# Efficiency and Competition in English and Welsh Universities 

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#### Abstract

There is a paucity of efficiency studies on the higher education sector in Britain. Only a small subset of those utilise stochastic frontier analysis (Izadi et al., 2002; Stevens, 2005). This paper bolsters the existing UK higher education stochastic frontier analysis literature through application of the conditional heteroscedasticity approaches to modelling environmental variables suggested by Coelli et al. (1999a). Our database consists of 142 higher education institutions within England and Wales from 2004 to 2009.

Application of the net and gross efficiency concepts allows the paper to distinguish between factors which affect the level of frontier cost faced by an institution, from those which only impact on efficiency. The analysis shows that institutions with higher proportions of female students, non-EU students, and STEM students suffer from lower efficiency. Conversely higher levels of female staff, membership to the Russell Group, and offering a Law programme are associated with greater efficiency of institution. Additionally, we provide evidence against the efficiency impact of geographical location and changing fee regime before reporting overall efficiency scores.

The disparity in efficiency between all institutions will enable Institutional managers to identify key examples of best practice within the Sector, allow managers to separate increased levels of cost from increased inefficiency, and will suggest potential future areas of regulation and legislation to policy makers. Furthermore, this paper contributes a newly derived measure for research output. This extends measures of research output currently used and improves the precision of the estimated frontier enabling future benchmarking analysis to be more robust.

The efficiency measures generated suggest that there may be benefits to mergers within the higher education sector. Following the Bogetoft and Wang (2005) model we evaluate the potential gains in efficiency to be realised through merging various institutions. We find that in


several instances there are indeed benefits to be achieved through merger, particularly through joining institutions with specific, narrow curricula to those with broader curricula. Additionally there is also benefit to scale efficiency through merging institutions which occupy similar geography such as Birmingham which hosts five institutions.

This thesis finally considers the competitive nature of the higher education sector and how intense that competition is. Through a novel application of the Boone (2008) model we evaluate the change in efficiency over the period of the sample find that there was an increase in competition across the full sample immediately following the fee increase in 2006-2007, though interesting the effects of competition are different between Russell Group and non-Russell Group subsamples.

The effects of merger and competition within the higher education sector could inform policy decisions with further fee increases looking ever more certain. Encouraging mergers amongst smaller, focused institutions may provide additional resilience within the system, however the effect on competitiveness within the system must also be considered to ensure ever increasing standards.

## CHAPTER 1. Introduction

### 1.1 Background

In the past two decades the accountability and transparency associated with public spending has increased with governments facing constant critique over their allocation of resources to publicly funded bodies culminating in the Open Data White paper designed to hold public "feet to the fire all year round" (Cabinet Office, 2012) (pg 5). The higher education sector has been an incredibly well financed sector and the financial burden on the government is large - with an average public expenditure per pupil of approximately $22 \%$ as a percentage of GDP per capita from 2004-2010 (UNESCO Institute of Statistics, 2010). The recent financial crisis has forced considerable restraint in public spending and the higher education sector has been targeted for savings. $79 \%$ of higher education funding councils funding has been removed, reducing funding from $£ 4.6$ billion to $£ 0.7$ billion (Richardson, 2010).

The issue of the funding burden has been around since the early 1980s, where value for money initiatives by the government forced universities to respond with the Committee of Vice Chancellors and Principals (1985). A timeline of steadily increasing fees began in 1998 with £1000 per year per student, which was raised to $£ 3000$ in 2006 and has since risen to $£ 9000$ per year per student in 2012 (Blake, 2010). Though clearly not a new issue, the magnitude of the current problem for universities is now substantially greater, being faced with both significant teaching funding reductions and research funding consolidation.

Efficiency is seen as a key solution for universities to deal with the changing funding landscape. The 'Students at the Heart of the System' White Paper (Department for Business and Skills, 2011) suggests, with reference to the sustainability of institutions, that there must be a focus on
the "quality [...] and the efficiency" ( pg 14 ) of their provision. To demonstrate the increasing emphasis on efficiency in the sector it is noted in the 'Students at the Heart of the System' white paper that Professor Ian Diamond would be leading a review of efficiency in the higher education sector.

As an important topic for the future of the higher education sector it is natural to consult the research literature and in doing so it is only cost or input and output distance function based efficiency measures that can be found (Stevens, 2005; Agasisti and Salerno, 2007) . It is natural to assume that universities will want to minimise costs as in doing so they will ensure more funds are available to invest and improve.

Recent literature has also begun to make use of the model of merger gains developed by Bogetoft and Wang (2005) to more closely analyse public utilities and services across Europe. These authors have found that there are significant gains to be made through the merger of geographically co-located branches or provincial offices (Zschille and Walter, 2012; Kristensen et al., 2010; Walter and Cullmann, 2008). The recent changes to funding for both the teaching and research activities of higher education institutions, or HEI, are sweeping and harsh. It is likely that in future funding will be concentrated towards top institutions and, as such, smaller ones may begin to struggle. This is precisely the situation where mergers take place and although there have been only a small number recently within the sector (e.g. Victoria University of Manchester and UMIST) there is a distinct possibility of more. The efficiency implication of mergers between HEI is therefore of paramount importance, which accordingly is modeled within this thesis.

The 'Students at the Heart of the System' White Paper (Department for Business and Skills, 2011) also gives attention to "enabling greater competition" (page 19) through the allocation of approximately $40 \%$ of student numbers on a contestable basis. These students represent the lost public funding and are a significant source of income for universities. It is therefore expected that inter-university competition will instensify in the future. It is likely that this increasing competition will affect the efficiency of HEI, a sentiment echoed in the research literature which has seen a number of examinations of competition and its effect on efficiency
in various markets (Orazem and Vodopevic (2003), Slovenian Manufacturing; Cooper et al. (2011), English NHS; Nickell (1996), UK Companies). The reverse is also of interest: how does efficiency, with its far reaching implications, affect competition? Given the importance placed upon competition by policy documents, the (Boone, 2008) model is applied to the higher education sector to estimate the degree of competition using estimates of efficiency.

### 1.2 Overview of the Study

The Students at the Heart of the System White Paper (Department for Business and Skills, 2011) has put efficiency and competition at the top of the policy agenda for the higher education sector. In addition, removal of nearly $80 \%$ of public funding has served as a catalyst for increased focus on efficiency in delivery and effective competition with others. Success in these areas will become ever more important to the survival of HEI.

Accordingly, the broad aim of this thesis is to examine the levels of efficiency and competition within the higher education sector. Three specific aims are noted and will form the three empirical chapters of the thesis:

1. Examine a range of stochastic cost frontier models to determine the environmental factors that determine institutional best practice;
2. Determine the potential gains from merging two or more institutions;
3. Utilise the cost efficiency scores developed in 1. to estimate the degree of competitiveness for each University in each time period.

Robust determination of the environmental factors that affect institutional best practice will be of considerable practical use, whilst the discovery of potential merger gains and estimating the degree of competitiveness will constitute novel contributions to the academic literature and will inform the policy debate. Section 3.2 on page 19 will present details of the function to be used, including diagrammatic exposition and properties. This is followed by a discussion of selected stochastic frontier models and methods that could be used for for efficiency estimation.

More specifically, Chapter 2 discusses the relevant policies which have had potential implications for efficiency, mergers, and competition in the higher education sector. The higher education sector has undergone a period of intense change, from a sector with abundant funding, to one with falling funding and increasing demand, and now to one with significantly reduced funding and declining demand, which has resulted in universities operating with a more competitive mindset. Particular issues which are considered in Chapter 2 are the possible implications for efficiency, mergers, and competition in the higher education sector of changes to the fee regime, value for money initiatives, and declining public financing.

Chapter 3 begins by setting the foundation for the parametric frontier analysis which takes place towards the end of the chapter. At the outset of Chapter 3 therefore, a detailed review of various stochastic frontier models are provided, with particular reference to the cost function. Additionally a variety of methods to include environmental variables into the stochastic frontier model and a variety of assumptions about the distribution of inefficiency are examined. Chapter 3 concludes with an efficiency analysis of HEI using a parametric technique, stochastic frontier analysis, or SFA.

Chapter 4 explores an application of data envelopment analysis, or DEA, and in particular the methodology of Bogetoft and Wang (2005), to examine the potential for mergers within the higher education sector. This approach utilises the super-additivity assumption to create a post merger decision making unit, or DMU, which can then be analysed for its efficiency. It will also build upon the results of Chapter 3 by incorporating environmental variables, whose contributions or detractions from efficiency were determined in Chapter 3, into the set of outputs for the DEA model.

Chapter 5 is the final empirical chapter and uses the efficiency scores created in Chapter 3 to apply the Boone relative profit differences model (Boone, 2008) to the higher education sector. Using the approach to solving the Boone model as offered by Deygun et al. this chapter is able to determine whether competition intensified in the period leading up to the increase in fees to $£ 3000$, and in the years following.

Chapter 6 summarises the salient features of the preceding empirical chapters and the contri-
butions to existing literature. Revisiting the aims of the thesis allows key conclusions to be drawn, and to finally close by proposing a few interesting areas for continued work.

# CHAPTER 2. Developments in the Higher Education Sector: Possible Implications for Efficiency, Mergers, and Competition 

### 2.1 Introduction

Over the last few decades the higher education sector in the UK seen a number of changes that have created a fundamental shift in how HEI, students, and funding councils interact.

In the 1980s following a period of increasing reliance on public funding by HEI the British Government moved to introduce a range of performance measures across the higher education sector. These performance measures were designed to hold accountable those in receipt of public funds and to drive improvements in efficiency (Johnes, 1996b), and were supported by the Committee of Vice Chancellors (Johnes, 1996b).

Traditionally, although divided into two the distinct groups of universities and polytechnics prior to 1992, HEI had been well funded public institutions. Each group had a different funding mechanism, the University Funding Council (UFC) and the Polytechnic and Colleges Funding Council (CFC), and although funding from non-public sources increased during the 1980s there remained a predominant reliance on state funding.

The Further and Higher Education Act 1992 (Department for Innovation and Skills, 1992) ushered in a period of tumult for the higher education sector. It removed the binary divide between universities and polytechnics (Harman, 2000) as well as prompting the consolidation of the two previous funding council bodies into a unitary authority, the Higher Education Funding Council for England (HEFCE). It is worth noting here that institutions in Wales are funded separately to English universities, receiving their funding from the Higher Education Funding

Council for Wales (HEFCW).
The result of this act was for 32 former polytechnic colleges to become full universities, bringing the total number of universities to approximately 90 and the total number of students to 1.25 million. This dramatically increased capacity of the higher education system but also created more competition and uncertainty.

The Further and Higher Education Act also brought about changes to the manner in which students were funded. Prior to the act there was a fairly straightforward system whereby a fee per student was given to each institution plus an extra block grant to top up where required.

In the early 1990s the system was finessed to factor in difference in costs of each subject to the block grant component (using the number of students in a subject the previous year multiplied by the unit cost of tuition for that subject), and to continue to issue the tuition fee on the current years intake. The effect of this was to penalise additional intake over previous levels in any given year but then to ensure they were fully funded subsequently. Here universities would have to weigh the cost of one year against the additional funding received over the rest of the study of the student.

After the Further and Higher Education Act in 1992 additional changes were made to the funding system, adding in a reduction component for assumed gains in efficiency. This reduction component varies inversely with the number of new students recruited over previous levels. Additionally the allocation of marginal funds was then done competitively across the sector which varies positively with the rate of expansion. Institutions would then receive a proportion of the level of additional recruitment times the unit cost for of students for that institution.

Then in 1996 the Dearing Report (National Committee of Inquiry into Higher Education, 1997) was commissioned to give recommendation on funding for higher education over the next 20 years. Released in 1997, the report recommended a number changes to the higher education system with particular focus on funding structures. It noted that "research expenditure in the UK compares unfavourably with that in many competitor countries" (point 53) and makes recommendation for "additional resources" to cover the "full indirect costs" of any funded
projects (Recommendation 34 ).

Further, it encourages restraint in the proposed cuts in funding to maintain quality (point 83) but that " $60 \%$ of total public funding" be distributed "according to student choice by 2003" (Recommendation 72). This was one of the first independent recommendations which pointed toward student fees. It also discussed the possibility of cuts in funding for the sector which were already beginning to affect HEI. Following this independent recommendation the then Labour government introduced the Teaching and Higher Education Bill (Department for Innovation and Skills, 1998) wherein an increase in tuition fees to $£ 1000$ was proposed, and later introduced.

This increase was not the tuition fee that has come to the fore of recent political campaigns, but rather an upfront payment which supplemented funding from the government. It was accompanied by a target to increase participation to $50 \%$ of university aged people (18-30) by 2010. Between 1996 and 2003 this target led to a rise by approximately $33 \%$ in student numbers. A rise in both income from research funding ( $67 \%$ ) and expenditure ( $45 \%$ ) was also evident over this period. It seemed that such a massive boom period for the higher education sector could not last and in 2003 the scene was set for something different once more.

In early 2003 the Labour government introduced The Future of Higher Education Bill (Department for education and skills, 2003) wherein funding for the higher education sector was to be changed once again. It comments on the challenges faced from economic competitors who "invest more [...] than we do" (1\% of GDP compared to the UK's $0.8 \%$ ) (point 1.12), and suggests an increase of $£ 1.25$ billion (page 6 ) in 2005 - 06 to maintain competitiveness. The bill also allows for variable tuition fees to be set by HEI "between $£ 0$ and $£ 3,000$ per year" to be "paid fairly when graduates are in work linked to their ability to pay" (page 5) shifting the financial burden further onto the beneficiaries and away from up-front costs.

Additionally, a new theme on endowment funds features in the bill where the government "see a much greater role for HEI establishing endowment funds and using income from them" (point 1.35), promoting the self funding of HEI. ${ }^{1}$ During this period of further change another 31

[^0]polytechnic colleges of various guises took advantage of the possibility to become HEI and with this second wave the total number of new HEI came to approximately 63 , almost doubling the amount of pre-1994. This resulted in a total of 115 HEI in the UK.

Over this period (1994/1995 to 2005/2006) the funding received by institutions rose by $29 \%$ in real terms leading to a massive $£ 7544$ million. Not only was this value of money vast, it represented approximately $40 \%$ of the institutional income across the sector. Student numbers also grew to over 2.4 million during this period. During financial turmoil there were also some closures of institutions to be merged with others, in 2002 University of North London and London Guildhall University merged to form London Metropolitan University, in 2004 Victoria University of Manchester and University of Manchester Institute of Science and Technology merged to become the University of Manchester. These two examples are clear reminders that universities are not too important to fail, but do hint at a preference of policymakers to keep institutions open where possible.

As time progressed numbers of students and funding continued to rise such that in the academic year 2008/2009 the higher education sector received approximately $£ 26800$ million with student numbers across the UK reaching nearly 2.5 million. More than a third of the $£ 26800$ million came from the Department of Business, Innovation, and Skills with other sources of income being residence and catering fees, services to business in the form of consultancy, international student fees, endowments and charitable giving (Baskerville et al., 2011). In light of the continued reliance upon public funding the topic of higher education funding and tuition fees once again featured in public discourse leading to the commission of the Browne Review (Department for Business and Skills, 2010).

In 2010 the Browne Review (Department for Business and Skills, 2010) of higher education was complete and recommended a "radical departure from the existing way in which HEI are financed" where block grants would stop and "finance follows the student" (page 3). Figure 2.1 (Universities UK, 2012) demonstrates the changes in constituent parts of teaching incomes for institutions. The top line represents government funding income, and the bottom teaching for the University to fund its ongoing operations.
income. Whilst there is a clear growth in income, tuition fees come to overtake government funding as the primary source of funding in 2010-11.


Figure 2.1 Trends in total teaching income by source, 2000-01 to 2010-11

This was followed by the Students at the Heart of the System White Paper (Department for Business and Skills, 2011) which proposed a maximum tuition fee of $£ 9000$ with a minimum of $£ 6000$ (point 1.5). This change would permit dramatic cuts in government funding. Steve Smith, President of HEI UK reports that budgets for HEI and research could fall from $£ 11.5$ bn to $£ 6 \mathrm{bn}$, representing a cut of $80 \%$ for teaching budgets (Richardson, 2010). The Students at the Heart of the System White Paper (Department for Business and Skills, 2011) makes further reference to "stimulating competition" within the HE Sector, celebrating the initiative to draw on cost saving experience by Universities UK to "support measurable improvements in efficiency in the higher education sector" (Department for Business and Skills, 2011) Point (1.21) .

Figure 2.2 (Universities UK, 2013) shows that by $201147 \%$ of the $25-34$ year old age group in
the UK had a tertiary education having grown from only $35 \%$ in 2005 . This trend and level is compared to other countries in across the world in a paper on funding the Universities UK (Universities UK, 2013) and demonstrates a favourable position, not the highest but above the US, Germany, and EUR21 average. Of course this assumes that higher levels of tertiary education are favourable. The paper also comments on the well established links between higher education in the workforce and substantive macroeconomic benefit.


Figure 2.2 Trends in tertiary education attainment, for 25-34 age group, 2005-2011

This link, combined with other analysis within the paper suggesting graduate recruitment and salaries remain high, suggests the trend in growing, or at very least high, student numbers will remain over the coming years. Indeed the paper begins by acknowledging an expectation for levels to remain high, and to grow, and that such numbers would place incredible strain on the student loans system (a, now privatised, organisation providing low rate of repayment loans specifically for education purposes to students (Universities UK, 2013).

The difference between Welsh and English students continues to be stark. Recent figures (Bawden and Young-Powell, 2014) show that Welsh students are dramatically better funded in comparison with their English counterparts. In the early stages of tuition fees Welsh students were not charged if the attended a Welsh institution. This began to flex with the introduction of higher fees although they continued to be heavily subsidised by the Welsh Assembly. As of 2014-2015 Welsh students pay only $£ 3,685$ of the $£ 9,000$ fees set by the majority of institutions.

