teaching staff at each college.[6] The measure for the quality of the student intake is problematic because the ‘qualification-on-entry’ information is incomplete in the student record files; hence we utilise the average point score of the student intake for each institution, as recorded by the UK Department for Education and Skills.[7] To control for the fact that FE colleges in different geographical areas may face separate input prices (for example costs may be higher in the inner London area than in the midlands and north) we include dummy variables for each of the nine English local government regions.[8]

Our U.S. data come from the National Center for Education Statistics (NCES) integrated postsecondary education data system (IPEDS) for fiscal years 2000 and 2001. These data provide information for each institution on finance, compensation and enrolments. Our dependent variable is the *institution’s total recurrent expenditure* which is a function of six outputs; research, full-time equivalent students in graduate programs, undergraduates in professional, science and classroom based subjects and non-degree seeking students[9]. After omitting institutions with missing variables we have a balanced sample of 959 institutions across our two years of interest, which comprise 564 private and 395 public institutions. We also construct a subsample of colleges with a positive number of non-degree seeking students to enable an accurate comparison between English FE colleges and their appropriate US counterpart.[10] Sample statistics for our variables of interest are presented in Table 1.

As discussed earlier, we model our cost function by use of two techniques: firstly the *random effects method* (Nerlove, 1971).

$$y_{it} = x_{it}^{'}\beta + (\alpha + u_i) + \varepsilon_{it} \qquad (6)$$

where; y_{it} is the observation of total cost for the *i*th college in the *t*th time period

x_{it} is the matrix of *k* explanatory variables (not including a constant)

α is the intercept term and denotes the mean of the unobserved heterogeneity

$u_i \sim IID(0,\sigma_u^2)$ and is the random heterogeneity specific to the *i*th observation $\varepsilon_{it} \sim IID(0,\sigma_\varepsilon^2)$ and is uncorrelated over time.

and second, to cover the possibility that production may not be efficient, *stochastic frontier analysis*, which entails fitting the cost function through our data points with a bias toward the data points that indicate a lower cost for a given level of output. In this technique we assume that the regression residuals can be split into two statistically independent components. We assume the first component, measurement error, follows a normal distribution and that the other component, designed to capture inefficiencies, follows a half-normal distribution (Aigner *et al* 1977).

$$x_i = f(y_{i1},...y_{im}) + \varepsilon_i \qquad (7)$$

where $\varepsilon_i = v_i + u_i$ and x indicates the inputs and y the m outputs of the *i*th FE college. $\varepsilon_i = v_i + u_i$ such that $v_i \sim N(0,\sigma_v^2)$, u_i and v_i are statistically independent and $u_i \geq 0$.

By using a quadratic specification of this model, where interactions between the outputs and squared terms are included, we can determine the presence of economies of scale and scope.

4. Results

Cost functions for FE colleges- linear models

We start (Table 2, columns 1 through 4) by analysing our estimates from the basic linear function. Our estimated coefficients are highly significant across both specifications with the exception of the coefficient on higher education in the sciences which we believe is due to the extremely low number of students selecting this option.[11] Comparison of estimation methods reveals remarkably similar marginal costs for each of the FE outputs.[12] The costs attached to the provision of higher education classroom-based subjects and vocational subjects are similar in the random effects model; however, when we drop our assumption that all FE colleges are running efficiently, the stochastic frontier estimates reveal that higher education vocational courses, such as engineering or construction, are far less costly to provide than classroom courses[13]. Our measures of teaching quality are found to be highly significant. The student-to-teacher ratio shows a negative relationship, as we would expect, with larger classes reducing overall costs. The proportion of teachers to total staff numbers is negative and highly significant, implying that some colleges may gain efficiency benefits from reducing their ratio of managers and administrators to teaching staff. The proportion of teachers holding a bachelor's degree is highly significant and, as we would expect, increases average costs.[14] Given our results, we feel this indicates the importance of including a measure of teaching quality in the model. Teacher pay is significant when included alone but reduces in significance when the other teaching quality measures are included; therefore it may not actually be measuring this quality difference[15]. Our measure of the quality of the student intake is never significant, consistent with other findings in this field (Johnes *et al* 2005); the regional dummies, except in the South-West, are all insignificant.