They are also eligible for over $£ 5,000$ worth of bursaries if family income is below $£ 50,000$; a higher threshold than either English or Scottish families, and a higher value of bursary. This difference is something that researchers must be aware of when conducting estimations as it may impact results.

Table 2.1 summarises the timeline of events for England and Wales is produced below with substantive reference to Blake (2010); Wyness (2010); BBC (2010); Department for Training and Education (2005).
Table 2.1: Timeline of events for England and Wales Higher
Education Sector

| Year | England | Wales |
| :---: | :--- | :--- |
| 1989 | Conservative government introduce loans of up to $£ 420$ for <br> all students. Grants of up to $£ 2265$ remain available for <br> poorer students. <br> 1996 <br> Conservative prime minister commissions Lord Dearing to <br> make recommendations on higher education funding. <br> 1997 | Labour government elected. Dearing report published and <br> recommends $25 \%$ of cost of tuition should be paid by stu- <br> dents. Labour Education Secretary announces tuitions fees <br> of £1,000 per year to begin in September 1998. Student <br> grant of £1,710 is abolish in favour of means-tested loans. <br> 1998 |
| $£ 1,000$ fees come into law (The Teaching and Higher Edu- |  |  |
| cation Act). |  |  |
| 2002 |  | Maintenance grants of $£ 1,500$ introduced for by Welsh As- |

Table 2.1 - continued from the previous page

Table 2.1 - continued from the previous page

| Year | England | Wales |
| :---: | :--- | :--- |
| 2010 | Lord Browne's report is published a recommends increased |  |
|  | fees with students paying at least $£ 21,000$ for a three year <br> course. <br> 2012 | First cohort of students to begin paying £9,000 tuition fees. |

### 2.2 Concluding Remarks

The changes in the higher education system over the last few decades have been dramatic; transitioning from a free, less utilised, more elitist system to one of expensive fees, high utilisation, and broad access. The increasing fees continued heavy funding by the public sector make the need for effective performance measurement even more pressing than when first introduced in the 1980s. The ability of institutions to transform incurred cost and used input into productive output such as students and research will become more critical than ever in determining the success, and survival, of institutions.

Those institutions that show low efficiency and begin to suffer may well not survive. This would be a very difficult political scenario and as the past would suggest institutions which seem likely to fail are merges with other institutions to form larger, more successful entities such as the University of Manchester. Similar scenarios have played out in European higher education sectors, and indeed, following analysis some higher education sectors have been subjected to compulsory mergers so as reduce the size of the sector (Kyvik, 2002). Perhaps within the UK the smaller specialist institutions have run their course and the changing economic climate and fee structures will force them into mergers with each other or to join larger institutions as an additional faculty. It will be important for policymakers to continue to monitor whether it would be best to follow the lead of some other nations (Harman, 2000; Curri, 2002; Kyvik, 2002) and reduce the number of institutions.

Substantial changes to pricing and demand in any industry are likely to cause changes in competitiveness, sometimes through new entry and sometimes through increased production amongst incumbents. Similar changes to pricing and demand within the higher education sector may lead to changes in efficiency and possible further mergers between institutions. The subsequent impact of these changes may be an effect on the level of competition within the sector. A benefit to having as large a higher education sector as the UK does is that, at least in theory, it generates competiveness amongst the institutions. They drive each to be more attractive to students to secure the revenue that they bring, and typically more attractive is
assumed synonymous with higher quality. Changes to that level of competitiveness may encourage policymakers to consider more carefully choices to allocate resources based on performance, or to legislate a contraction of the sector.

# CHAPTER 3. A Stochastic Cost Frontier for English and Welsh Universities 

### 3.1 Introduction

There have been a number of efficiency studies on a range of higher education sectors (Avkiran, 2001; Abbott and Doucouliagos, 2003; Agasisti and Salerno, 2007) and the majority use data envelopment analysis (DEA). DEA is one of two popular frontier modelling methods for estimating efficiency and is advantageous for its flexibility since it does not require the specification of a functional form (Abbott and Doucouliagos, 2003). It is, however, a deterministic method, assigning all deviation from the efficient frontier to inefficiency, which forces sources of error or random external factors to affect the level of inefficiency reported (Flegg et al., 2004). A more theoretically grounded method is stochastic frontier analysis (SFA), independently developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), which uses a stochastic error term. The stochastic error term consists of two components. The first is an idiosyncratic error, to capture external factors and sources of error, and the second measures inefficiency allowing for the inefficiency reported to be independent of shocks. Though disadvantageous in requiring a functional form and an assumption about the distribution of the inefficiency term, the advantage of being stochastic, rather than deterministic, and therefore not misinterpreting random prediction errors as inefficiency is of greater impact. Several studies have utilised SFA to examine the higher education sector (Stevens, 2005; Izadi et al., 2002; Johnes, 1998) and have been a source of inspiration for this research. A study using SFA will therefore not only benefit from the advantage of its stochastic nature, avoiding the deterministic pitfalls of DEA, but will also contribute to a smaller pool of research, as opposed to a DEA study where there
is a bounty of research, and so for this study SFA will be used.

As this chapter progresses it will consider: the formulation of the basic cost function; an exploration of efficiency estimation using stochastic frontier models; a variety of stochastic frontier models which could be used; and application to the higher education sector including the typical inputs, outputs, and environmental variables that will need to be estimated. The chapter will then present the model to be estimated, develop a function form, tabulate the data to be used along with sources, and finally discuss the results of the estimated model. The discussion will consider variables affecting the position of the frontier, the conditional mean of the distribution, and the efficiency scores, before contemplating the implications of this research. It is also worth noting that that efficiency scores produced in this chapter will provide a basis for the empirical work on the higher education sector, estimating potential mergers (Chapter 4) and determining the level of competition (Chapter 5).

### 3.2 The Cost Function

Focus on a cost function will be central to this research, and the reasons for its use are two fold; attractive mathematical properties and credible intuition. As a choice over other functions the intuition is clear, in reacting to competition and a difficult business environment many firms look first to reducing costs. It is a facet of business that is internal and relatively self determined in comparison with revenues where little direct control can be exerted by the company. Further, the data required for estimation of the model is readily available, which obfuscates a number of issues that can occur with other functions, in particular profit and revenue.

It is important here to briefly consider the evolution of cost function analysis of higher education. Initially much of the research focused on a single output (student enrollment) HEI and assumed away all other outputs. Cohn et al. (1989) note this tradition, and the progress shown in Verry and Davies (1976); Verry and Layard (1975) in recognising the multi-dimensionality of HEI, but feel it does not engage in full and "rigorous analysis of scale and scope economies" (pg 284) that can be found in multi-product environments as conceptualised in Baumol et al.
(1982).

It is intuitively clear that HEI are multi-dimensional, being charged with creating and dispersing knowledge (commonly research and teaching) and, lately, engaging communities with the knowledge they are creating, otherwise known as the third mission. It is therefore core to the current research to consider HEI on these terms, taking the lessons on economies of scale and scope from Baumol et al. (1982). As an advancement of research Cohn et al. (1989) take these lessons and go on to estimate a multi-product cost function of HEI, providing the a seminal work in this particular area and ensuring the future research would involve a multi-dimensional HEI.

As Cohn et al. (1989) demonstrates, choosing the right cost function is key and so, given its importance, a more detailed consideration of cost function formation is validated. Rao et al. (2005) build their cost function in a very appealing way which will be mirrored here. Consider first a perfectly competitive firm, whose output is so small that it does not affect market price of its inputs. The simple cost function faced is:

$$
\begin{equation*}
c(w, q) \tag{3.1}
\end{equation*}
$$

equation 3.1 shows the costs of the firm as a function of $w$, input price, and $q$, output. It is important to note here that multi-input and multi-output firms will have vectors for both $w$ and $q$, i.e. $\boldsymbol{w}=\left(w_{1}, w_{2}, \ldots, w_{n}\right)^{\prime}$ and $\boldsymbol{q}=\left(q_{1}, q_{2}, \ldots, q_{n}\right)^{\prime}$. Additionally the firm will also face an output function:

$$
\begin{equation*}
q=g(x) \tag{3.2}
\end{equation*}
$$

This output function lies within the output set:

$$
\begin{equation*}
F(q, x)=[x, q: x \text { can produce } q] \tag{3.3}
\end{equation*}
$$

These two functions combine to give the cost minimisation problem as in equation 3.4,

$$
\begin{equation*}
c(\boldsymbol{w}, \boldsymbol{q})=\min _{x} \boldsymbol{w}^{\prime} \boldsymbol{x} \text { such that } \boldsymbol{x} \in \mathrm{F}(\boldsymbol{q}, \boldsymbol{x}) \tag{3.4}
\end{equation*}
$$

which states that cost is a function of input prices $\boldsymbol{w}$ and outputs $\boldsymbol{q}$ and that the minimised input, $\boldsymbol{x}$, must be an element of the output set $\mathrm{F}(q, x)$. As the study builds towards an examination of efficiency, it is prudent to add a definition at this stage. Rao et al. (2005) add their own definition as $q-f(\boldsymbol{x})=0$, meaning that the outputs produce are exactly the same as the level of inputs should produce. The simpler expression is that efficiency represents, in this case, a ratio of attainable costs to actual costs i.e. $\frac{\text { attainable cost }}{\text { actual cost }} \mathrm{x} 100$; if costs are higher than could be achieved then there is lower efficiency. Returning to equation 3.4, $\boldsymbol{q}$ is found on the left side but not the right because costs vary with output, but it is the quantity of inputs which is varied to change output and hence lead to a change in cost. Figure 3.1 shows the isoquant representation of a cost function graphically, and suggests a number of other characteristics.


Figure 3.1 Cost Function

Figure 3.1 shows the relationship between input prices, inputs, and a set level of output. The
set level of output is the isoquant at $q=10$ and shows all the combinations of Input 1 and Input 2 that could be used to produce 10 units of outputs. The line $c / w_{2}$ to $c / w_{1}$ shows the substitution between the two goods based on exogenously set prices. These two lines are tangential at one point which gives the optimum number of Input $1, X_{1}^{*}$, and Input $2, X_{2}^{*}$, that would produce the required output.

As the cost function has a number of important properties its properties, as set out by Rao et al. (2005), are given in (Table 3.1, Page 22).
C. 1 Non-negativity Costs can never be negative
C. 2 Non-decreasing in $\boldsymbol{w}$ An increase in input prices will not decrease costs. Formally, if $\boldsymbol{w}^{\boldsymbol{a}} \geq \boldsymbol{w}^{\boldsymbol{b}}$ then $c\left(\boldsymbol{w}^{a}, \boldsymbol{q}\right) \geq c\left(\boldsymbol{w}^{\boldsymbol{b}}, \boldsymbol{q}\right)$
C. 3 Non-decreasing in $\boldsymbol{q} \quad$ Producing more output does not cost less. Formally, if $\boldsymbol{q}^{\boldsymbol{a}} \geq \boldsymbol{q}^{\boldsymbol{b}}$ then $c\left(\boldsymbol{w}, \boldsymbol{q}^{\boldsymbol{a}}\right) \geq c\left(\boldsymbol{w}, \boldsymbol{q}^{\boldsymbol{b}}\right)$
C. 4 Linear Homogeneity in $\boldsymbol{w}$ Any proportional increase in all input prices will cause the same proportional increase in costs (doubling all input prices will double costs). Formally, $c(k \boldsymbol{w}, \boldsymbol{q})=k c\left(\boldsymbol{w}^{\boldsymbol{a}}, \boldsymbol{q}\right)$ for any $k>0$
C. 5 Concave in $\boldsymbol{w}$

This, though not easy to see from the formal statement, is a necessary condition so that input demand functions cannot slope upwards, and assumes that costs increase less than proportionally when one input price increases as inputs are substitutable. $c\left(\theta \boldsymbol{w}^{a}+(1-\theta) \boldsymbol{w}^{b}, \boldsymbol{q}\right) \geq \theta c\left(\boldsymbol{w}^{a}, \boldsymbol{q}\right)+(1-\theta) c\left(\boldsymbol{w}^{b}, \boldsymbol{q}\right)$

## Table 3.1 Cost Function Properties

### 3.3 Selected Stochastic Frontier Models and Efficiency Estimation

There are a great many extensions of the original Stochastic Frontier Model which have been developed since the seminal work of Aigner et al. (1977) and Meeusen and van den Broeck (1977). These models, based on the panel data extension developed by Pitt and Lee (1981), cover time invariant inefficiency (Schmidt and Sickles, 1984), time varying inefficiency (Cornwell et al., 1990; Kumbhakar, 1990; Battese and Coelli, 1992), and environmental variables (Coelli et al., 1999a; Reifschneider and Stevenson, 1991); of course there are different approaches to
each of these different types. These models, however, do not directly estimate the inefficiency but instead give values for the residuals within the function. The residuals can then be used with one of three estimators, two proposed by Jondrow et al. (1982) and one by Battese and Coelli (1988) to give values for the (in)efficiency.

### 3.3.1 Efficiency Estimation

The split error term of SFA presents a difficulty when it comes to estimation of the actual value of efficiency. As Jondrow et al. (1982) note the model presented by Aigner et al. (1977) is functionally specified as $y_{i}=f\left(x_{i}, \beta\right)+\varepsilon_{i}$ where $\varepsilon$ represents a combined error term $\varepsilon_{i}=v_{i}+u_{i}$. When the model estimated, the returned values are for estimates of the error term $\varepsilon_{i}$, the residual of the model which are commonly referred to as $e$, and not (in)efficiency. ${ }^{1}$ The estimates of $\varepsilon$ do however, contain information on both error terms (inefficiency and idiosyncratic error) and so it may be possible to separate the two effects, and to do so for each firm. Two methods (Jondrow et al., 1982; Battese and Coelli, 1988) have been utilised to estimate inefficiencies relating to each firm, but both require knowledge of the distributions as of the error terms. Hence before the efficiency estimators are examined the distributions must first be discussed.

### 3.3.2 Composed Error Distribution

An intuitive thought over how the residuals can help to reveal the inefficiency term is as follows. Knowing that the distribution of the idiosyncratic error term is normal and symmetric and that the inefficiency term is distributed as a half-normal leads to two obvious examples: if the composed error is positive, clearly there has been a positive realisation of the idiosyncratic error term that is sufficiently positive so as to more than offset the inefficiency term and so the inefficiency term is likely relatively small; alternatively if the composed error is very negative then the symmetric error term has been overruled by the efficiency term and so it is likely to be quite large. Though probable conclusions can be drawn based on the realisations, what is in

[^1]fact realised is a probability of larger or smaller numbers, a probability distribution, rather than a set number. It is this probability distribution that allows Jondrow et al. (1982) and Battese and Coelli (1988) to develop estimators. Jondrow et al. (1982) provide an estimation technique which can give estimates of the inefficiency term given a particular realisation of the residual. They work on the assumption that the idiosyncratic error is distributed normally $v_{i} \sim N\left(0, \sigma_{v}^{2}\right)$, whilst the inefficiency term has a truncated normal distribution $u_{i} \sim N\left(0, \sigma_{u}^{2}\right)$ which allows only non-negative realisations of $u_{i}$. Following the exposition given in the appendix of Jondrow et al. (1982), we need to derive the conditional distribution of $u_{i}$ given $\varepsilon_{i}$ which is found as the ratio of the joint density of $u_{i}$ and $\varepsilon_{i}$ and the density of $\varepsilon_{i}$.
$u_{i}$ and $v_{i}$ are independent and so their joint density is the product of their individual densities,
\[

$$
\begin{equation*}
f(u, v)=\frac{1}{\pi \sigma_{u} \sigma_{v}} \exp \left(\frac{-1}{2 \sigma_{u}^{2}} u^{2}-\frac{1}{2 \sigma_{v}^{2}} v^{2}\right), u \geq 0 \tag{3.5}
\end{equation*}
$$

\]

Transformation of $\varepsilon_{i}=v_{i}-u_{i}$ gives the joint density of $u_{i}$ and $\varepsilon_{i}$ as,

$$
\begin{equation*}
f(u, \varepsilon)=\frac{1}{\pi \sigma_{u} \sigma_{v}} \exp \left(\frac{-1}{2 \sigma_{u}^{2}} u^{-2} \frac{1}{2 \sigma_{v}^{2}}\left(u^{2}+\varepsilon^{2}+2 u \varepsilon\right)\right) \tag{3.6}
\end{equation*}
$$

The density function of $\varepsilon_{i}$ is given in Aigner et al. (1977),

$$
\begin{equation*}
f(\varepsilon)=\frac{2}{\sqrt{2 \pi} \sigma}(1-F) \exp \left(-\frac{1}{2 \sigma^{2}} \varepsilon^{2}\right) \tag{3.7}
\end{equation*}
$$

where $\sigma^{2}=\sigma_{u}^{2}+\sigma_{v}^{2} \lambda=\frac{\sigma_{u}}{\sigma_{v}}$, and $F$ is the standard normal cumulative density function evaluated at $\frac{\varepsilon \lambda}{\sigma}$. We then have the conditional probability distribution of $u_{i}$ given $\varepsilon_{i}$ :

$$
\begin{equation*}
f(u \mid \varepsilon)=\frac{1}{\sqrt{2 \pi} \sigma_{*}} \frac{1}{(1-F)} \exp \left(\frac{-1}{2 \sigma_{*}^{2}} u^{2}-\frac{1}{\sigma_{v}^{2}} u \varepsilon-\frac{\lambda^{2}}{2 \sigma^{2}} \varepsilon^{2}\right), u \geq 0 \tag{3.8}
\end{equation*}
$$

where $\sigma_{*}^{2}=\sigma_{u}^{2}\left(\frac{\sigma_{v}^{2}}{\sigma^{2}}\right)$. Finally, after some simplification we have,

$$
\begin{equation*}
f(u \mid \varepsilon)=\frac{1}{\sqrt{2 \pi} \sigma_{*}} \frac{1}{(1-F)} \exp \left[\left(\frac{-1}{2 \sigma_{*}^{2}}\right)\left(u+\sigma_{u}^{2} \frac{\varepsilon}{\sigma^{2}}\right)^{2}\right], u \geq 0 \tag{3.9}
\end{equation*}
$$

This is then compared to the density of a variable distributed as $N \sim\left(\mu_{*}, \sigma_{*}^{2}\right)$ and, noting that $(1-F)$ is simply the probability that the distribution variable be positive, the conditional distribution can be the density of a $N \sim\left(\mu_{*}, \sigma_{*}^{2}\right)$ variable truncated at zero. Having found these conditional distributions $u_{i}$ can now be estimated.