Utilising the results from the stochastic frontier model in Table 2, efficiencies for each quartile are derived.[16] According to this specification, at least a quarter of FE colleges are highly efficient, with the third quartile having an efficiency score of 0.90. However, with a mean (1st percentile) score of 0.84 (0.82), some sixteen (eighteen) percentage points below unity, there appears to be room for gains in cost efficiency for many colleges. In order to obtain a clearer picture of the efficiency scores we explored, in table 3, the characteristics of our most and least efficient FE college. In this analysis, the quality of the student intake takes a similar value in both FE colleges and the most efficient FE college has a *greater* student -teacher ratio.[17]

Quadratic models

Our results lead us to hypothesise that there are efficiency gains with respect to resource allocation to be made by increasing the numbers of higher education students in FE colleges. We investigate this hypothesis by examining whether or not economies of scale or scope exist from expanding the proportion of students in each of our categories. In order to do this we estimate, in table 4, models using the quadratic specification that includes interaction and squared terms involving student numbers of all types. The fit of the random effects model is clearly good (R-squared = 0.90). The SFA quadratic specification reveals some significant interactions between the higher education subjects and further education higher-level (e.g. A levels), and a test of the restriction that the coefficients on all the interaction and quadratic terms are zero indicates that the interaction and quadratic terms are in fact jointly significant and should be included in the model.[18] This finding is similar to that of Johnes *et al* (2005). The estimates of the quadratic model are used to calculate our economies of scale and scope.

In Table 5 we present the average incremental costs for each type of student per annum, estimated using the coefficients from the stochastic frontier estimates reported in table 2.[19] The figures in the first column reflect the costs for an institution producing the mean value of all outputs. As this is a hypothetical institution we contrast these estimates with those taken from a FE college with median levels of output and shown in column 2. Both models produce remarkably similar average incremental costs. HE vocational courses are by far the most expensive to provide (at an average cost of over £17000, the estimates of the quadratic model are much higher than the linear specification). Other types of courses are far cheaper: average incremental costs of HE arts courses, at £5600 per student-year, are only one-third of the costs of vocational courses, followed by FE higher and then FE lower.

Comparison of FE colleges with other UK HE institutions

Whilst we have argued that FE colleges provide a route through higher education for specific groups of individuals, such as those of lower socioeconomic status who otherwise would not see higher education as a viable option, we nevertheless investigate here the cost of increased provision of higher education between FE and HE institutions. Table 6 reports a comparison of estimates of these costs, along with scale and scope economies between FE colleges, all higher education institutions and HE colleges[20]. Here we clearly see that our estimate of the cost of classroom-based higher education courses in FE colleges is remarkably similar to the cost of providing these courses in higher education colleges and close to the cost of providing these courses in a traditional university. In essence, there are significant economies of scale to be exploited within the FE college, both in vocational and classroom based degree-level courses, whereas they are exhausted within the university sector. In addition, our estimates reveal that the marginal cost attached to a student taking a higher education vocational subject within an FE college is some £1500, on average, less than the cost of non-science undergraduates found in either HE colleges or across all institutions. We are unable at present to identify and include a measure of the value added by further education colleges[21], which means that our estimates are likely to be biased upwards. The pattern of results for ray economies of scale and global scope economies appear identical across all institution types, revealing that economies of scale are present for all institutions and scope economies ubiquitous.