### 3.3.3 Efficiency Estimation

There are three versions of estimators for the efficiency (inefficiency) which is represented by these distributions; two are enumerated within Jondrow et al. (1982) and a further one comes from Battese and Coelli (1988). To arrive at the estimator involves two steps; deriving a single value representation of the distribution, and then taking the exponent of that value.

Commencing with the first step, derivation of a single value representation of the distribution, the literature presents two distinct options. One option is to take the mean of the distribution and use that in further calculations (this approach is used by both Jondrow et al. (1982) and Battese and Coelli (1988)), the other option is to utilise a modal measure of the distribution (Battese and Coelli, 1988).

The mean representation is more specifically a conditional mean based measure of the conditional distribution. Its derivation below follows the example given in Jondrow et al. (1982):

$$
\begin{equation*}
E(u \mid \varepsilon)=\mu_{*}+\sigma_{*} \frac{f\left(\frac{-\mu_{*}}{\sigma_{*}}\right)}{1-F\left(\frac{-\mu_{*}}{\sigma_{*}}\right)} \tag{3.10}
\end{equation*}
$$

where $f$ and $F$ represent the standard normal density and cumulative density functions. It is further noted that $\frac{-\mu_{*}}{\sigma_{*}}=\frac{\varepsilon \lambda}{\sigma}$ with $\lambda$ as defined in equation 3.8, which produces evalation of $f$ and $F$ at the same value for the likelihood function which results in a transformation to equation 3.11:

$$
\begin{equation*}
E(u \mid \varepsilon)=\sigma_{*}\left(\frac{f\left(\frac{\varepsilon \lambda}{\sigma}\right)}{1-F\left(\frac{\varepsilon \lambda}{\sigma}\right)}-\frac{\varepsilon \lambda}{\sigma}\right) \tag{3.11}
\end{equation*}
$$

The alternative single value representation proposed is a modal measure of the conditional distribution and is the minimum of $\mu_{*}$ and zero, or mathematically;

$$
M(u \mid \varepsilon)= \begin{cases}-\varepsilon\left(\frac{\sigma_{u}^{2}}{\sigma^{2}}\right) & \text { if } \varepsilon \leq 0  \tag{3.12}\\ 0 & \text { if } \varepsilon \geq 0\end{cases}
$$

Estimates of either $\mathrm{E}(u \mid \varepsilon)$ or $\mathrm{M}(u \mid \varepsilon)$ will render a single value, typically deemed $\hat{u}_{i}$, which can be exponentiated by the researcher to give a value of technical efficiency $\left(T E=\exp \left(-\hat{u}_{i}\right)\right)$ when following the Jondrow, Lovell, Materov, and Schmidt (JLMS) procedure (Jondrow et al., 1982). There is some dispute over the ordering of the expectation and exponentiation which
gives rise to the alternative suggestion by Battese and Coelli (1988), who suggest that technical efficiency would in fact be estimated by exponentiating the error term first, and then taking the expectation i.e. $T E=\mathrm{E}\left(\exp \left(-u_{i} \mid e_{i}\right)\right)$.

Research is generally divided between the Jondrow et al. (1982) measures, though most use the mean estimator, and the Battese and Coelli (1988) measure. It is important to note that the Jondrow et al. (1982) measures are central tendencies of first order approximations of the distribution rather than a mean of the actual distribution.

A crucial characteristic at this stage is that both estimators are based on the assumption of a half normal distribution for the inefficiency term and a normal distribution for the stochastic error term; should this not be the case then the described formulations will require adjustment. This having been said it is then important to consider the options available for the type of distribution that can be chosen for the inefficiency term, assuming of course that the model chosen offers a free choice.

### 3.3.4 Selected Extensions for Panel Data

Following the seminal paper of Aigner et al. (1977) only two authors (Meeusen and van den Broeck, 1977; Lee and Tyler, 1992) presented applications of the technique to data, though Pitt and Lee (1981) comment in reference to stochastic frontier analysis that as a whole "empirical investigations utilizing these new techniques is limited and not entirely satisfactory" (page 2). The first extension to panel data was made by Pitt and Lee (1981) which quickly became a highly used method, and saw much iteration in successive research. The models that will be examined in the remainder of this section are panel data models that make varying assumptions about the distribution of (in)efficiency.

### 3.3.4.1 Time Invariant Inefficiency Models

Some of the initial extensions of the Aigner et al. (1977) model were made by Pitt and Lee (1981), as already mentioned, and Schmidt and Sickles (1984). Pitt and Lee (1981) whilst in-
cluding the time dimension of panel data introduce a model which has time invariant efficiency. The panel data model is as follows:

$$
\begin{equation*}
y_{i t}=x_{i t} \beta+u_{i t}+v_{i t} \tag{3.13}
\end{equation*}
$$

where $y_{i t}$ represents output, with $x_{i t}$ a matrix of inputs for each firm in each time period, $\beta$ a matrix of coefficients and the two error terms $u_{i t}$ and $v_{i t}$ representing the one sided inefficiency term and the idiodyncratic error term respectively. With time invariance, the error term $u_{i t}$ term is replaced with $u_{i}$ as shown in equation 3.14.

$$
\begin{equation*}
y_{i t}=x_{i t} \beta+u_{i}+v_{i t} \tag{3.14}
\end{equation*}
$$

Pitt and Lee (1981) further specify that the error terms are independently and identically distributed which gives a random effects model, where the error term is not correlated with any regressors. Schmidt and Sickles (1984) apply a different set of assumptions to the same basic model instead providing a model of fixed effects, where a dummy variable is estimated for each firm which represents all the time invariant effects. Such a model is exemplified in equation $3.15^{2}$ :

$$
\begin{equation*}
y_{i t}=\alpha_{i}+x_{i t} \beta+v_{i t}+u_{i} \tag{3.15}
\end{equation*}
$$

where $\alpha_{i}$ represents the firm specific dummy variables and can be combined with the time invariant firm specific inefficiency to give

$$
\begin{align*}
& y_{i t}=\alpha_{i}^{*}+x_{i t} \beta+v_{i t}  \tag{3.16}\\
& \alpha_{i}^{*}=\alpha_{i}-u_{i}
\end{align*}
$$

### 3.3.4.2 Time Varying Inefficiency Models

Soon after the panel data extension of Pitt and Lee (1981) and the time invariant model by Schmidt and Sickles (1984) a number of authors began to rethink the assumption of time invariant inefficiency. For cross section data only or short panel data (few time periods) the

[^2]assumption of time invariant inefficiency was acceptable, but as noted in a follow up paper (Cornwell et al., 1990) the assumption of time-invariant inefficiency is strong and may prove unrealistic for many empirical applications, in particular those with a greater number of time periods or where the firm is aware of its inefficiency; a firm would obviously make changes if it knew it was inefficient (Kumbhakar, 1990). In response to this Cornwell et al. (1990) set out a model similar to that of Schmidt and Sickles (1984), though with an allowance for time variance in the firm effects.
\[

$$
\begin{equation*}
y_{i t}=\alpha+x_{i t} \beta+v_{i t}-u_{i} \tag{3.17}
\end{equation*}
$$

\]

Here the variables are specified as in equations 3.15 and 3.16. The model can be altered into a form with specific time invariant firm effects as below.

$$
\begin{align*}
& y_{i t}=\alpha_{i}+x_{i t} \beta+v_{i t}  \tag{3.18}\\
& \alpha_{i}=\alpha-u_{i}
\end{align*}
$$

However, as Cornwell et al. (1990) note, a time variant transformation can be made by replacing the identification of $\alpha_{i}$ with a function of time:

$$
\begin{equation*}
\alpha_{i}=\theta_{i}+\theta_{i 2} t+\theta_{i 3} t^{2} \tag{3.19}
\end{equation*}
$$

This parameterization allows for inefficiency to vary over time and between firms whilst retaining "the advantages of panel data" (page 15), and is estimated using a generalized least squares framework with efficient instrumental variables. Kumbhakar (1990) presents a different perspective on time varying inefficiency and suggests an error term of the following form:

$$
\begin{equation*}
\varepsilon_{i t}=v_{i t}-u_{i t}=v_{i t}-\gamma(t) \tau_{i} \tag{3.20}
\end{equation*}
$$

Here $\varepsilon_{i t}$ represents the composed error term, and $\tau_{i}$ represents a time invariant firm specific effect distributed independently and identically, and truncated at zero. The $\gamma(t)$ can be specified from a "wide range of choices" (page 204) but the given example is presented in equation 3.21:

$$
\begin{equation*}
\gamma(t)=\left(1+\exp \left(b t+c t^{2}\right)\right)^{-1} \tag{3.21}
\end{equation*}
$$

This formulation has several advantageous properties which result in the inefficiency term having the expected sign, $\gamma(t)$ being bounded by 0 and 1 , and being monotonic in either
direction depending on signs and magnitudes of $b$ and $c$, giving the added advantage of letting the data "determine the time behaviour of $\gamma(t)$ and hence $u_{f t}$ instead of imposing it a priori" ${ }^{3}$ (page 204). Battese and Coelli (1992) proposed a similar alternative to the Kumbhakar (1990) model, suggesting that it is easier to estimate. Here the inefficiency term is specified as:

$$
\begin{align*}
& u_{i t}=\eta_{i t} u_{i}  \tag{3.22}\\
& \eta_{i t}=\exp [-\eta(t-T)], \quad t \in F(i) ; i=1,2, \ldots, N
\end{align*}
$$

This model depends on the value of $\eta$, where positive values will give decreasing efficiency and negatives values increasing efficiency. However, the authors note that the "exponential specification of the behaviour of the firm effects $\left[\eta_{i t}\right]$ over time is a rigid parameterization in that technical efficiency must either increase at a decreasing rate ( $\eta>0$ ), decrease at an increasing rate $(\eta<0)$ or remain constant $(\eta=0)$ " (page 154). The rigidity of this model is countered by their second suggestion in the same paper which uses a two-parameter specification as follows:

$$
\begin{equation*}
\eta_{i t}=1+\eta_{1}(t-T)+\eta_{2}(t-T)^{2} \tag{3.23}
\end{equation*}
$$

Here $\eta_{1}$ and $\eta_{1}$ are unknown parameters. The addition of the second parameter allows for greater flexibility, allowing for convexity and concavity of firm effects as well as a time invariant model where $\eta_{1}=\eta_{2}=0$.

### 3.3.4.3 Introducing Environmental Variables

Once accurate methodologies had been developed for finding the value of the efficiency term attention turned towards determinants of efficiency, assuming the values are not totally random, and how to find them. Time variant efficiency models were the beginning of this process but limited in that the firm effects could not vary over time. Wang and Schmidt (2002) remark that there have been some empirical analyses which utilise a two stage model to calculate the determinants of inefficiency, specifying the inefficiency term as a linear function of firm effects and a random variable.

$$
\begin{equation*}
u_{i}=g\left(Z_{i}\right)+w_{i} \tag{3.24}
\end{equation*}
$$

[^3]Here $u_{i}$ represents the inefficiency term, and $w_{i}$ represents a random factor to complement the systematic error given by $g\left(Z_{i}\right)$, where $Z_{i}$ is a vector of firm specific variables. $g\left(Z_{i}\right)$ is later expanded to a linear function used to investigate the environmental effects of electricity generation based on an earlier paper by Christensen and Greene (1976). The inefficiency values as reported are regressed on a the linear function of firm effects looking for significant variables as with normal regression modelling.

Kumbhakar et al. (1991) determined two serious issues with such a two-stage approach; inefficiency may be correlated with the input variables which could result in "inconsistent estimates of the parameters" (page 280) and that ordinary least squares estimation of the second stage is likely to be inappropriate as the inefficiency term is one sided. Wang and Schmidt (2002) also criticised of the two stage approach suggesting that in assuming the inefficiency term is a function of some variables and not including them in the first stage of the regression, the first stage amounts to a misspecification of the model.

Coelli et al. (1999a) discuss two alternatives for a single stage model of the determinants of inefficiency, gross and net. The net approach (Case 1 in the paper) includes the environmental variables in the function as regressors allowing them to alter the shape, and location, of the frontier.

$$
\begin{equation*}
\ln y_{i t}=\beta_{0}+\sum_{k=1}^{K} \beta_{k} \ln x_{k, i t}+\sum_{j=1}^{M} \theta_{j} \ln z_{j, i t}+v_{i t}-u_{i t} \tag{3.25}
\end{equation*}
$$

Here, aside from some slight differences in notation, the production function is as expected and has an additional term $\sum_{j=1}^{M} \theta_{j} l n z_{j, i t}$ for the effect of the environmental variables. By treating all firms as equal this method apportions any efficiency variation between firms to differences in managerial efficiency. This is internally advantageous as senior leadership can draw comparisons between their own institutions and others to determine whether they are following best practice and, if not, where to look so that they may begin to improve. Conversely, and in some ways disadvantageously, to any persons not in the business of regulating or running such institutions the efficiency scores are somewhat meaningless. By way of example, both regulators and airline operating companies such as EasyJet and British Airways would be interested to know the
managerial efficiency variation between various airline operating companies. The people who travel with these companies are far more concerned with low cost and quality service.

The gross efficiency approach allows the environmental variables to directly affect the inefficiency term and hence affect distance of an individual from the frontier. Here the inefficiency effects are specified as part of the distribution characteristics of the inefficiency term, and thus affect the mean of the inefficiency distribution rather than moving the frontier.

$$
\begin{align*}
\ln \left(y_{i t}\right) & =\beta_{0}+\sum_{k=1}^{K} \beta_{k}\left(\ln x_{k, i t}\right)+v_{i t}-u_{i t}  \tag{3.26}\\
u_{i t} & \sim N^{+}\left(\left[\delta_{0}+\sum_{j=1}^{M} \delta_{j}\left(\ln z_{j, i t}\right)\right], \sigma^{2}\right)
\end{align*}
$$

This results in a stochastic frontier production function where $u_{i t}$ is independently but not identically distributed as it is dependent on environmental variables $z_{j, i t}$ and parameters $\delta_{j},(j=$ $0,1, \ldots, M)$. This alternative perspective to the net efficiency measure, where each firm is considered to have access to the same technology and so their performance is measured against the same best practice frontier, and the environmental factors influence a firms distance from the efficient frontier, provides estimates of efficiency given the situation of a particular firm. It does this without allowing comparison between firms as the situation of each firm will be different. Typically this method is not used by regulatory bodies because benchmarking firms against each other to foster improvement in firm performance is much harder to achieve. Firms can, and do, simply hide behind heterogeneity as the reason for the variation in efficiency. However, the external advantage is that the firm efficiency scores are a true reflection to any person who wishes to view them. This is particularly important in competitive markets where the consumer chooses where to spend their money, such as higher education.

It is important to note that these measures (gross and net) are not directly comparable though procedures exist to make them so. Specifically the gross approach can be transformed into the net approach by replacing the environmental factors $\sum_{j=1}^{M} \theta_{j} l n z_{j, i t}$ of each with the minimum $\left(\min \sum_{j=1}^{M} \theta_{j} l n z_{j, i t}\right)$ of the sample, thereby ensuring that all firms are treated equally to the most favourable conditions (page 256, (Coelli et al., 1999a)).

### 3.4 Application to Higher Education

Characterizing the production process within a university is conceptually simple; creation of knowledge (through research) and transfer of knowledge (through teaching). As well described in Johnes et al. (2008) universities are considered to also some form of community output which includes "storage and preservation of knowledge and skills; the provision of advice and other services to business; and the provision of a source of independent comment on public issues". The paper does not go on to account for the third mission in their paper and this research shall follow that lead as this is still a developing area in terms of both estimation and data collection and, crucially, for the period under consideration no data is available. It is important to remain mindful that this omission may lead to some bias in the results presented in later sections.

There is considerable debate on how to best measure the inputs and outputs that go into the creation and transfer of knowledge. Despite a growing literature in the area there is no consensus on the choice and measurement of the inputs or outputs, which is made more challenging as there are no direct measures to choose from. Proxy variables are used to closely represent either an input or an output, however, by their very nature they are not perfect substitutes and so alternatives are numerous.

Further to the basic input and output discussions some studies have utilised prices for inputs and/or outputs. Where these are required (input prices), they will be will be examined and finally, many studies find there are significant variations when certain environmental differences are taken into account; rural or non-rural situation, use of teaching hospitals, age of institution. Moreover, as determined by the function which is to be estimated, some studies have had to devise proxies for input prices or output prices. As a cost frontier is to be estimated within this chapter it is also necessary to use proxies for input prices.