Quadratic model US colleges

We now compare our results for English colleges with our samples of US tertiary-level institutions drawn from the IPEDS database[22]. The estimates for our sample and subsample of US colleges are very similar and are presented in Table 7. The overall fit of the random effects models is clearly good (R-squared= 0.96 in both samples). Both techniques reveal some significant interactions between non-degree seekers and most of the other outputs. We find that the compensation paid to teaching staff has a significantly positive effect on costs and that the staff-to-student ratio has the expected negative relationship with costs. A test of the restriction that the coefficients on all the interaction and quadratic terms are zero indicates that the interaction and quadratic terms are in fact jointly significant and should be included in the model. Significant differences exist between our English and US samples. The characteristic US college is a well-established provider of higher education, conducts research and has a large proportion of degree seeking undergraduates and/or graduate students, whereas the English FE college is still evolving as a provider of higher education and as such has a much larger share of further education students (non-degree seekers).[23]

Economies of Scale and Scope FE colleges and US colleges

We report in table 8 the economies of scale and scope for the English and both US samples, derived using both estimation methods. Following Laband and Lentz (2003) we examine economies of scale and scope from the expansion of all types of students at each institution by calculating all economies at both mean values and twice mean values of the outputs[24]. The striking similarity in the predictions of scale economies from both estimation methodologies in both countries is clearly evident.

For English colleges there is evidence of large product-specific economies of scale for higher education arts courses and diseconomies of scale for science subjects. The random effects model provides evidence of economies of scale still to be exploited for HE vocational courses; however, the stochastic frontier estimates imply that these are exhausted. Using the estimates from both methodologies we find there are significant ray economies of scale. Whilst this result is initially puzzling, given the diseconomies found for science subjects and only small economies of scale for vocational courses, the paradox is explained by the finding of economies of scope, which are present for all course types.[25] This indicates substantial synergies between the course types and qualification levels. Both models predict high economies of scope for vocational subjects and both predict significant global economies of scope. This finding appeals to intuition if we consider that laboratories or workshops once constructed can be used for the teaching of further education or higher education courses. We consider that our results confirm our hypothesis that the expansion of higher education within colleges can increase cost-efficiency.[26] There are product-specific economies of scope to be exploited in both vocational and arts higher education courses as well as FE courses. The large global economies of scope found from both specifications indicate cost efficiency gains from expanding all these types of provision simultaneously. Columns 3, 4, 6 and 8 of Table 8, reporting our economies for twice the mean value of students, reveal that whilst most economies of scale and scope have been exhausted there are still economies of scale to be exploited for higher education courses in the arts.

The scale economies calculated for US colleges reveal that product-specific economies are largely exhausted, especially in our subsample where some diseconomies are found. However, the calculations resulting from the random effect estimates from our full sample indicates that there are further product-specific economies of scale to be exploited from expanding outputs of classroom-based undergraduates. The random effects model also suggests that there are product-specific economies present for research in both our US samples. Using both techniques we find that substantial ray economies of scale are achieved in both samples, from increasing all outputs proportionally. Looking across the table to columns 3 and 7, we can see that a doubling of all inputs would lead to ray diseconomies. However, as Laband *et al* (2003) point out, universities do not typically experience proportionate growth of their outputs. The two methodologies disagree in their findings of economies of scope. Small economies of scope are found using the random effects estimates suggesting that these are nearly exhausted, hence US colleges are utilising the synergies between their outputs to the full.

As mentioned above, the two college types we have compared are not identical either in their evolution or their current outputs. However, our results suggest that US colleges enjoy a cost advantage in the provision of higher education courses, namely a spreading of teaching and space resources, permitting greater efficiency in resource allocation; but by comparison with the English system, this cost advantage has already been fully exploited, especially in our subsample, whereas the potential cost advantage of English further education colleges is under-exploited.

5. Conclusions

We have estimated cost functions for a two-year panel of 96 colleges of further education in England by comparison with two panels of 959 and 719 colleges in the US. The FE college in England, being accessible to all socio-economic groups and providing a potential bridge to enrolment in higher education programmes, is strategically vital to the UK government's aim of universalising access to tertiary education. The analogous US college system includes both private and public institutions which we analyse together.

We use random effects and stochastic frontier methods to model our cost functions. Our English models include measures of full-time equivalent student numbers. Our measure of student quality was found to be insignificant; however, teaching quality variables were found to be highly significant, thus supporting the claim by Getz *et al* (1991) that teaching quality at the institutional level must be taken into consideration when comparing levels of cost efficiency.

Estimation of the linear specification by stochastic frontier analysis reveals that although there is room for substantial cost efficiency gains in at least half the cases examined, higher education vocational courses are the most cost-efficient. This supports our view that FE colleges, like community colleges in the US, can provide the link between the high level of vocational skills required by the local business community and students who, for whatever reason, did not make the grade the first time around. Thus, even though the market for higher education is far from perfect (Dill 1997) there is a presumption that competition serves as a vehicle to increase efficiency (Hoxby 2002, Barr 2004). Policy measures which would make such competition easier – such as, in the UK, a change in university admissions procedures to admit students from HE colleges into the second and third levels of degree courses, as is possible for community-college students in the US – are to be welcomed for this reason.

Estimation of the quadratic specification for both countries presents us with evidence of ray economies of scale, indicating that cost efficiencies can be gained by proportionally increasing the numbers of all students. For English colleges we also find evidence of substantial economies of scope, both product-specific and global, whereas these are found to be exhausted for our US sample. It appears therefore that whereas most US colleges have already exploited potential scale and scope economies by efficient resource management, substantial economies of scale and scope remain unexploited within the English FE system. An expansion of numbers within the English FE sector would appear, therefore, likely to yield a dividend in terms of efficiency as well as equity.

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Table 1: UK and US colleges: descriptive statistics

UK Variables	Obs	Mean	Std. Dev.	Min	Max
Total operating costs £	2 x 96	15309.57	8346.40	2257	51786.00
HE Science student numbers	2 x 96	27.76	45.80	0	320.17
HE vocational student numbers	2 x 96	91.92	174.49	0	1563.91
HE classroom student numbers	2 x 96	152.70	203.36	0	1387.82
FE high qualification numbers	2 x 96	357.26	319.99	0	1889.15
FE low qualification numbers	2 x 96	3361.80	1827.57	293.36	9616.08
Proportion of teachers to total staff (%)	2 x 96	0.55	0.09	0.239	0.75
Proportion teachers holding a degree (%)	2 x 96	0.59	0.16	0.154	0.89
Student-to-teacher ratio	2 x 96	10.24	3.93	4.80	27.94
Average teacher pay £	2 x 96	4685.18	2841.20	673	18389.00
Intake quality – average point score	2 x 96	2.93	2.23	2	7.50
US Variables					
Total operating costs $000	2 x 959	105.943	207.767	2.42	2063.27
Research $	2 x 959	28.466	91.469	0	1527.47
Graduate student numbers (000)	2 x 959	1.155	1.813	0	13.42
HE vocational student numbers (000)	2 x 959	0.108	0.331	0	2.62
HE classroom student numbers (000)	2 x 959	1.678	2.432	0	20.29
HE science student numbers (000)	2 x 959	1.667	1.809	0	18.06
Non-degree qualification numbers (000)	2 x 959	0.096	0.356	0	5.79
Student-to-teacher ratio	2 x 959	20.31	10.348	0.894	175.22
Average teacher pay[a] $	2 x 959	54.837	105.854	0.988	1159.28
US subsample[a]					
Total operating costs $000	2 x 719	111.136	214.770	2.42	2063.27
Research $	2 x 719	28.936	89.886	0.10	1527.47
Graduate student numbers (000)	2 x 719	1.200	1.822	0	13.42
HE vocational student numbers (000)	2 x 719	0.125	0.359	0	2.62
HE classroom student numbers (000)	2 x 719	1.732	2.343	0	20.29
HE science student numbers (000)	2 x 719	1.698	1.798	0	18.06
Non-degree qualification numbers (000)	2 x 719	0.133	0.417	0.01	5.79
Student-to-teacher ratio	2 x 719	12.02	7.042	03.75	175.22
Average teacher pay[a] $	2 x 719	57.713	109.512	0.988	1159.28

[a] 'Subsample' refers to colleges with a positive number of non-degree seeking students.