### 3.4.1 Inputs

The teaching portion of an institution's mission and the factors that go in to enabling the teaching process to occur are staff and capital. Staff provide the teaching and capital expen-
diture on premises and facilities allow for a space where the staff can work. These two inputs are common and are utilised in a number of studies ${ }^{4}$, though there still remains choice over how to measure the quantity of each. Choices are mostly divided between a simple count of the number of staff ${ }^{5}$ and the use of full time equivalent ${ }^{6}$ number of staff. Studies using either measure offer no explanation as to their choice, though a possible reason could be a simple data availability restriction. Reasoning offered by the QS Intelligence Unit ${ }^{7}$ suggests that the use of full time equivalent measures overcomes any extremes of part time employment (high or low) and possible prevents some bias. Some authors (Flegg and Allen, 2007; Johnes et al., 2008; Abbott and Doucouliagos, 2003) advise that distinctions between the quality of inputs found at each institution cannot be measured as there is no data published in this area and so whilst not a major concern it should be borne in mind when considering results.

Turning now to capital, Glass et al. (1995) make a fairly strong point that preceding papers had lacked an adequate measure for capital which would likely have biased their results, to compensate for this they included a measure for both capital and labour. Lecture theatres and exam halls in which the teaching take place form part of the capital stock, as do any libraries and computer labs, representing a major input into the transfer of knowledge and many authors agree: McMillan and Chan (2004) viewed capital as important enough to mention in their study despite having no data for it, Carrington et al. (2005) considered it too complex but noted a number of options, whilst Bonaccorsi et al. (2006) use number of spaces in lecture halls as yet another proxy.

Carrington et al. (2005) discuss a number of issues with measuring capital which prevented them from even attempting to represent it. The first is that capital is highly heterogenous "in type, value and age. It consists of land, buildings, plant and equipment etc." (pg 152), which causes difficulty in deciding what should count as capital. Although there are different types of capital there is likely to be some kind of accounting metric which gives an overall value and

[^4]would allow for comparison. They suggest a problem with value comparisons in that, though the usefulness of capital stock is assumed rather than observed (and assumed to be in some way proportional to the stock), different accounting structures and valuations can make comparison very complex. Further they suggest that due to the way capital is typically priced, annual depreciation, the value of a new purchase divided by the expected life span, gives a value of practically zero on older buildings though they still provide services in some way or another. ${ }^{8}$ Glass et al. (1995) confirm the issue with differing accounting practices for capital, but suggest that they are primarily due to location in the US and that no such problems are encountered in the UK (footnote 5).

Moving to research, it is fairly straightforward to identify the inputs, staff and capital, which are mostly shared with teaching; as an example libraries can be used for teaching and research, whilst many academic staff within a university have a joint contracts which stipulates both teaching and research responsibilities (Abbott and Doucouliagos, 2003). ${ }^{9}$ Hence, studies which consider a multi-output system (Stevens, 2005) have made no effort to separate those staff who do research from those who do teaching because of dual contracts and the inherent complexity separating time spent on each factor to avoid double counting.

### 3.4.2 Outputs

Measuring the output of knowledge creation (research) and knowledge transfer (teaching) presents a much less certain spectrum of choice than the inputs. Though a consensus seems to be that the teaching output is related in some way to students and research output in some way to publications, there is great division about which measures most accurately proxy these two outputs. Additionally, unlike the inputs into the process, the outputs are very distinct and are not shared, which creates further difficulty for an aspiring researcher.

[^5]
### 3.4.2.1 Teaching Output

An initial option for representing the teaching output of a university is the number of graduates. This seems to be a logical option and is utilised in several studies (Stevens, 2005; Flegg et al., 2004; Athanassapoulos and Shale, 1997). The advantage of the number of graduating students is that it represents a complete package, the teaching is finished and the output is something that the market desires. This option draws helpful parallels to an intermediary firm such as a furniture factory which takes in the lumber output from a lumber mill and delivers an improved product in furniture, where A-Level students are lumber and graduates the furniture ready for firms to take in as raw materials to their production process. Though in this case the A-Level student, or even the graduate, can be both an input and an output when looking at the entire system, in the isolated higher education sector this is not the case and each type of student (A-Level or graduate) acts either an input or an output. In such a model it is difficult to assign value to a student who drops out before completing their course as there will be no demand for such students.

This approach has been criticised by several authors (Avkiran, 2001; Carrington et al., 2005; McMillan and Chan, 2004) who take issue with the lack of value placed on situations where students have dropped out. All argue that despite non-completion the university has still expended resources in teaching the student and the student has still received some education suggesting that a portion of the teaching process has occurred. Hence should be given some value as an output to correctly assign the inputs that have gone into the creation of a partial completion. They further argue that this would unfairly bias results against newer institutions with lower entry grades which will typically have higher dropout rates and will penalise them for accepting students from wider backgrounds and abilities, and offer student enrollments as the appropriate choice.

Placing abstract fairness to one side momentarily, the financial implications of students dropping out part way through a course are difficult to represent. Failure to adequately provide for this may leave an institution with misrepresented costs and revenues; a student leaving after their registration has been processed but before payment of fees has occurred will incur costs
but provide no revenue stream, alternatively, payment of fees and not taking part in the course or utilising student accommodation may allow for additional revenues to be acquired through clearing or reassigning student accommodation. Further, there is a considerable difficulty in using student graduates; the allocation of costs and revenues. Costs are incurred for three years prior to the awarding of a degree and there is no way to accurately distribute the costs or revenues to each individual and hence, accurately establish the efficiency with which that graduate was produced. This could become an issue if recruitment takes a sudden jump, or grows particularly quickly. There will be much increased cost in that year but as the new students will only be in their first year, and the graduates will be from a smaller intake year, there could be larger costs for smaller a number of graduates, misleading the results.

In addition to which type of student will form the teaching load (total or graduate), a great deal of thought and discussion has centred around a distinction between students taking arts subjects or those taking science based subjects. Most authors (Johnes, 1996a; Stevens, 2005; Flegg et al., 2007) find that a separation is entirely justified with both returning significant results in estimations. Once again the logic behind such a formulation is clear; arts based students can be more easily taught in lecture theatres with little specialist equipment or resources by fewer members of staff, science bases students on the other hand require a great deal more resource in terms of chemicals, laboratories which are inherently more expensive than lecture theatres, and supervision.

### 3.4.2.2 Research Output

Measuring the research output of a HEI is perhaps the most debated subject within the literature and there is even less consensus than with teaching output. As mentioned by Abbott and Doucouliagos (2003) it is essential to capture not only quantity of research but also quality. Since quantity and quality of research are interrelated issues both are discussed here. Avkiran (2001) suggests a number of popular alternatives, number of publications, number of citations, impact, and reputational ranking, though there is a fifth option which has been used more recently by Stevens (2005) and Flegg et al. (2004) which is research income. Johnes (1992)
provides a comprehensive discussion of the measurement of research output the key points of which we will now elaborate on.

Publication Count A simple count of the number of publications created by a researcher, department, or institution is the common starting point for any discussion on measuring research output though Johnes (1992), and many others, challenge this as too simplistic. They suggest that simply counting each leads to a situation where top four-star journals are considered equal to one-star journals, though it is common knowledge that this is not the case. Further difficulty is encountered when attempting to include different categories of research within the same count i.e. books chapters as opposed to journals.

Proposed modifications to this simple count include narrowing the field of count or assigning weights to particular journals or types of publication. Narrowing the field of counting to higher ranked journals, much like only counting a first or upper-second class degree, can, as Johnes (1992) notes, increase the possibility that specialist works will not be counted as higher ranked journals prefer to appeal to a wider range of audience. Adding weights to particular types of output or specific journals carries its own set of problems. As an example, Johnes (1990) finds that, in a study of economics departments, the weightings assigned to the different types of publications hugely affected the efficiency rankings.

Both of these alternatives require a decision to be made on which journals to count or which weightings to give to each type of publication creating an abstract problem as Carrington et al. (2005) note, decisions will all be incredibly subjective and results would be sensitive to the decision maker, whilst Johnes (1992) summarises the issue concisely, "arbitrary weighting rules [...] lead to arbitrary outcomes" (p27).

Supplementary problems with a simple count are considered by Johnes (1992), the age and size of a department. The size of a department will have a fairly apparent effect, a straight count of publications will be larger in larger departments. As with all size related data issues a normalisation process is applied to remove the bias towards larger departments, however, it can be difficult to accurately determine the number of staff in a department, particularly in terms of contribution to the research efforts. This difference in size and level of resourcing is
found to be a significant factor in Johnes (1988) which suggests that over half the variation of output was caused by different levels of resourcing. Young departments, with a number of new members of staff, are also likely to be hindered in a straight count as it is easier for older, more experienced members of staff to publish regularly.

Different disciplines will also publish in completely different cycles with some subjects publishing frequently and others less frequently (Avkiran, 2001). By way of example, subjects like business, economics and finance have a tendency towards high volume publication, whilst subjects like medicine require a great deal of initial research and experimentation, leading to a much longer publishing cycle.

Research, as many famous authors have found, is a first past the post system. It is very unlikely that the second person to publish will receive as much credit for the work and so it is highly plausible that huge differences in measured output could actually represent very minor differences in actual output (Johnes, 1992).

Perhaps the most difficult problem to circumvent is that of the time lag involved. It would take an incredible centralised investment to carry a real time count of all of the publications and research output of the nations institutions. The best that a researcher can do currently is use outdated counts or private databases.

Citation count Mindful of the issues with publication counts an alternative suggestion is a citation count, though such a count only tackles a few of the problems mentioned and indeed creates some of its own. Initial inspection of a citation count would suggest that they overcome the impact and quality issue of work by virtue of the fact that those which are cited most frequently are highly impactful and clearly of superior quality. However, the opposite can very well be true, it could be the case that a piece of research is obviously wrong or has significant drawbacks and as such many authors cite it as the wrong way to do it, yet still this would give a positive result to research output (Johnes, 1992).

Additional problems with this can be the lack of a centralised database and the bias that can occur given the cumulative nature of citation counting. The lack of a centralised database was a significant problem in the early part of the century (Johnes, 1992), and more importantly
as some still find, if a researcher writes under their own name and then a married name, or includes a middle name, it can frequently give inaccurate returns on citations. Moreover, there are now a number of different citation scores (including Google Scholar or H-Index) which make comparison difficult particularly in an interdisciplinary setting. The cumulative nature of citation counting can potentially lead to a bias in favour of older departments or those that are more male dominated (as career breaks are less frequent) as opposed to those departments with a higher proportion of younger, or female, researchers. Citation circles, where a group of colleagues or researchers cite each others work frequently so as to boost the number of citations, are also a concern (albeit for the cynical researcher) in the use of this measure.

The final problem, much like a publication count, is the necessary time lag that occurs between the research output and a citation count reflecting the output. Many works can take up to a year before they are accepted and published in a journal, and then after that stage another author has to write a paper in a similar field which cites the initial output. This could take some time, even a famous contemporary idea like the Nash Equilibrium was not fully appreciated for some time after it was written; a citation count would only begin to value it after that period of time.

Peer Review An alternative to both of these methods is one of peer review and this is the process by which institutions are currently ranked, as a result of the Research Assessment Exercise, or RAE, now called the Research Excellence Framework, or REF. There are considerable benefits to this type of assessment in that it is less mechanical and therefore likely to give a better consideration of the overall output rather than just the statistics (Johnes, 1992). Drawbacks to this system are congruent with any measurement where humans are directly involved and are fairly obvious in that judgements are necessarily subjective and so can favour those departments which publish in the reviewers chosen area.

Most importantly for a practical application, peer review is exceptionally expensive and slow, making it unlikely for any researcher on their own to utilise it as a method of rating research unless, of course, they use the RAE or REF scores. However these scores will be the same for a given 5-6 year period, which does not allow for any measurement of research output growth,
making it less helpful in that regard.

Research Income The final measure to be considered is perhaps the most controversial: research income. This has been used by Flegg et al. (2004) and Stevens (2005) as it can be deemed a price that governing bodies and private institutions are willing to pay for a universities research, thus taking into account quantity and quality. Further, it is a more up to date method than publication or citation counts, reflecting annual changes in quantity or quality.

Many authors, particularly Johnes (1992) and Avkiran (2001), suggest that research income is quite clearly an input and so is an inappropriate choice for an output measure. These objections are noted by Flegg et al. (2004) however they realise that it is the only real option they have as it is the only proxy for which data is readily available and up to date Johnes (2006); Flegg and Allen (2007); Flegg et al. (2007); Izadi et al. (2002); Stevens (2005); Johnes et al. (2008); Worthington and Lee (2008); Johnes (2014) agree and uses research funding as a measure of research output also suggesting it balances quality and quantity). A further, similar, argument to that of citations can be levelled against use of research income. Often the success of an institution in receiving research income is in part determined by previous success, by its track record in a particular area, thus a similar situation to that of older departments and citations occurs. Newer, younger departments find it difficult to attract funding and so may be unfairly biased in comparison to older more established departments.

### 3.4.3 Prices

The cost function makes use of input prices when determining a unit's level of efficiency. Fortunately there is a converging standard on the set of input prices that are used for evaluating HEI.

Staff cost is most typically measured by the readily available "Total Expenditure on Staff". However, this is a total price, proportional to the size of an institution, and so normalisation is common leading to average staff cost measures as generated by Stevens (2005).

Obtaining the price of a unit of capital is not as simple as obtaining the price of a member of
staff and has been carefully considered by a number of authors over a number of years, from the seminal work of Jorgenson (1963), though to the work of Auerbach (1982) which set the foundation for more recent attempts by authors such as Gale and Orszag (2005). These authors all worked towards the modern day standard formula for the 'user cost of capital', which refers to the price of a particular investment that, in a private sector sense, represents the minimum rate of return that is required in order for the investment to break even. Whilst of course the higher education sector is not a private corporation (in the majority of cases), the user cost of capital formula can still be used to give an indicative price of the capital for an institution. Gale and Orszag (2005) present the following formulation for the user cost of capital for a $£ 1$ investment:

$$
\begin{equation*}
c=\left(\frac{r-\pi+\delta}{1-u}\right)(1-u z) \tag{3.27}
\end{equation*}
$$

Here, $c$ is the user cost of capital, $r$ is the nominal after-corporate-tax discount rate that the firm must earn to attract investors, $\pi$ is inflation, $\delta$ is the rate of economic depreciation, $u$ is the statutory corporate tax rate, and $z$ is the present value of depreciation deducations on a unit investment.

Now it is important to consider the values for these variables as some may be zero values which will allow for simplification. As Gale and Orszag (2005) note $r-\pi$ is the opportunity cost. Obviously in the case of HEI the type of investment that is attracted is different from the private sector in that it is charitable giving by doners, or grant funded. Hence, it is reasonable to assume that the opportunity cost of capital is zero, leaving only $\delta$ as the numerator. Similarly the $u$ term which denotes the corporate tax rate, can, given the charitable status of most HEI, be assumed to be zero.

With these values assumed as zero, the formula suggested by Gale and Orszag (2005) reduces to a simple economic depreciation term. Caution must be exercised, however, as economic depreciation and accounting depreciation are not synomous nor equal, however accounting depreciation can represent a robust and intuitive proxy if the reseacher remains mindful of
these issues and that raised by Carrington et al. (2005). ${ }^{10}$
In their study of Australian universities Carrington et al. (2005) remark that particularly for old buildings, the depreciation value assigned may be close to zero but revenue streams and usage are still present. Consider two situations: (i) a university constructs a new building and is prepared to replace that building in 20 years but the building is still in sound structural condition so they do not have to replace it, that university is then rewarded with more efficient expenditure, (ii) alternatively should the university design and construct a building with the view that it will be replaced at the end of its useful life, that university will be fully described in terms of capital expenditure and depreciation even though it seems a rather inefficient process.

### 3.4.4 Environmental Variables

There are a number of factors that are external to HEI but will still have an effect on its costs. Glass et al. (1995) recognise these differences and, doing something which few before had, segregate the Institutions. The segregation was based on their research output, high, medium and low, so as to allow for more accurate descriptions of the different groupings within the higher education system. Such a segregation is fairly arbitrary both in terms of scale and what would classify as low, medium, or high, however it is important to draw such distinctions between institutions and not all metrics lend themselves to objective, scaled segregation. Considering all of the differences between institutions represents the heterogeneity between institutions. Location, courses offered, and staff and student demographics are all examples of such environmental factors and are factors which need to be captured when comparing the performance of HEI because they can differ greatly between institutions.

### 3.4.4.1 Location

An obvious first factor is that of location, Koshal et al. (2001) in a study of American institutions note, importantly, that the colleges are scattered all over the US and as such will face different

[^6]factor costs, with the obvious effect on their total costs. The same could be said of the UK where there may be large geographical differences in both capital cost and labour premiums, institutions in London and the South East, for example, would be subject to inflated land costs, rates and wages in comparison to the North.

This downward effect on prices in the North may be offset by location in a metropolitan area (Manchester or Newcastle) where space is a scarce resource and therefore once again premiums will be in effect. Further, rural institutions, without a particular specialism like Bristol, may struggle to attract students. This could work to offset the effects of reduced capital costs through increased student acquisition costs via increased marketing and incentive schemes. Agasisti (2009) found that location in a metropolitan area would enhance efficiency, though it was teaching measures that were the focus in this paper. The co-location with other institutions that occurred in a metropolitan area was suggested as the cause for the increased efficiency, however Agasisti et al. (2011) were unable to find evidence to support these results when considering university departments of science, technology and medicine in the Lombardy region of Italy.

### 3.4.4.2 Course Costs

An important extension to the discussion of geographical variation is the difference in the course offering of various institutions. This distinction is made by a number of authors (McMillan and Chan, 2004; Stevens, 2005; Carrington et al., 2005; Agasisti and Salerno, 2007), who all cite the increased cost intensity in science and laboratory based subjects as an important consideration in modelling the teaching output of any university.

Of particular concern are those institutions with Medical Schools, which create a two-fold problem. The first, as Johnes (1997) realised, is that institutions with medical schools had a significantly different capital structure and hence, required exclusion from his panel. Agasisti and Salerno (2007) raise this issue as they feel it would be inappropriate to continue to exclude Institutions with medical schools from investigation and instead should tackle the issue. The most important question: how should the institution in question account for usage of a hospital?