Table2: English FE colleges: estimated coefficients of the linear specifications

Total operating costs	Specification 1				Specification 2			
	Random Effects		Stochastic Frontiers		Random Effects		Stochastic Frontiers	
N= 96 X 2	Coefficient	(z)	Coefficient	(z)	Coefficient	(z)	Coefficient	(z)
HE Science	-3.274	-0.46	1.022	0.21	-4.122	-0.58	1.552	0.3
HE Vocational	5.346	2.41***	3.822	2.28**	5.028	2.24**	3.218	1.93**
HE Classroom	4.979	2.97***	5.822	4.27***	4.931	2.88***	5.634	4.03***
FE High qualification	4.237	6.28***	4.530	7.81***	3.673	5.05***	3.890	6.31***
FE Low qualification	3.553	21.51***	3.336	24.79**	3.394	18.63***	3.151	20.42***
Proportion of teachers –holding a degree	3117.288	1.81***	1679.936	1.2	-	-	-	-
Proportion of teachers To total staff	-7946.118	-2.62***	-7658.071	-3.09***	-	-	-	-
Student/teacher ratio	-233.445	-3.56***	-200.743	-3.71***	-	-	-	-
Average teacher pay	-			-	0.212	1.89**	0.214	2.08**
Intake quality	-226.117	-1.56	-150.489	-1.28	-214.727	-1.48	-161.002	-1.35
Year1 (2000-01)	-1518.943	-5.56***	-1508.508	-5.97***	-1761.645	-6.15***	-1742.238	-6.7***
South-West	2665.613	3.61***	689.798	1.2	3056.870	4.15***	1150.308	1.92**
Constant	6850.862	3.01***	5764.174	3.22***	1740.821	2.04	441.740	0.66

* significant at 10% ** significant at 5% *** significant at 1%

Table 3: England: characteristics of the 'most efficient' and 'least efficient' FE colleges

	Most efficient college	Least efficient college
Total operating costs £ 000's	20815	11765
HE Science student numbers	38.5	0
HE Vocational student numbers	123	23
HE Classroom student numbers	188.6	49.6
FE High qualification numbers	522.3	330.7
FE Low qualification numbers	5297.4	3159.4
Proportion of teachers holding a degree	.32	.63
Student-teacher ratio	10.7	8.0
Intake quality – average grade point	3.8	3.6

Table 4: English FE colleges: estimated coefficients of the quadratic specification

	Random effects		Stochastic frontiers	
	Coefficient	(z)	Coefficient	(z)
HE Science	-11.965	-0.44	-5.553	-0.25
HE Vocational	26.230	3.33***	24.121	3.88***
HE Classroom	5.845	5.13*	4.484	1.28
FE High qualification	2.524	1.31	3.47	2.25**
FE Low qualification	2.650	5.07***	2.316	6.06***
HE Science squared	-0.166	-1.48	0.104	1.16
HE Vocational squared	-0.052	-1.99***	-0.032	-1.34
HE Classroom squared	-0.001	-0.14	0.001	0.16
FE High qualification squared	0.000	0.11	-0.001	-0.04
FE Low qualification squared	0.000	0.82	0.001	1.5
HE Science*HE Vocational	0.222	1.88*	0.135	1.29
HE Science*HE Classroom	-0.165	-2.12**	-0.113	-1.77*
HE Science*FE High qualification	-0.028	-0.90	-0.037	-1.45
HE Science*FE Low qualification	0.001	-0.09	0.004	0.64
HE vocational*HE Classroom	0.029	1.39	0.015	0.95
HE vocational*FE Highqualification	-0.000	-0.49	-0.002	0.61
HE vocational*FE Low qualification	-0.002	-1.45	-0.003	-2.29**
HE classroom*FE High qualification	-0.002	-0.28	-0.004	-0.63
HE classroom*FE Low qualification	0.001	0.50	0.001	0.99
FE high *FE Low qualification	0.001	1.44	0.001	1.62
Proportion teachers holding a degree	3037.386	1.6	1669.701	1.12
Year1	-1671.661	-5.77***	-1637.594	-6.54***
SouthWest	2661.826	3.57***	749.066	1.26
Constant	681.768	0.62	541.524	0.68