Using the whole value of the hospital will dramatically overstate the amount of capital on their books, using a zero value for the hospital will understate it. Despite the fairly vague way in which medical faculties were accounted for (the authors admit they couldn't effectively cover the issue of how to account for hospital capital) there were significantly different results between those with and those without.

The second problem is the higher costs associated with medicinal study, in comparison to other disciplines, and the larger resources per student that are required; cadavers will need to be purchased, dissection laboratories provided, completely different reference material, time in training hospitals, and a staff that will require higher than average salaries.

This problem can be extended to those institutions which offer veterinary training (Bristol, London, Liverpool, etc). Like medical students, veterinary students require a great deal of additional resource in terms of laboratory space and time on farms to fully complete their course. This will likely drive up the cost of such students similarly to medical students. Law departments, though quite different from medical/veterinary departments share some of the traits that make them more costly to bear. In many disciplines core texts can be used across courses, e.g. management texts can be used for most business studies courses as well as some engineering and combined honours subjects, there is, however, little scope for that with law texts because of the detail required. Further, when new laws are published they are folded into new textbooks, this reduces the usefulness of older editions and increases the turnover of books, again increasing cost. Lastly, many Law teachers are former, or even current, practicing professionals which will have upward pressure on wages.

### 3.4.4.3 Programme Portfolio

The programme portfolio on offer at any particular university is also going to affect the efficiency of its operation. Though not strictly an external factor, the management team are in charge of the programme portfolio and may add programmes as and when they wish, the addition of a new department to offer a different programme requires a great deal of time. Institutional governing bodies will insist on demand studies to prove there is a market. Following
such studies the resources will then need to be approved, ordinances altered, codes of conduct drawn up, facilities developed, senior staff hired who will then hire lecturing staff, marketing of the new course, all before a single student arrives to begin said programme. It will then take a further three years, at minimum, before this department graduates any students as a measurable output. This lengthy process will, for short to medium term samples, represent another environmental factor, a difference that cannot be changed.

The relevance of the programme portfolio to efficiency is focused on the resources required to put on certain courses and the staff-student ratios that can be successfully maintained. Typically reference is made to the difference between STEM and non-STEM based subjects. An institution that has a particular focus on science or engineering subjects (such as Imperial College) may well find that its efficiency is markedly reduced as it requires more laboratory facilities, greater resources per students, and greater numbers of staff. Conversely an institution focusing mainly on humanities requires a well stocked library, inexpensive (comparatively) lecture theatres, and substantially fewer staff to output the same number of students.

Finally, there is no standard set of weights which determine the importance of any institution's various outputs and so it becomes difficult to assess the contribution of any particular programme to the overall efficiency score of a university. The difficulty will arise from differences in competing universities; Loughborough focuses on sport and engineering, whilst Leicester tends toward medicine. A weighting system which favours sport because of its lecture based approach over medicines (or other sciences) laboratory based approach, will present a more favourable picture of Loughborough than Leicester. The converse could also be true. Absent standardised weightings, or means to take into account institutional focus, comparison cannot comment on internal efficiency though results could demonstrate efficiency in an absolute sense.

### 3.4.4.4 University Grouping

Universities in the UK are divided into a number of groups based on their year of creation and the intensity of research being conducted, referring of course to the Russell Group, The 1994 Group, etc. There is a certain amount of prestige that comes with membership in these
groups (some more so than others), particularly with regard to research, research funding and attracting academics. Taking this one stage one may assume that less prestigious institutions are more likely to incur higher costs as part of recruitment and retention of staff and in attracting research grants, making the whole process more inefficient. Of course, the converse may also be true in that by virtue of being in these groups increased expenditure is expected to maintain the facade that comes with being prestigious.

### 3.4.4.5 Staff Demographics

(Stevens, 2005) found that staff demographics were a contributing factor in the efficiency of a particular university and that staff aged over fifty had a negative effect on efficiency. Older staff, it could be argued, are sometimes less efficient as they have attained a comfortable level of seniority and are no longer 'hungry to prove themselves' anymore. Though, conversely they are likely to be more established in their fields and so more effective at attracting research funding. Younger staff tend to be more motivated to produce high levels of output in short periods of time both in terms of teaching and research as this will be of significant import during considerations for promotion. It is also widely debated as to which age demographics are more effective in their use of technology; younger generations tend to use more but this does not necessarily equate to more efficiency and a great deal of time can be wasted answering emails or using social media rather than actually performing job-related tasks. A final demographic to consider is that of gender.Female staff are more likely to take career breaks to have children, whilst paternity leave tends to be much shorter and not impact quite so harshly on working life. Given the importance of track record in both publishing and attracting research funding career breaks such as those taken to have children may prove detrimental to output and efficiency. In addition to the age profile of staff consideration should also be given to the employment balance between non-academic and academic staff. The reasons for this are quite clear, academic staff produce the outputs but without the additional support of administrative personnel etc the academics would also have to engage in administration work such as pay claims, visa applications, student recruitment, promotion, the list goes on. There will be, as with everything,
a balance to be struck between the two types of staff; too many academic staff would lead to little teaching output as there would be no students nor would it last very long as payroll would be considerably less reliable, on the other hand too many administrative (and other) staff would result in effective administration, great publicity and lots of recruitment, but there wouldnt be sufficient capacity to deal with the volume of students, nor the research output to generate revenue.

### 3.4.4.6 Student Demographics

Having discussed the demographics of the staff it is sensible now to consider the demographics of the student body. Instead of age, which is fairly uniform and mostly unchanging, other student characteristics are more likely to have some effect on efficiency, namely whether a Home or International student, whether undergraduate or postgraduate, whether full time or part time, and, if evidence from A-Level results can be extrapolated, whether male or female.

Domestic students can be more efficiently administered, there is little doubt in that, as they do not require visas and follow a more uniform process of application. ${ }^{11}$ International students, particularly those from outside the EU, often require pre-sessional language courses as well as increased support throughout the year in terms of adjusting to the UK system and developing the required English Language skills to succeed.

Whilst less cost efficient, international students are charged significantly increased fees which mean that could contribute in other areas. There are also institutional advantages that can be generated through relationships built with international institutions which send a number of their students to study at a single UK university. These can include work exchange programs, which have become popular under the Erasmus scheme, and can lead to international campuses, exemplified by Nottingham university's campus in Ningbo, China, or even research collaborations. All three of these offer a great deal of benefit to an institution, particularly in terms of attracting grants and revenue, though their contribution towards efficiency is yet to be fully examined.

[^7]The differences between undergraduate and postgraduate are slight in the case of taught postgraduates (PGT) and stark in the case of research postgraduates (PGR). Undergraduate courses tend to have high numbers of students for each lecturer, require some access to academic journals and reference material and, on average, little additional staff time (outside of lecturers). PGR students are the complete opposite, even the most established and experienced Professors will only supervise around 10 students. These students will require a great deal of one on one time with their supervisor, will need access to a wide range of, sometimes expensive, resources and necessitate the use of external academics for vivas and thesis marking. PGTs represent a middle ground where there are lower, staff-student ratios, but there is less cause for one on one time and it is unlikely that there will be requirement for expensive resources.

The obvious differences between the inputs required and the output produced by each of these types of students will again require balance; some institutions have opted only for postgraduate study, though these tend to be private institutions with high levels of fees, demonstrating that there is choice in how a university balances their UG and PG intake.

### 3.4.4.7 Quality Considerations

Quality is raised as an important consideration by Agasisti and Salerno (2007) and Avkiran (2001) who both make the point it is not enough to simply measure the quantity of inputs and outputs from an institution; Abbott and Doucouliagos (2003) advise that this could lead to biased results. Appropriate measure for research output, must also measure the quality of research. To revisit this briefly, many authors agree that measuring the output is difficult in itself, let alone the quality. However, several papers have indicated that the use of a research income based measure will, to some degree, account for quality as it unlikely that funding will be secured for low quality research. Research funding is increasingly determined by previous successful bids and track record of output in particular areas and so it is therefore more likely that higher quality outputs will result from funded research. Researchers have settled on a primary method to factor in teaching quality within the institutions. The method, as exemplified by Stevens (2005), is to adjust graduate totals by the proportion of 'good' degrees, where 'good'
is classified as first class or upper second class degrees, giving rise to a cross-term within the function. Such an approach is beneficial as it avoids penalising fewer high quality degrees and rewarding lots of lower class degrees which may occur if there was a simple count of graduate. Some drawbacks exist with this method, specifically as discussed in Flegg et al. (2004) that it necessitates the removal of Scottish universities which do not split their second class degrees.

A more fundamental drawback to such a method is, as Abbott and Doucouliagos (2003) argue, that it is inappropriate to utilise exit grades as a measure of quality because it is not a point amount but a spectrum of results due to the grading system employed within the UK. Also of concern is that the grade is entirely administered by the university and represents a mix of marking standards, teaching quality, and entry level ability.

Another, more difficult, way to measure teaching quality is by use of the value-added approach. This type of measures focuses on the improvement in the graduate from the time the being their university education to the time they leave. Avkiran (2001) suggests that a university is good if it graduates a large percentage of upper second and first class degrees. However, if the intake of students at the same university is only those with top A-Level grades then it could be argued that the institution is not responsible for the final degree classification and that the student may have achieved a similar result with average teaching.

Additionally, students with higher A-Level scores may require less staff time to get the same results meaning staff can either have heavier teaching loads or more likely greater research output. (Agasisti and Salerno, 2007) considers that this characteristic can in fact have the opposite effect in that students who have higher grades are likely to have a greater thirst for knowledge and therefore be more likely to ask advanced questions and require more staff time for discussion. This value added approach is considered more informative when judging the quality of teaching output, however modelling can be difficult and perhaps more important Rodgers (2007) notes that the link between A Levels and degree class is generally very weak and contribute merely as one of a range of background variables.

The final consideration regarding output quality is regarding the institution of origin. It could be suggested that a degree from Oxbridge is perhaps worth more than a degree from Bangor,
indeed there would be few who would argue against this and indeed there is academic support from authors such as Koshal and Koshal (1999) who quote their 1995 study which states "the quality of education, whether perceived or real, is different at different institutions" (pg 269). However, there seems to be no objective way in which to measure or to model this, and (Cohn et al., 1989) posit that these differences may not have anything to do with teaching quality but rather with the ability of the students upon entry and the prestige of the institution which is more often linked to research than teaching.

Before leaving quality of inputs and outputs it is important to consider the quality of both staff and capital. When considering staff quality Carrington et al. (2005) used the rank of members of staff to determine a measure for input quality. It was not possible to find any other studies that have used staff quality in terms of teaching though some others have in terms of research. It is possible that there are no studies which used quality measures for staff or capital were not forthcoming because it is an incredibly subjective, murky area. Teaching quality is mainly measured through student or peer review. There can be no objectivity in either of those measures, students may be positive or negative about a staff member dependent upon how difficult they find the subject, and colleagues may disagree with a particular style of teaching, or even the subject being taught, and could then offer a biased evaulation. Most importantly, no ranking of staff would be comparable to any other as different people will conduct the reviews, using different criteria. Quality of capital would also be incredibly difficult to measure, particularly in the context of higher education. The first difficulty would be in quantifying what characteristics made "good" capital as opposed to "bad" capital. Initial thoughts may lead to a declining ranking proportional to age, as all capital eventually becomes outdated. However, older buildings still find use for tutorials, seminars, or quiet study, all very important parts of teaching. Beyond assessing the quality of the capital itself it would then need to be established if, and in what way, quality affected teaching.

### 3.5 Model Variables

There has been considerable discussion about the array of options available to a researcher when estimating the efficiency of institutes within the higher education sector. In this section the options chosen for use in this study will be presented (forming the inputs and outputs), along with the form of the model to be used (time variant or invariant, particulars of environmental variable included), and the functional form to be estimated (translogarithmic).

### 3.5.1 Inputs, Outputs, and Prices

Cost Representing the cost term for HEI requires a little more thought than it would initially seem, particularly when minimising a cost function. The major inputs of capital and labour are obvious, however, in the sprawling, multi-faceted operations that HEI have now become there are likely to be additional inputs that are not yet measured, or even fully understood. If these are not quantified then they will lead to spurious results for those variables which are specified as they capture additional effects.

Quasi fixed factor research, such as that done by Ouellette and Vierstraete (2004), provides one solution. It focuses on inputs which are subject to external controls limiting the speed of alteration and leading to periods of sub-optimal input levels. This sub-optimal input usage would obviously lead to lower efficiency, however, it would be preferable if the externally controlled nature of the inputs could be factored into the efficiency scores.

Within this study these additional inputs cannot be accounted for through assignment of a price and so in order to avoid unfairly treating any HEI the independent variable cost will be represented by a summation of the observable and measurable terms of capital and labour which can also be given a price. Fortunately for such variables there is little disagreement nor difficulty in collecting data so this remains the most appropriate choice.

## Inputs and associated Prices

Though there seems to be a consensus that staff and capital represent the two main inputs into
the university production process, there is some difference of opinion as to how best to measure these inputs.

Staff Input Staffing input is typically measured by either staff number (a simple count) or full time equivalent. In this study we will use staff numbers ${ }^{12}$ as this will not dilute any potential effects of the full time/part time mix that will affect some institutions more than others. Use of a staff count and an additional proportional variable for part time staff will allow the model to capture the effect of high part time staffing volumes and potentially indicate whether this is a wise managerial decision or not.

Capital Capital has caused some concern for other studies because differing accounting methods give way to volatile measurements for capital across the sector, however, recalling Glass et al. (1995) words on the subject the issues are only because of American Accounting styles which vary widely, this will not occur in UK studies as"UK universities employ uniform accounting practices" (Footnote, Page 62, (Glass et al., 1995)). Hence, the choice in measuring capital is made confidently. Further, in an approach borrowed from banking literature (Kenjegalieva et al., 2009), the measurement of capital stock will be done via a valuation of total fixed assets, an easily available and accurately measured facet of HEI. ${ }^{13}$

Staff Price Deriving a price for staffing input is fairly straightforward; dividing the staffing expenditure by total number of staff gives a representative unit price faced by a particular institution and helps to avoid any bias caused by extremes of many low paid employees or a few highly paid employees. ${ }^{14}$ Normalising through division of both cost and labour price by

[^8]capital price allows for the assumption that the cost function is linearly homogenous in relation to input prices (Jorgenson, 1963).

Capital Price The few higher education studies in which a capital price is required conclude that the most appropriate choice is depreciation, which would concur with the effective user cost of capital (Section 3.4 Page 41). Carrington et al. (2005) recognise that depreciation would be the cost of capital were they to include it, though a lack of data prohibits this, and instead use operating cost which includes depreciation. This study will continue to utilise accounting depreciation as the widely accepted proxy for economic depreciation, however, just as an average was effected on staff cost so to remove any bias for high or low paid employees or indeed larger institutions, so must the same be done to total depreciation, allowing for balance between those institutions with an expansive capital redevelopment plan and those with more conservative building programs.

## Outputs

Teaching Teaching output in this study will be measured by two individual student enrollments, those for science students and those for non-science students (as in Johnes (1996a); Stevens (2005); Flegg et al. (2007)). Science students are termed as total students doing Medicine and Dentistry, Veterinary Science, Subjects allied to Medicine, Biological Sciences, and Physical Sciences. This options provides the most balanced way to consider the total teaching output of a university, rather than considering only the completed teaching in terms of the number of graduates. An additional benefit of using the number of student enrollments as opposed to the number of graduates is that the costs and revenues involved will be temporally congruent; the revenues and expenditures will match with the number of students enrolled, whereas numbers of graduates would match with revenues and expenditures from $3-5$ years previous dependent on the course studied.

Research Reflection upon the current crop of measures of research output highlights the fact that most are difficult to use, out of time with more up to date data, or inappropriate for use over a panel set with several years of data. Due to these difficulties, and in seeking a complementary price, a new measurement of research output was constructed for use in this thesis. This new measure of research output was formed through a two stage process.

Each research council reports the total funding given to Institutions as well as the number of outputs generated by this funding. $\frac{\text { ReportedFunding }}{\text { ReportOutputs }}$ gives an average price for an individual piece of research for a single research council. Creation of an equally weighted average across all research councils presents an overall price of research faced by each Institution in each year $\left(\frac{\text { Sumof AverageResearchPricesacrossallCouncils }}{\text { NumberofCouncils }}\right)$. From this the total research income of each institution could be divided by the appropriate years price of research to give an approximation of the the number of outputs. A similar method of forming an output proxy was suggested in Boone (2008) should data for outputs not be readily available.

This measure has not been found in any previous literature but offers a number of advantages. It allows for the use of research income in a manner of speaking, which although considered by some to be an input, remains a very good indicator of both quantity and quality of output. It allows for a price to be externally determined which resembles the actuality more closely: research councils will have varying levels of funding and be stricter in some years than others which will require more research for less funding i.e. a lower price. It overcomes many of the issues found in publication counts or citations such as time inconsistency, citation circles, quality measures etc. This method also fits an intuitive understanding of the production of research whereby unit price multiplied by units sold render total revenue, this is translated in the research setting to unit price multiplied by research output rendering research income. Finally it measures closely to research income which is itself closely aligned to RAE scores (Johnes and Johnes, 2009) and so confidence can be drawn from this alignment that the measure will be representative.

### 3.5.2 Environmental Variables

These variables are characteristics and indicators of heterogeneity that separate one university from all others. Some have been considered in previous studies and, in aiming to conduct a broader investigation, some extra variables will be included that have not previously been utilised.