Lagrangian[27] tests for random effects chi^2= 17.54: Overall R^2 0.985

Table 5: English FE colleges: estimated average incremental costs FE colleges[b]

£	All institutions mean values	All institutions median values
HE Science	-	-
HE Vocational	17180	15000
HE Arts	5610	5860
FE Higher	3890	4440
FE Lower	2810	2740

[b] Calculated using the stochastic frontier estimates

Table 6: UK: comparison of costs between FE colleges and higher education institutions

	Costs 000s			Economies of scale/scope[e]	
	All HEIs	HE colleges	FE colleges	All HEIs	FE colleges
Non-science undergraduate/vocational	4.713	4.809	3.218	0.86	1.09
Non-science undergraduate/classroom	4.511	5.096	4.931	0.86	1.51
Ray economies of scale				1.13	1.17
Global economies of scope				0.58	0.51

[e] for an accurate comparison these are calculated using the random effects estimates

Table 7: US colleges: estimated coefficients of the quadratic specification

	All US colleges N=959 x 2				US colleges – subsample N=719 x 2			
	Random effects		Stochastic frontiers		Random effects		Stochastic frontiers	
	estimate	(z)	estimate	(z)	estimate	(z)	estimate	(z)
Non-degree seekers	1.107	0.12	-9.869	-0.82	4.568	0.42	-13.006	-0.85
Degree classroom	6.772	4.33***	5.131	4.01***	6.926	3.54***	6.023	2.84***
Degree science	-0.033	-0.02	1.607	1.77*	0.101	0.04	2.562	1.81*
Degree professional	58.408	5.41***	10.3001	1.74*	61.416	4.53***	16.057	2.00**
Graduate	8.509	5.28***	6.691	4.39***	10.008	5.09***	8.145	4.38***
Research	1.204	25.06***	0.896	31.77***	1.202	19.03***	0.769	16.07***
Non-degree*degree classroom	9.127	3.83***	5.893	2.38**	10.839	3.98***	4.102	1.92*
Non-degree*degree science	-6.560	-2.38**	-2.636	-0.84	-11.132	-3.28***	-2.469	-0.63
Non-degree*degree professional	-77.848	-3.7***	-53.554	-2.55***	-88.940	-3.75***	-38.330	-1.39
Non-degree*graduates	-1.931	-1.13	1.245	0.40	-2.501	-1.35	0.652	0.25
Non-degree*research	0.453	4.51***	0.093	0.83	0.534	4.66***	0.164	1.28
Degree classroom*science	-0.364	-0.98	-0.0168	-0.08	-0.953	-1.82*	0.051	0.15
Degree classroom*professional	-1.084	-0.58	-0.912	-1.16	-1.346	-0.59	-1.912	-1.57
Degree classroom*graduate	-0.084	-0.36	0.163	0.95	0.144	0.50	0.281	0.98
Degree classroom*research	-0.017	-2.09**	0.001	0.07	-0.017	-1.80*	0.011	2.14**
Degree science*professional	0.976	0.37	0.795	0.66	-2.265	-0.64	1.459	0.65
Degree science*graduate	0.478	1.45	0.216	0.77	0.511	1.18	0.141	0.39
Degree science*research	0.015	0.82	0.023	3.24***	0.043	1.78*	0.027	1.91*
Degree professional*graduate	5.535	3.33***	5.456	5.23***	5.072	2.57***	5.256	4.02***
Degree professional*research	-0.069	-1.99**	-0.067	-3.85***	-0.118	-2.62***	-0.096	-2.80***
Graduate*research	0.006	1.01	0.018	3.66***	0.002	0.30	0.025	3.39***
Non-degree^2	-0.932	-0.44	2.122	0.37	-1.562	-0.66	2.849	0.55
Degree classroom^2	0.012	0.07	-0.068	-0.55	-0.082	-0.39	-0.230	-1.09
Degree science^2	0.833	3.65***	0.250	2.08**	1.247	4.26***	0.160	0.99
Degree professional^2	-4.205	-0.58	11.060	3.30***	2.474	0.28	13.382	2.65***
Graduate^2	-0.224	-1.23	-0.209	-1.53	-0.453	-1.99**	-0.359	-2.16**
Research^2	-0.001	-14.67***	-0.004	-15.41***	0.001	-12.28***	-0.001	-13.23***
Compensation	0.745	33.75***	0.694	54.22***	0.759	27.61***	0.636	35.26***
Staff/student ratio	-238.080	-2.77***	-256.019	-2.99***	-283.53	-2.62***	-249.172	-2.62***
Year1	3.754	5.630***	2.991	3.52***	4.800	5.74***	2.852	2.67***
2year college	-10.367	-0.640	-23.141	-0.99	-	-	-	-
Constant	3.669	1.36	-10.271	-2.48***	1.855	0.52	-11.080	-1.80*
	Overall R^2 = 9636				Overall R^2 = 9577			
Lagrangian tests for random effects chi^2 = 348.92					Chi^2 = 273.70			

Table 8: UK and US colleges: economies of scale and scope

	Random effects estimates				Stochastic frontiers estimates			
	Mean values		Mean values x 2		Mean values		Mean values x 2	
	scale		scale	scope	scale	scope	scale	scope
HE Science	0.31	0.18	0.42	0.12	0.45	0.12	0.41	0.09
HE Vocational	1.09	0.14	0.65	0.02	1.00	0.14	0.43	0.06
HE Arts	1.51	0.16	1.16	0.09	1.15	0.10	1.05	0.05
FE Higher	1.29	0.13	1.07	0.03	1.09	0.10	1.02	0.05
FE Lower	1.04	0.13	1.0	0.03	1.01	0.06	0.97	0.03
	Ray	G	Ray	Global	Ray	Global	Ray	Global
	1.17	0.51	1.06	0.24	1.24	0.43	1.05	0.16
All US colleges								
Research	1.05	0.02	0.73	-0.01	1.08	-0.15	1.00	-0.01
Graduates	1.02	0.02	0.71	-0.01	0.99	-0.15	0.89	-0.09
HE vocational	0.99	0.04	0.76	0.03	0.98	-0.13	0.90	-0.03
HE Science	0.99	0.04	0.84	0.03	1.01	-0.14	0.77	-0.10
HE classroom	1.03	0.04	0.64	0.03	1.07	-014	0.61	-0.06
Non-degree	1.02	0.03	0.87	0.01	1.03	-0.13	0.77	-0.10
	Ray	G	Ray	Global	Ray	G	Ray	Global
	1.05	-0.22	0.87	-0.15	1.12	-1.28	0.93	-0.85
US college subsample								
Research	1.05	-0.01	0.85	-0.01	1.05	-0.14	0.64	-0.02
Graduates	0.94	0.00	0.65	-0.02	0.97	-0.16	0.59	-0.11
HE vocational	0.86	0.03	0.75	-0.01	0.92	-0.16	0.58	-0.04
HE Science	1.00	0.04	0.59	0.02	0.98	-0.13	0.62	-0.02
HE classroom	0.99	0.03	0.67	0.03	1.02	-0.17	0.35	-0.01
Non-degree	0.97	0.01	0.63	0.00	0.99	-0.17	0.55	0.00
	Ray	Global	Ray	Global	Ray	Global	Ray	Global
	1.07	-0.30	0.88	-0.18	1.14	-1.30	0.77	-0.54