Intensive Cost Courses In several studies medicine has rightly been singled out as a particularly burdensome course in terms of cost. The staff-student ratios are very low, a great deal of extra laboratories are needed, cadavers must be supplied, teaching time in hospitals forms a significant portion of the course, the required library resources have almost no economies of scope, the list goes on. Similar concerns can be levelled at veterinary and law courses. As such a dummy variable will be included for Law $\left(D_{\text {law }}\right)$, and for an aggregate of medical or veterinary courses ( $D_{\text {medic }}$ ).

Location The location of the university site is another factor which has seen a lot of investigation, particularly in the Italian market, by authors such as Agasisti et al. (2011) however, as far as reading indicates, this has not been directly tackled within the United Kingdom to date. The region of location for an individual institution can be hugely influential on running costs and capacity, as discussed in Koshal et al. (2001), however their study focused on the United States where regional differences are vastly wider than in the United Kingdom. Dummies will therefore be included for London ( $D_{\text {london }}$ ), where it is expected that costs are significantly higher, and Wales ( $D_{\text {wales }}$ ), where it is expected that costs are significantly lower.

University Groupings Whilst there is no specific reason yet uncovered as to why membership to a particular group would affect the efficiency of a particular institution, significant results may suggest that there is a particular aspect common amongst the members of the group which may affect efficiency, be it the higher research intensity of the Russell Group,
or the youth of those in the 1994, University Alliance, or Millennium Group. Additionally, significant results may indicate further areas for research and consideration.

PhD students PhD Students require a lot of one-on-one staff time which is clearly less efficient than class room teaching of other forms of postgraduates. If an institution starkly favours PhD postgraduates rather than taught postgraduates the output will be considerably reduced and fall into the research category rather than the teaching category. To capture this effect, the proportion of PhD students is included.

Quality of Teaching Output The proportion of firsts and upper seconds was used as a quality variable by Stevens (2005), as part of the main regression. Additionally it was used as an interaction term with the number of science and art students. ${ }^{15}$ In this study the teaching output used is student enrolments rather than graduates and so an interaction term similar to that used in Stevens (2005) is not appropriate. It is still the case that high quality teaching is expected to have an impact on efficiency, as it typically requires more time and resources to achieve. This effect will be taken into account by including a proportion variable for the number of first and upper-second class degrees.

Proportion of Non-EU Students International recruitment is becoming a significant target for universities due to the increased fees they bring. However, a case could be made that international students, suffering from immigration and language barrier difficulties, can be highly labour intensive to recruit and teach. Hence, whilst they may have a positive effect on revenue as compared to domestic students, their effect on cost efficiency will likely be negative.

Staff Demographics The number of staff a university has can be a slightly misleading input. Intuitively if there is only administrative staff then no teaching or research will take place, conversely no administrative staff may create a the opposite issue where so much time is spent by academics on the non teaching or research duties that output falls. It is probable

[^9]that most universities are somewhere in between these two extremes and it will be interesting to discover how much of an impact on the efficiency of a university the ratio between academic and non-academic staff has.

### 3.6 Model Specification

The various methods discussed and their associated pitfalls demonstrate the difficulty faced when attempting to measure performance of the higher education sector with each particular variable having advantages and disadvantages. Though there is no consensus of opinion for some variables it is necessary to utilise at least one, because without such measures we cannot even begin to measure efficiency. It is simply a case of knowing the limitations of the choices, rather than trying to find the perfect one. Mindful of these limitations, this section on model specification will consider the appropriate model for application to the efficiency analysis to be conducted within this empirical chapter, as well as the functional form of the model to be estimated.

### 3.6.1 Model Selection

The SFA literature presents a number of alternatives, however, some models might be considered either too restrictive or unsuited to an application in the higher education sector. Time invariant models seemed particularly inappropriate and as both Pitt and Lee (1981) and Schmidt (1985) note, time invariance is a difficult assumption to reconcile if we concede that firms will know about their own performance. If a company is aware of its performance it will try to improve over time. In the current climate of performance monitoring and benchmarking, as well as modern managerial practice, it would seem an incredible step to assume that an institution was unaware of its performance, rendering it reasonable to assume that efficiency is time invariant. This ruled out models the models proposed by Schmidt and Sickles (1984) and Pitt and Lee (1981).

There are a number of time variant models which could be used though many present a very
rigid variance condition. The Cornwell et al. (1990) model sets out a quadratic time function for the intercept, Kumbhakar (1990) presents an exponential and quadratic function of time, Battese and Coelli (1992) present another exponential function though without any quadratic terms, and Battese and Coelli (1992) present a two parameter quadratic but non-exponential function. All of these models, with their specification on the time variance of the model, would not adequately allow for the fluid nature of the higher education sector with a number of variables, nor would they allow easy adaptation to allow for particular environmental effects. The general model considered, and chosen, was the model described by equation 4 in Pitt and Lee (1981)l (as shown in equation 3.28).

$$
\begin{equation*}
y_{i t}=x_{i t} \beta+u_{i t}+v_{i t} \tag{3.28}
\end{equation*}
$$

Adaptations by Coelli et al. (1999b), such as conditional heteroscedasticity, allow this basic model to take into account environmental factors whilst allowing for time variant efficiency. The simplicity of the model, as well as its adaptability to this particular application, made it a sound choice for this study. The extensions are of course the 'net' and 'gross' approaches which individually provide helpful insights into the performance of a firm. An application of the 'net approach' could be considered a balanced view treating firms as if they were equal, variables are only able to affect the environment, whilst an application of the 'gross approach' is a more black and white view of efficiency, taking the firms without any leveling for different situations (such as location, staffing variation, and type of production). However, it is highly likely that there are grey areas, particularly in this case where some environmental variables, such as location, are fixed and others, such as the proportion of academic staff or the proportion of international students, are unlikely to be so. An application which allowed for this distinction and includes both effects on the frontier and on the efficiency term would be more balanced. Such a model is to be used in this study and is exemplified in equation 3.29.

$$
\begin{align*}
\ln y_{i t} & =\beta_{0}+\sum_{k=1}^{K} \beta_{k} \ln x_{k, i t}+\sum_{j=1}^{M} \theta_{j} \ln z_{j, i t}+v_{i t}-u_{i t}  \tag{3.29}\\
u_{i t} & \sim N^{+}\left(\left[\delta_{0}+\sum_{j=1}^{M} \delta_{j} \ln z_{j, i t}\right], \sigma^{2}\right) \tag{3.30}
\end{align*}
$$

### 3.6.2 Functional Form

Having decided upon the general form of the functions it is now necessary to progress towards an empirical model to estimate. Its use in a major paper reviewed for this thesis (one of only two to estimate a stochastic frontier model) presents the translog ${ }^{16}$ function as the appropriate choice (Stevens, 2005); there seemed, however, to be no presentation of alternatives. Initially a Cobb-Douglas cost function was considered however as it is not a member of the family of flexible cost functions it would gives constant returns to scale throughout the sample which would not allow for the possibility of some universities being too small and others too large. This prompted investigation of different options, and a paper by Caves et al. (1980) enumerated such options along with criterion for choosing one model over another.

Entitled 'Flexible Cost functions for Multi-product Firms' it discusses in depth three candidates to properly describe the multiproduct cost function. The first, proposed by Diewert (1971) is the generalized Leontief functional form for a cost function and for the production function, though these were quickly combined by Hall (1973) to form a hybrid - the Hybrid Diewert Multiproduct Cost Function (HDMCF). The second option was the Translog Multiproduct Cost Function (TMCF) suggested by Burgess (1974) and the third the Quadratic Multiproduct Cost Function (QMCF) proffered by Lau (1974).

The conditions for a suitable candidate are listed, "linearly homogeneous in input prices for all possible price and output levels; parsimonious in parameters; and containing the value zero in the permissible domain of output quantities" (Caves et al., 1980) (page 478). The HDMCF is appealing in that it can accommodate zero value inputs as well as being linearly homogenous. However, in order to examine non-constant returns to scale between cost and output a large

[^10]increase in the number of parameters is required. This moves contrary to the parsimony objective and cannot be easily avoided. This rules out the HDMCF from use. The QMCF does not satisfy the linear homegeneity objective and so is also ruled out as a suitable candidate. The TMCF is technically unable to deal with any values of zero as it take logarithms of all values. This can, however, be side-stepped through the addition of unity to every data point in an affected category. As a simple translation it will not affect any relationships between the data, but will maintain the characteristic of a zero value as when logarithms are taken the values of unity become zero. The importance of this work is demonstrated through an application to the US railroad industry, where taking a subset which have only positive values can give significantly different results to one using the full sample.

### 3.6.3 Model to be Estimated

There are many different aspects of a model which must be considered in preparation for an empirical study. This section has looked at these aspects and has narrowed the field of models options to a single base time variant model. This is extended in two complementary directions by Coelli et al. (1999b), and a hybrid model will take account of the costs and benefits of both the gross and net approach, and provide information for all parties. Finally the Translog function form has been chosen to functionalize the model due to its flexibility and ease of use in standard packages. This choice is further supported by Stevens (2005) given the focus of this study on determinants of inefficiency rather than economies of scale or scope. Hence, the final model to be estimated is:

$$
\begin{align*}
\ln C_{i t}= & \alpha+\sum_{j=1}^{n} \beta_{j} \ln Q_{j}+\sum_{j=1}^{n} \gamma_{j} \ln W_{j}+\sum_{k=1}^{n} \sum_{j=1}^{n} \gamma_{j k} \ln W_{j} \ln W_{k}+\sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{j k} \ln Q_{j} \ln Q_{k} \\
& +\sum_{k=1}^{n} \sum_{j=1}^{n} \theta_{j k} \ln Q_{j} \ln W_{k}+\sum_{l=1}^{q} \phi_{l} Z_{l, i t}+u_{i t}+v_{i t}+\delta_{1} t+\delta_{2} t^{2} \\
u_{i t} \sim & N^{+}\left(\left[\delta_{0}+\sum_{h=1}^{p} \lambda_{h} Z_{h, i t}\right], \sigma^{2}\right) \tag{3.31}
\end{align*}
$$

where, $\ln C_{i t}$ is the natural $\log$ of costs (as defined in Table 4.1) of university $i$ at time $t$, $\alpha$ is an intercept, $\ln Q_{j}$ is the natural $\log$ of output $j, \ln W_{j}$ is the natural $\log$ of the price
of output $j, Z_{l, i t}$ is a matrix of environmental variables $l$ affecting the frontier, $Z_{h, i t}$ is a matrix of environmental variables $h$ affecting the mean of the inefficiency distribution, $u_{i t}$ is the inefficiency term, $v_{i t}$ is the idiosyncratic error term, $t$ is a time variable, $\beta, \gamma, \theta, \phi, \delta, \lambda, \sigma$ are parameters of the estimation, and subscript $k$ also maps to the different outputs being a twin of subscript $j$ which allows for the formation of interaction terms where $j$ does not equal $k$ and square terms where it does.

Hence we have a model with cost on the left hand side, the stated inputs and outputs along with input prices, interaction, and square terms on the left. In the environmental variables that will be allowed to affect the frontier are the dummy for location in London and for location in Wales. The location of these institutions in areas with different factor costs are clearly beyond the control of any management and therefore should be folded into the frontier so as to ensure a level playing field upon which to derive efficiency scores. All other environmental variables (proportions and dummy variables) are within the control of an institutions management, where the management would be able to determine a preference from domestic or EU students over non-EU, or to increase the amount of academic staff in relation to the number of non academic staff, or to offer particularly burdensome courses such as law and medicine. These variables will therefore form part of the $Z$ matrix determining the distribution of the efficiency term and in turn the size of efficiency.

### 3.7 Data Sources and Descriptive Statistics

The efficiency analysis conducted within this chapter is highly data intensive and required data from several sources. The Higher Education Statistics Agency ${ }^{17}$ (HESA) track information on a huge range of variables across HEI and tabulate the information for purchase.

The tables purchased for this work were: Resources of Higher Education Institutions (2004/05 through to, and including, 2008/09), Students in Higher Education Institutions (2004/05 through to, and including, 2008/09), HE Finance Plus (2004/05, through to, and including,

[^11]2008/09).
The financial data drawn from HE Finance Plus was conditioned using a GDP Deflator supplied by HM Treasury ${ }^{18}$ and finally the information used to construct the Research Price Index (See Section 3.4) was derived from each funding council's annuals reports. ${ }^{19}$, ${ }^{20},{ }^{21},{ }^{22},{ }^{23},{ }^{24},{ }^{25}$

After some data processing to make the different years compatible it became apparent that some institutions were particularly specialised or had anomalous characteristics such as, having no reported value of total assets in the case of the Royal College of Nursing, receiving no government funding for teaching in the case of Homerton College, having a completely unique provision of teaching as well as a very large size in the case of The Open University, or having no undergraduate students as in the case of The Institute for Cancer Research, London Business School, London School of Hygiene and Tropical Medicine, and the Royal College of Art. As in Johnes et al. (2008) institutions with these characteristics were removed, as were a cumulative entries for the UK, Wales, and England. Despite these removals the sample which remained contain observations for 139 institutions for a period of up to 5 years, creating 669 individual observations.

[^12]Table 3.2: Data Summary

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University ID | University IDNumber | HESA assigned code for each University (consistent across name changes) | 669 | $9.883 \mathrm{E}+01$ | 57.568 | 7.000 | 209.000 |
|  |  |  |  |  |  |  |  |
| year id | Year ID Number | Number for academic year 04-05 to 08-09 | 669 | $2.996 \mathrm{E}+00$ | 1.414 | 1.000 | 5.000 |
| normcost | Normalised Cost | Total cost (staff expenditure plus depreciation), with a GDP deflator applied and then logged and demeaned | 669 | $-2.295 \mathrm{E}-15$ | 1.485 | -10.595 | 2.743 |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  | Continue | on the | ext page |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| scistudout | Science Student Output | Total students do- | 669 | $-1.722 \mathrm{E}-15$ | 3.005 | -6.751 | 2.932 |
|  |  | ing Medicine and |  |  |  |  |  |
|  |  | Dentistry, Veterinary |  |  |  |  |  |
|  |  | Science, Subjects allied |  |  |  |  |  |
|  |  | to Medicine, Biological |  |  |  |  |  |
|  |  | Sciences, and Physical |  |  |  |  |  |
|  |  | Sciences |  |  |  |  |  |
| nonscistudout | Non Science Student Output | Total students do- | 669 | -6.057E-16 | 1.545 | -8.738 | 1.499 |
|  |  | ing subjects other |  |  |  |  |  |
|  |  | than Medicine and |  |  |  |  |  |
|  |  | Dentistry, Veterinary |  |  |  |  |  |
|  |  | Science, Subjects allied |  |  |  |  |  |
|  |  | to Medicine, Biological |  |  |  |  |  |
|  |  | Sciences, Physical |  |  |  |  |  |
|  |  | Sciences |  |  |  |  |  |
|  |  |  |  |  | Continue | on the | xt page |

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| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| resout | Research Output | Research income divided by an index of research prices | 669 | -1.102E-15 | 2.435 | -4.186 | 4.892 |
| normstaffprice | Normalised Staff Price | Staff expenditure divided by staff numbers, with a GDP deflator applied and then logged and demeaned | 669 | $-1.036 \mathrm{E}-16$ | 0.815 | -9.254 | 1.904 |
| time | Time | year id demeaned | 669 | $2.701 \mathrm{E}-15$ | 1.414 | -1.996 | 2.004 |
| scistudoutsq | Science Student | As above, squared | 669 | $9.016 \mathrm{E}+00$ | 14.640 | 0.000 | 45.570 |
| nonscistudoutsq | Output Squared <br> Non-Science | As above, squared | 669 | $2.382 \mathrm{E}+00$ | 9.694 | 0.000 | 76.350 |
|  | Student Output <br> Squared |  |  |  |  |  |  |
| resoutsq | Research Output <br> Squared | As above, squared | 669 | $5.918 \mathrm{E}+00$ | 6.149 | 0.000 | 23.930 |
| Continued on the next page |  |  |  |  |  |  |  |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| normstaffpricesq | Normalised Staff | As above, squared | 669 | $6.627 \mathrm{E}-01$ | 5.082 | 0.000 | 85.635 |
|  | Price Squared |  |  |  |  |  |  |
| timesq | Time Squared | As above, squared <br> Components as above | $\begin{aligned} & 669 \\ & 669 \end{aligned}$ | $1.995 \mathrm{E}+00$ | 1.675 | 0.000 | 4.018 |
| scinonsciout | Science Stu- <br> dent Output <br> and Non-Science |  |  | $2.468 \mathrm{E}+00$ | 4.305 | -14.361 | 18.607 |
|  |  | Components as above |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  | Student Output interaction term |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| sciresout | Science Student | Components as above | 669 | $4.949 \mathrm{E}+00$ | 7.921 | -5.915 | 28.256 |
|  | Output and Research Output interaction term |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| nonsciresout | Non-Science Student Output and Research Output interaction term | Components as above | 669 | $1.581 \mathrm{E}+00$ | 3.347 | -18.874 | 36.574 |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  | Continu | on the | page |

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| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| scinormstaff | Science Student | Components as above | 669 | $6.607 \mathrm{E}-01$ | 4.677 | -9.746 | 62.469 |
|  | Output and Normalised Staff |  |  |  |  |  |  |
|  | Price interaction term |  |  |  |  |  |  |
| nonscnormstaff | Non-Science Student Output and | Components as above | 669 | $2.969 \mathrm{E}-01$ | 1.517 | -3.124 | 18.773 |
|  | Normalised Staff |  |  |  |  |  |  |
|  | Price interaction term |  |  |  |  |  |  |
| resnormstaff | Research Output and Normalised | Components as above | 669 | $5.368 \mathrm{E}-01$ | 2.978 | -6.026 | 38.734 |
|  | Staff Price interaction term |  |  |  |  |  |  |
| scistud time | Science Student | Components as above | 669 | $6.219 \mathrm{E}-02$ | 4.216 | -13.531 | 13.471 |
|  | Output and Time interaction term |  |  |  |  |  |  |
|  |  |  |  |  | Continue | on the | xt page |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| nonscistudtime | Non-Science Student Output and Time interaction term | Components as above | 669 | $5.927 \mathrm{E}-02$ | 2.228 | -17.515 | 17.436 |
| restime | Research Output and Time interaction term | Components as above | 669 | $1.101 \mathrm{E}-01$ | 3.446 | -8.586 | 9.806 |
| normstafftime | Normalised Staff Price and Time interaction term | Components as above | 669 | $1.614 \mathrm{E}-01$ | 1.172 | -14.972 | 15.665 |
| lawdummy | Law Dummy | Indicating students engaged in the study of Law | 669 | $6.577 \mathrm{E}-01$ | 0.475 | 0.000 | 1.000 |
| Continued on the next page |  |  |  |  |  |  |  |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| aggmedvetdummy | Aggregated Medical and Veterinary Dummy | Indicating students engaged in the study of Medicine, Dentistry, allied to Medicine, and Veterinary Science subjects | 669 | $2.960 \mathrm{E}-01$ | 0.457 | 0.000 | 1.000 |
| london | London Dummy | Indicating location of university in London | 669 | $2.317 \mathrm{E}-01$ | 0.422 | 0.000 | 1.000 |
| wales | Wales Dummy | Indicating location of university in Wales | 669 | 8.221E-02 | 0.275 | 0.000 | 1.000 |
| guildhe | GuildHE Dummy | Indicating membership of Guild HE university grouping | 669 | $1.405 \mathrm{E}-01$ | 0.348 | 0.000 | 1.000 |
| ninetyfour | 1994 Dunny | Indicating membership of 1994 university grouping | 669 | $1.345 \mathrm{E}-01$ | 0.341 | 0.000 | 1.000 |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| million | Million Plus Dummy | Indicating membership of Million-Plus university group | 669 | $1.495 \mathrm{E}-01$ | 0.357 | 0.000 | 1.000 |
| russell | Russell Group <br> Dummy | Indicating membership of the Russell Group | 669 | $1.345 \mathrm{E}-01$ | 0.341 | 0.000 | 1.000 |
| universityalliance | University Alliance Dummy | Indicating membership of the University Alliance Group | 669 | $1.570 \mathrm{E}-01$ | 0.364 | 0.000 | 1.000 |
| ukadia | Ukadia Alliance <br> Dummy | Indicating membership of the Ukadia Group | 669 | $4.335 \mathrm{E}-02$ | 0.204 | 0.000 | 1.000 |
| newfees | New Fees dummy | Dummy for increased fees in 2006 | 669 | $5.994 \mathrm{E}-01$ | 0.490 | 0.000 | 1.000 |
| PropFEStudent | Proportion of Total Students that are in Further Education | Total FE Students divided by Total Students | 669 | $4.790 \mathrm{E}-02$ | 0.133 | 0.000 | 0.886 |
| Continued on the next page |  |  |  |  |  |  |  |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| PropPGStudent | Proportion of Total Students that are Postgraduates | Total PG Students divided by Total Students | 669 | $2.296 \mathrm{E}-01$ | 0.134 | 0.000 | 0.970 |
| PropPHDofPG | Propotion of <br> Postgraduate <br> Students that are <br> doing PhD | Total PhD Students divided by Total Postgraduates | 669 | $2.314 \mathrm{E}-02$ | 0.027 | 0.000 | 0.183 |
| PropPTStudent | Propotion of Total Students that are Part Time | Total Part Time Students divided by Total Students | 669 | $3.225 \mathrm{E}-01$ | 0.172 | 0.000 | 0.964 |
| PropGoodHons | Proportion of <br> Good Honours | Number of Firsts and Upper Seconds divided by Total Qualification Awarded | 669 | 7.634E-18 | 0.042 | -0.129 | 0.247 |
| AcademicNon <br> AcademicRatio | Academic Staff to Non-Academic Staff Ratio | Total Academic Staff divided by Total NonAcademic Staff | 669 | $1.670 \mathrm{E}-18$ | 0.472 | -0.638 | 3.040 |
| Continued on the next page |  |  |  |  |  |  |  |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| PropPTAcademic | Proportion of | Total Part Time Aca- | 669 | $3.762 \mathrm{E}-01$ | 0.202 | 0.000 | 0.955 |
| Staff | Academic Staff | demic Staff divided by |  |  |  |  |  |
|  | that are Part | Total Academic Staff |  |  |  |  |  |
|  | Time |  |  |  |  |  |  |
| PropPTNon AcademicStaff | Proportion of | Total Part Time | 669 | $3.409 \mathrm{E}-01$ | 0.106 | 0.000 | 0.753 |
|  | Non Academic | Non-Academic Staff |  |  |  |  |  |
|  | Staff that are | divided by Total |  |  |  |  |  |
|  | Part Time | Non-Academic Staff |  |  |  |  |  |
| PropPTStaff | Proportion of To- | Total Part Time Staff | 669 | $1.257 \mathrm{E}-17$ | 0.133 | -0.372 | 0.424 |
|  | tal Staff that are Part Time | divided by Total Staff |  |  |  |  |  |
| PropEU | Proportion of HE | Total EU Students di- | 669 | -6.804E-18 | 0.039 | -0.051 | 0.203 |
|  | Students from EU | vided by Total Stu- |  |  |  |  |  |
|  | Domiciles | dents |  |  |  |  |  |

Table 3.2 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| PropNonEU | Proportion of | Total Non-EU Students divided by Total Students | 669 | $1.639 \mathrm{E}-18$ | 0.080 | -0.101 | 0.545 |
|  | HE Students |  |  |  |  |  |  |
|  | from Non-EU |  |  |  |  |  |  |
|  | Domiciles |  |  |  |  |  |  |

### 3.8 Results and Analysis

An aim of this study is to investigate some previously unexamined variables. Consequently function estimation begins simply including all of the variables to provide a base from which to iterate. All coefficient and efficiency measures have been calculated using the Stata 12 software (StataCorp, 2011). These estimations showed significance of outputs, input prices, and some other variables when evaluated at the sample mean (data have been log-mean corrected). The model appears well formed with only two variables showing insignificance and importantly they appear as determinants of efficiency distribution rather than the main variables. These variables, a dummy for the new fees regime in 2006 and membership to the ukadia group, are removed in turn and the model re-estimated.

This produces three models for which results are presented. Model 1 is the full model containing all variables, model 2 has ukadia removed from affecting the mean of the distribution, and model 3 has both newfees and ukadia removed from affecting the mean of the distribution. Spearman's rank correlations coefficients were determined between the three models to ascertain whether removal of the variables had caused a dramatic change in the efficiency values returned. The coefficient between each pair of models was over 0.99 and so the transition from full to parsimonious model has not influenced the efficiency scores considerably.

### 3.8.1 Determinants of the Frontier

Table 3.3 shows the full model, a parsimonious version of the model, and an intermediary stage, which all contain expected significant terms. Notably, and importantly for this research, the new environmental variables and the new measure of research have returned highly significant results.

In concurrence with many of the studies considered thus far (Stevens, 2005; Izadi et al., 2002; Avkiran, 2001) the student output has a positively significant effect on the position of the frontier, as does the normalised staff price. Both of these are to be expected, the student output is by far the most voluminous of an institutions outputs and staff costs the most expensive single

Table 3.3 Estimation Results - Frontier

|  | Model 1 |  | Model 2 |  | Model 3 |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Variable | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. |
| resout | 0.116 | 0.009 | 0.117 | 0.010 | 0.117 | 0.010 |
| scistudout | 0.059 | 0.011 | 0.059 | 0.011 | 0.059 | 0.011 |
| nonscistudout | 0.514 | 0.017 | 0.515 | 0.017 | 0.515 | 0.017 |
| normstaffprice | 1.000 | 0.019 | 1.002 | 0.019 | 1.001 | 0.019 |
| scistudoutsq | -0.001 | 0.002 | 0.000 | 0.002 | 0.000 | 0.002 |
| nonscistudoutsq | 0.046 | 0.002 | 0.047 | 0.002 | 0.047 | 0.002 |
| resoutsq | 0.028 | 0.002 | 0.028 | 0.002 | 0.028 | 0.002 |
| normstaffpricesq | 0.021 | 0.006 | 0.021 | 0.006 | 0.021 | 0.006 |
| scinormstaff | -0.036 | 0.008 | -0.036 | 0.008 | -0.036 | 0.008 |
| nonscinormstaff | 0.031 | 0.015 | 0.030 | 0.015 | 0.030 | 0.015 |
| resnormstaff | 0.011 | 0.012 | 0.011 | 0.012 | 0.011 | 0.012 |
| time | 0.025 | 0.009 | 0.025 | 0.009 | 0.025 | 0.009 |
| timesq | 0.000 | 0.005 | 0.000 | 0.005 | -0.001 | 0.004 |
| scistudtime | -0.001 | 0.003 | -0.001 | 0.003 | -0.001 | 0.003 |
| nonscistudtime | 0.000 | 0.004 | 0.000 | 0.004 | 0.000 | 0.004 |
| restime | -0.004 | 0.004 | -0.003 | 0.004 | -0.003 | 0.004 |
| normstafftime | -0.025 | 0.008 | -0.025 | 0.008 | -0.025 | 0.008 |
| london | 0.185 | 0.027 | 0.185 | 0.027 | 0.185 | 0.027 |
| wales | -0.089 | 0.030 | -0.089 | 0.030 | -0.088 | 0.030 |
| cons | 0.054 | 0.032 | 0.052 | 0.032 | 0.055 | 0.032 |

cost (if staff price increases the overall staff cost will obviously rise dramatically). Further the results for both science and non-science based student output confirms that the general model is in line with that similar works (Stevens, 2005; Johnes and Johnes, 2009) who also found statistical significance in a disaggregated output of students.

The total research output measure is also significant which, though intuitively expected, was not as sure an outcome as the total student output as there was little to no research based evidence to support such a proposition and hence represents a contribution to the current literature by this research. In addition to its significance, it also has the expected sign, more research output will inevitably incur more cost - increasing research output will take more staff or more facilities which will both cost more. This is an important validation for this study, and offers a new method for future researchers to use when calculating the research output of an institution, one which is simple to formulate, current, and has readily available data.

Importantly this new research measure, though highly correlated with a straight forward research income based measure, also fits more intuitively into an interpretation of a university as a production environment. As in Boone (2008) the creation of an output through division of a monetary value by a price index gives a unit of output for research as a simple number rather than a monetary value which matches to the student output and hence gives an easier understanding for those considering the results. With both output measures achieving significance with the correct sign there is a strong indication that the model satisfies the monotonicity property at the sample mean, and gives justification for the model chosen.

The environmental factors that have been included within the frontier estimation, a dummy for location in London and for location in Wales, are also significant. Moreover, the signs of both variables are in line with the expectations set out when forming the model; costs are significantly lower for universities operating in Wales, and higher for those operating in London. It is important to note however, that this difference in cost is not absolute but rather relative to location elsewhere in the UK. These results are in line with research from other countries (Agasisti et al., 2011) and appear to be early results within the UK market providing another direct contribution to the literature.

### 3.8.2 Determinants of the Conditional Mean of Efficiency Distribution

Having considered the effect the variables will have on the frontier, it is now time to consider the effect they have on the distribution of the conditional mean of the efficiency term. Only the signs of the coefficients can be estimated and so, like Stevens (2005), only the signs will be evaluated.

Looking first to the insignificant results it is interesting to see that a dummy for the new fees regime is returned as an insignificant factor. Initially it might be considered that the insignificance of this new fees dummy has been assumed by the time trend which is a significant result. However, upon re-estimating the models without a time trend it becomes clear that there is not misrepresentation and that the new fees regime appears to have no significant effect on the distribution of the efficiency term and therefore no significant effect on efficiency.

Table 3.4 Estimation Results - Efficiency Distribution

|  | Model 1 |  | Model 2 |  | Model 3 |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Variable | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. |
| aggmedvetdummy | -0.354 | 0.075 | -0.355 | 0.075 | -0.357 | 0.076 |
| lawdummy | -0.339 | 0.053 | -0.342 | 0.053 | -0.342 | 0.053 |
| propphdofpg | -12.600 | 1.637 | -12.413 | 1.638 | -12.443 | 1.641 |
| propgoodhons | 2.813 | 0.472 | 2.707 | 0.459 | 2.710 | 0.461 |
| academicnonacademicratio | 0.463 | 0.087 | 0.456 | 0.087 | 0.453 | 0.087 |
| propptacademicstaff | 2.407 | 0.521 | 2.300 | 0.512 | 2.287 | 0.513 |
| propptnonacademicstaff | 2.671 | 0.641 | 2.571 | 0.635 | 2.551 | 0.636 |
| propptstaff | -7.575 | 1.143 | -7.355 | 1.123 | -7.326 | 1.125 |
| guildhe | 0.112 | 0.058 | 0.092 | 0.055 | 0.093 | 0.055 |
| million | -0.191 | 0.054 | -0.190 | 0.054 | -0.189 | 0.054 |
| russell | -0.230 | 0.097 | -0.229 | 0.098 | -0.229 | 0.098 |
| universityalliance | -0.475 | 0.085 | -0.474 | 0.085 | -0.475 | 0.085 |
| propfe | -1.060 | 0.168 | -1.104 | 0.168 | -1.106 | 0.169 |
| proppg | 0.262 | 0.132 | 0.257 | 0.132 | 0.257 | 0.133 |
| proppt | 0.872 | 0.143 | 0.878 | 0.145 | 0.881 | 0.145 |
| propeu | -1.810 | 0.618 | -1.792 | 0.620 | -1.780 | 0.621 |
| propnoneu | 1.350 | 0.321 | 1.351 | 0.322 | 1.347 | 0.323 |
| time | 0.054 | 0.029 | 0.055 | 0.029 | 0.037 | 0.019 |
| cons | -0.905 | 0.411 | -0.835 | 0.408 | -0.859 | 0.409 |
| newfees | -0.061 | 0.070 | -0.060 | 0.070 |  |  |
| ukadia | -0.104 | 0.093 |  |  |  |  |

The ukadia group ${ }^{26}$, a group specifically for art and design based HEI such as Ravensbourne and Arts University Bournemouth, is also insignificant in determining efficiency. A likely explanation for this is that the majority of the members of ukadia are also members of the guildhe university group which has received a significant result and there would be insufficient data given the small number with the ukadia group to give an additional effect beyond that.

Moving on to those significant results and following the Stevens (2005) style of interpretation, recalling that a cost function is a minimisation approach, positive coefficients describe a movement away from the cost frontier and a greater value of inefficiency, negative coefficients describe decreasing inefficiency for increasing values of the variable. Revisiting the time trend, after touching on it when discussing the new fees dummy, it presents as positive and significant across all three models. This results speaks to a trend away from the frontier over time indi-

[^13]cating decreasing efficiency across the sector. Its significant result also confirms the discussion prior to estimation which centered around the assumption that over a five year period universities would be aware of, and able to influence, their level of efficiency. The result also agrees with Stevens (2005) in a similar study of a preceding time period.

The proportion of non-EU students also achieves a positive coefficient indicating that increasing proportions of the total student body that were non-EU domiciled would increase inefficiency. This is likely due to the increasing administrative burden through visa and language support requiring large amounts of staff time. This staff time would come from additional staff rather than current staff simply working longer which brings with it associated costs of employment. Further institutions with larger non-EU demographics will need specialist language support which may become a department of its own rather than an officer within a student support department which creates additional cost. These costs are all post-arrival, it must not be forgotten that prior to the arrival of students there would need to be additional staffing effort in terms of recruitment and advertising from developing additional media to attending international recruitment fayres.

The proportions of totals students that are postgraduate or part time students also return positive coefficients and hence increasing values of these variables will worsen efficiency. Postgraduate tuition is done in much smaller groups that undergraduate tuition and is inherently more specialised. This requires particular staff skillsets and lower staff to student ratios which in turn increases the amount of staff required, particularly if staff are also expected to research. It is therefore clear that costs will then increase in line with the required additional staffing.

The dummy variable indicating membership to the guildhe university group also returns a positive coefficient. Inspection of the group membership reveals offers an indication of why positive result may be likely; all have outputs of teaching and research that are the bottom end of all institutions whilst having costs that are more evening distributed amongst the table. There is also typically a preference in these institutions for teaching based output over research based output which would likely leave them penalised by a model which includes a research output component such as the one used.

An increasing ratio of academic to non-academic staff echoes very clearly the discussion of variables preceding the estimation and suggests that either too much administrative burden is falling on academic staff who are relatively less specialised and hence spend a longer period of time doing so, or there is simply insufficient administrative support for the teaching and research output that is being created hence introducing congestion into the institution. A similar line of argument can be given to the positive coefficients for the proportions of academic and non-academic staff who are part time. Increasing proportions of these variables likely point to further imbalance between academic and non-academic staff meaning administrative work bleeds into academic staff time (in the case of too high a proportion of academic staff) or there is insufficient academic staff required to produce the output needed to keep all of the administrative staff utilised (in the case of too high a proportion of non-academic staff).

Moving to those variables which move the institution closer to the frontier and therefore indicate a reduction of inefficiency and first to the particular subject variables. Initially it was proposed that the offering of law and medicine would likely increase inefficiency due to the increased costs of supply. The results provided suggest that in fact the opposite is true and that offering either of these courses would improve the efficiency of an institution.