[1] Individuals not completing high-school in the US take the General Education Diploma whereas in the UK they can attend an FE college either full-or part-time to retake their courses.
[2] Datasets include the staff information records, the individualised student records and the college account records for the years 2000/01 to 2001/02.
[3] Students are classified as full-time if, within their course, they complete 450 guided learning hours (glh). The hours of part-time students are summed for each college.
[4] Classroom subjects include arts, humanities and business studies. Vocational subjects include construction, engineering and agriculture.
[5] Staff recorded in the LSC data includes teachers, administrators, managers and technical staff.
[6] Staff details are taken from LSC staff individualised records. The practice of measuring teaching quality by pay is open to criticism (as discussed in section 4), but we have included it here because teachers may be seen as more productive if they have experience in teaching across a range of courses and therefore may command a higher salary.
[7] Information and scores available at http://www.dfes.gov.uk
[8] The nine English regions comprise: South; South West; South East; East Anglia; Greater London; East Midlands; West Midlands; North West; North East.
[9] Whilst the US and English college analyses consist of higher education outputs of science, classroom and vocational/professional subjects, it is not possible to separate the US non-degree seekers, equivalent to the English further education students, by 'high' or 'low' type studies.
[10] Ideally one would wish to create a subsample containing principally 2 year colleges. However, over 95% of the 2 year colleges, in the data provided by IPEDS, have missing information in the subject fields leaving us with only 10 complete records. We have endeavoured to control for the characteristics of the 2 year college by the inclusion of a '2 year' dummy in the full sample model , shown in columns 1 through 4 of Table 7.
[11] Of our 96 FE colleges 37 report zero outputs, half of the remaining ones reporting extremely low numbers.

[12] Differentiating the linear cost function partially with respect to each output results in its respective coefficient hence, the coefficients are the respective marginal costs.
[13] The null hypothesis of no cost inefficiency present was tested using the likelihood ratio test based on a comparison of the ML random effects and SFA model (Coelli et al 1998 ch 9). The chi square statistic of 48.5 is sufficient for us to accept the stochastic frontiers model. See Coelli *et al* (1998).
[14] Because of the wide range of types of courses on offer, not all teaching staff at each FE college are required to hold a bachelor's degree.
[15] Pay is determined by seniority and tenure as well as the ability to teach. Therefore, whilst a measure of teaching quality should be incorporated in the modelling, we do not believe that pay is an adequate indicator of this quality.
[16] Total efficiency is given by a score of unity.
[17] We should point out here that in this study we are not concerned with output quality.
[18] x^2=23.41 with 15 degrees of freedom
[19] The average incremental costs are not reported for HE science as the small number partaking leads us to doubt the estimates, as alluded to on p14.
[20] Estimates for HE colleges and all institutions relate to the same time period , Johnes *et al* (2005)
[21] Value added, for example, from business links with employers and the local community
[22]The Integrated post-secondary education database contains all public and private tertiary-level institutions in the US. Information on enrolment, finances, compensation and students are recorded.
[23] An inspection of college characteristics on the relevant websites revealed that UK FE colleges have an average proportion of 7% students in higher education whereas in Connecticut the corresponding proportion is 62%.
[24] These measures are derived for a hypothetical college producing average levels of all outputs.
[25] The relationship between economies of scope and product-specific aggregate scale economies are illustrated by Baumol *et al* (1988 p 74). By definition: the incremental costs of producing product T in isolation plus the incremental cost of producing all other outputs barring product T must equal the cost of producing all ouputs plus the cost of producing all outputs less the cost of product T and less the cost of all outputs excluding T.
[26] The finding of economies of scope for science subjects is to be treated with some caution because there are a small number of students in this category and we have assumed average outputs for our hypothetical FE college.
[27] The Breusch and Pagan Lagrange multiplier test tests the null hypothesis that $var(u_i) = 0$ against the alternative that $var(u_i) \neq 0$. It follows a chi-squared distribution with 1 degree of freedom. Rejection of the null hypothesis (if chisquared>6.63) suggests that the random effects model is significant (at the 1% significance level).