Turning first to medicine and veterinary based subjects the results is initially surprising, however, consider that the frontier of the model has already been moved outwards (increasing cost) in relation to the number of science students (within which both all those included in the aggmedvet dummy would be counted). The negative coefficient is likely speaking to type of accounting issue discussed by Agasisti and Salerno (2007) whereby either none or all of the hospital cost is accounted for by the institution, and in this case it would appear they are not counted. In essence they are receiving some teaching facility without the additional cost and the expected premium on tuition staff is not sufficient to counter balance this effect. Further the reduction in inefficiency may speak to a concentration of medical research funding within the UK. Research within medical fields is more highly concentrated than other areas as there will be certain clinical standards to be met before medical research funding is released and so not everyone can access that funding or produce those outputs. Institutions which have medical
or veterinary departments my therefore be able to bolster their research output in comparison with other institutions who cannot enter the same market.

Within law whilst the effect is similar the reasons are different to that of medicine and associated subjects. Within law there is a wider practice of senior law professionals taking one or two days a week to teach within an institution. This type of teaching arrangement, whilst likely more costly on a per month basis, when considered across the year is much cheaper than employing a full time member of staff. The subjects are also easy to teach within current facilities not requiring new buildings, and like medicine and associated subjects the provision of law is more concentrated than other subjects due to external accreditation of law courses. This results in a similarly bolstered student output, taught by staff who produce an intense level of teaching output over short periods of time.

The model also suggests that the variable which indicates an increasing proportion of postgraduate students are PhD students is also negative, it leads to less inefficiency. This was an initially unexpected result; the expectation prior to estimation was that PhD students take a large amount of staff time, which would reduce the amount of teaching or research output they can achieve. However, this result prompted a reconsideration and a possible explanation for the effect on efficiency is that PhD students can be considered as very low cost staffing. In many institutions PhD students will support tuition by covering tutorials and even some lectures, and in most institutions PhD students will eventually publish research work with their supervisor. When considered in this light the reducing effect on inefficiency becomes clearer; outputs of both teaching and research are increased without additional costs for staff. The higher the number of PhD students, the higher this effect can reach. Two small caveats must be included here - firstly some institutions do pay PhD students, however this cost will be minimal and on an hourly rate so is not comparable to hiring another lecturer, and secondly some PhD students will be funded through internal rather than external scholarships however these costs would not be included in staff expenditure and so may increase the effect of this particular variable.

The proportion of staff which work part time also has the effect of reducing inefficiency. Prior
to estimation there was not a clear expectation of how this variable would manifest in the results. One consideration is that part time staff take additional human resource effort to process which may increase costs, the alternative is that as part time staff they are scheduled to provide additional assistance where it is needed due to increasing output and have less unproductive time as their workload must be completed in a shorter period of time. There is of course also the cost implications, part time staff cost less than a full time member of staff and can typically be scheduled to avoid the seasonal troughs of work that are common within an institution (holiday periods). The result suggests that it is the latter effect that is more predominant, that part time staff can be used to more cheaply manage fluctuating output and give management the capability to cope with more output without constraining them to be over-resourced in less busy times. This variable is in contradiction to the proportion of academic and non-academic staff who are part time, which suggests it is speaking more to general staffing levels and that if the proportion of part time staff is to be increased it must do so in a balanced fashion between the two types of staff.

Looking next to particular student demographic variables such as the proportion of further education students and the proportion of students from the European Union which both having negative coefficients and hence provide a decrease in inefficiency. The effect of the proportion of further education students is likely due to the different staff premiums attracted by higher and further education; where further education staffing costs less. Therefore with a lower cost of staffing a higher proportion of further education students will enable higher levels of output at a reduced cost and thus increased cost efficiency. As to the proportion of EU students whilst no clear reason for this to be beneficial to the efficiency of an institution is forthcoming, a possible explanation could be as a complement to the detrimental effect of a higher proportion of non-EU students. International recruitment need not be specific to non-EU countries such as China, and many EU students study abroad so as to improve language skills and employability. Fortunately for institutions the additional support required by non-EU students in terms of visas and language support are not needed by those from other EU countries who have freedom to move and study in different countries and typically have very good language skills. This
effect may also be a spillover from particular relationships that researchers have built with European institutions which allows for a higher research output without additional cost, thus reducing inefficiency.

Finally we consider membership to university groupings, Million Plus, Russell Group, and University Alliance all of which seem to decrease inefficiency. Once again, as with GuildHE as discussed earlier, these groupings cannot be concluded to confer efficiency advantages simply through membership. It is more appropriate to consider them as identifying particular styles of institution where replication of that style will be advantageous in terms of decreasing inefficiency. A prime example of this is the Russell Group which has high outputs of both research and teaching (particularly high in the case of research) which will of course decrease inefficiency. The University Alliance meanwhile is a group of institutions that produce research output but with a predominant focus on teaching, having some of the highest student output within the panel, whilst having middling costs. The Million Plus group is similar but has an even higher focus on teaching than the University alliance institutions and is able to balance this with lower costs. These dummy variables are therefore perhaps indicating that these types of institute are able to strike a slightly better balance between cost, student output, and research output which allows them be more efficient.

The positive effect of these variables may also speak to reputation advantages to being in these groups (particularly within the Russell group) which may allow them to reduce costs of staff because they can exchange a slightly lower wage for the opportunity to work at a prestigious university. It may also talk to reduce ongoing capital costs as many buildings have been around for sufficient time that they no longer need to be counted in depreciation but still provide service as discussed in Carrington et al. (2005). A small overall caveat here, the model is specified to value both research and teaching. Some institutions focus more on teaching and thus might be disadvantaged in the such a model whilst those who do both will obviously be advantaged.

### 3.8.3 Cost Efficiency Scores

An important part of this study is to consider the actual efficiency scores of each institution. A detailed listing of each institution on an annual basis, an average, and a change over the course of the study metric is available in Table B. 1 on Page 236, here, for brevity, focus is given to overall themes and particular interesting cases. Analysis begins by considering a simple bar graph showing how many institutions fit into each 10 percentage point group in each of the 5 academic years. Figure 3.2 demonstrates a similar distribution of efficiency to that found by other authors (Johnes, 2006; Stevens, 2005), where a large number of efficient institutions are accompanied by a long tail of institutions with medium and low efficiency. This similarity lends further confidence to the results of this study.


Taking a closer look at the make up of the different groupings specialist institutions such as the Central School of Speech and Drama and Courtauld Institute of Art find themselves at the end of this long tail, whilst those typical of a post-1992 institution such as York St John and London South Bank University find themselves in the fatter middle section. The high efficiency right hand side of the distribution is predominantly Russell Group institutions such Cardiff University, The University of York, and The University of Southampton.

As Table 3.5 demonstrates, broadening the observations from Figure 3.2 to analysis of three typical groupings of institutions (Russell Group, Pre-1992, and Post-1992 as has been done in previous works (Johnes and Johnes, 2009)) confirms that there seem to be notable differences in efficiency between the groups. The table shows a clear efficiency premium is achieved by those in the Russell Group, approximately 14 percentage points over the Pre 1992 group who are in turn between 15 and 20 percentage points less efficient than the Post 1992 group.

Table 3.5 Results by Institutional Group - Mean

|  | Year |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Group | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| Russell | 0.902 | 0.882 | 0.902 | 0.911 | 0.900 |
| Pre 1992 | 0.771 | 0.759 | 0.763 | 0.771 | 0.763 |
| Post 1992 | 0.732 | 0.719 | 0.699 | 0.693 | 0.684 |

Table 3.5 also demonstrates distinct patterns for each group over time. The positive coefficient on time within the mean of the conditional distribution (those which indicate a direct effect on efficiency) suggested that over time efficiency was decreasing across the whole sample. However a closer examination of the table reveals that this is effect is felt far more intensely in the Post 1992 group, which has fallen by approximately 5 percentage points as opposed to the 1 percentage point of the Pre 1992 group or indeed the less than 1 percentage point of the Russell Group.

Both Table 3.5 and Figure 3.2 suggest however that, particularly for the Russell and Pre 1992 groups, this decline was not linear but rather there was a more undulating level of efficiency, falling, increasing beyond original levels, and then falling again. The Post 1992 group is exceptional in this regard, its mean efficiency falls each year ending up nearly 20 percentage points
below the ending efficiency of the Russell Group.

Next, in Table 3.6 the standard deviation of these groups is examined. Here a slightly different set of patterns is forthcoming. Once again the Russell Group performs "well" having a small standard deviation indicating that the high average mean is achieved through consistent high performance rather than a lot of low performing and lot of high performing institutions. It may also suggest that the institutions are very similar, which is expected for the Russell Group particularly due to the smaller membership. However, the same would not be expected of the Post 1992 group, with a membership nearly 3 times the size of the Russell Group, which also has a low standard deviation. Moreover, the steady decline in efficiency and low standard deviation suggest that the particular traits of this group which are distinct from the other two groups are fairly consistent within the group and thus all were vulnerable to the environment which led to reduced efficiency. Unexpectedly it appears, with a higher standard deviation, that the Pre 1992 group was most diverse in terms of efficiency whilst also having a high mean. Analysis of the types of institutions included within this group actually make this result more understandable; there has been a great deal of "organic" growth of institutions from a wide range of backgrounds and ages (from the University of Birmingham in 1900 to the University of Kent in 1965) rather than the Post 1992 group which were typically a functioning polytechnic which become a full university.
Table 3.6 Results by Institutional Group - Standard Deviation

|  | Year |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Group | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| Russell | 0.055 | 0.066 | 0.056 | 0.051 | 0.057 |
| Pre 1992 | 0.208 | 0.208 | 0.205 | 0.217 | 0.215 |
| Post 1992 | 0.156 | 0.155 | 0.177 | 0.181 | 0.178 |

The observations drawn from Table 3.6 are reinforced by the Tables 3.7 and 3.8 which show the minimum and maximum efficiency scores attained by each group. The tables confirm that the Russell Group maintains a concentration at the top end of the efficiency spectrum, with all institutions fitting within a 20 percentage points spread whilst other institutions are spread from the very lowest to the very highest efficiency.

Table 3.7 Results by Institutional Group - Minimum

|  | Year |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Group | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| Russell | 0.767 | 0.679 | 0.725 | 0.759 | 0.727 |
| Pre 1992 | 0.149 | 0.181 | 0.198 | 0.210 | 0.204 |
| Post 1992 | 0.441 | 0.450 | 0.182 | 0.161 | 0.158 |

Table 3.8 Results by Institutional Group - Maximum

|  | Year |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Group | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| Russell | 0.961 | 0.966 | 0.952 | 0.968 | 0.952 |
| Pre 1992 | 0.940 | 0.940 | 0.948 | 0.956 | 0.964 |
| Post 1992 | 0.961 | 0.961 | 0.976 | 0.955 | 0.970 |

At the very bottom, as already touched upon, are institutions such as the Central School of Speech and Drama or Courtauld Institute of Art, or Newman University College. The majority of the institutions in the left of the long tail are very specialised, smaller scale institutions with low outputs of both teaching and research. The institutions are obviously incurring greater "cost per output" because their large capital and staffing costs are comparable to much institutions with much bigger outputs.

| University | Deflated <br> Total Cost <br> $(£ 000$ 's $)$ | Total <br> Science <br> Students | Total Non- <br> Science <br> Students | Research <br> Output | Efficiency |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Newman Univer- <br> sity College <br> University of <br> Chichester | $£ 12,404$ | 500 | 2275 | 5.399 | $29.6 \%$ |

Table 3.9 Comparison of Cost, Output, and Efficiency between Newman University College and University of Chichester

Table 3.9 gives a prime example of an two institutions having comparable costs but markedly different outputs. Here the University of Chichester is able to produce slightly more research, as well as $50 \%$ more science student output and approximately $100 \%$ more non-science student output for comparable cost. This is then reflected in the considerable difference in efficiency.

Finally it is very interesting to note that there appears to be a number of institutions where marked changes in efficiency have occurred following a merger or secession between two or
more of these Institutions. A prime example of this is the University of Cumbria, which following a merger between St Martin's College, Cumbria institution of the Arts and the Carlisle and Penrith Campuses of The University of Central Lancashire in 2007-2008 saw a jump of approximately $23.6 \%$ efficiency from $63.0 \%$ to $86.6 \%$. A similar shift can be seen for De Montfort University for 2006-2007, where the cessation of its Bedford Campus (which later joined University of Bedfordshire) was preceded by an approximate $10 \%$ fall in efficiency.

### 3.9 Concluding Remarks

This study extends the literature on stochastic frontier analysis of higher education by developing and testing a new measure of research output based. Using research income has become a growing consensus within the body of literature citing it as the most suitable proxy of research output, due to its capture of both quality and quantity. Refining this measure through use of a derived price index creates a new measure, one with a more intuitive involvement in a production environment and, most importantly, one which returns significant results within the model.

An examination of disaggregated outputs of an institution, specifically science and non-science based student outputs, supports the work of Johnes et al. (2008); Johnes and Johnes (2009) who found significant results in for a similar disaggregation. Johnes et al. (2008) also finds that PhD students are less costly than standard postgraduate taught students, a result contrary to HEFCEs own findings. Their suggestion that HEFCEs results were founded upon evaluation of the gross costs as opposed to the net costs is supported by the findings of this study that greater proportions of PhD students within the postgraduate student body can bring reductions to inefficiency.

As an implication for wider communities these findings should begin to cast doubt on the official position over the cost of PhD students. They should also encourage institutions to consider more freely expansions of PhD programmes, or simply to view current students more positively. Whilst the results of this paper strongly agree with some of those presented in Johnes et al.
(2008) there are some areas which do not align. This study finds, for example, that there is a significant effect on the cost frontier of locating in either London or Wales whereas Johnes et al. (2008) found no such significance. ${ }^{27}$ Additionally whilst Johnes et al. (2008) found medical students to be the most costly of all students this study finds that there are efficiency advantages to be appropriated by offering medicine, veterinary, or similar course.

These differences may well derive from model choice, Johnes et al. (2008) uses a quadratic cost function as opposed to the translog cost function used here. Further, whilst this study uses a dummy variable to alter the conditional mean of the efficiency distribution if a medically related course is offered, Johnes et al. (2008) includes it as part of the frontier which would likely chnage how it is weighted by the model.

The results of this research which focus on levels of part time staff, either the proportion of academic or non-academic staff, confirm what was an intuitive expectation prior to estimation. The expectation being that too many academics or too many non-academic staff would create inefficiency within an institution, as confirmed by the ratio variable which shows the ratio between the two. Here increasing values are associated with increasing inefficiency, and whilst it would appear the opposite (a very low ratio) would be desirable the other part time proportional variables contradict this. Importantly, the variable for overall proportions of part time staff receives a negative coefficient suggesting increasing values decrease inefficiency. This is an important distinction for institutions as the conclusion of these variables can be described thus; using part time staff is cost efficient as long as a balance remains between academic and non academic staff. This is important as many institutions rely on part time staff to cover seasonal volatility in work and the individual variables taken out of context may suggest taking part time staff of any nature will create higher inefficiency.

The levels of efficiency amongst the institutions whilst fairly high on average are falling, in some groupings more than others. This finding broadly agreed with a similar study in Johnes (2014) which also found an approximate one percent per annum fall on efficiency. This study further confirms these results and suggests that particular institutions are weaker than others

[^14]to external pressures, something which governments and high education bodies should keep firmly in mind as the economic situation remains tepid, tuition fees increase, and competition for students escalates. Perhaps there is scope for policymakers to look to strengthen particular segments of the market to avoid any closures, should such an outcome be undesirable.

When considering any of the efficiency results discussed within this study care must be taken. Application of the hybrid environmental variables model ensures that each institution is put on a level playing field with the others, but it still remains important to remember that these efficiency measures are all related to the best practice within the sector. There is no inclusion of what could be achieved within the market, and so it is more accurate to suggest that in fact many of the institutions within the higher education sector are performing at the current level of best practice.

Of course there is some history within Great Britain of institutions in financial difficulty being subsumed by others to create bigger, more successful institutions through merger. Such examples include the University of Manchester and Cardiff University. Within this study there are a few examples (University of Cumbria and De Montfort University) which demonstrate marked changes in efficiency following a merger or cessation suggesting that there is indeed potential for this to occur more broadly throughout the sector. Mergers, particularly of the smaller specialist institutions suffering from lower efficiency with larger more generalist institutions benefiting from higher efficiency, may lead to an overall improvement in efficiency across the sector. The next chapter of this thesis seeks to test this theory by calculating the potential gains to be achieved through merger of different groups of institutions.

## CHAPTER 4. Mergers within the Higher Education Sector

### 4.1 Introduction

Mergers have occurred within many higher education sectors, both domestically and internationally. The UK however, has perhaps the longest and most prevalent history in merging universities with one another. Over the past 3 decades "thirty percent of the 184 higher education institutes have been involved in mergers" (Bevan, 2014), from the early 1990's to late 2000's, creating new educational units which have re-branded and become strong competitors within the market, examples include the University of Creative Arts and the merger of the campus of Northumbria with Newcastle University.

The results of the stochastic frontier analysis (Section 3.8) demonstrated that a number of institutions were performing poorly in terms of efficiency caused by shortfalls in one of the two major components of a university: teaching or research. Under previous regimes that may well have been sustainable, fulfilling a niche demand and being able to continue along a specific, focused path. Now with an increased marketization of the higher education sector in the UK, rising fees and falling funding, it is far less likely that niche institutions will survive. Indeed many have suggested that the new regime of tightened funds will cause some universities to either close, or to merge with other more financially sound partners (The Huffington Post UK, 2013).

The results also draw attention to some examples of universities which have merged, successfully, and begun to profit from the merger in terms of increased efficiency, numbers, and revenues. Given the impact of these mergers, the harsher financial climate that exists within the UK, and the history of mergers within the UK, this empirical chapter seeks to discover
whether there is scope for merging universities throughout the UK to utilise the full possible efficiency gains from increasing scale and synergy. This chapter will proceed with an in-depth examination of merger analysis literature; how mergers are defined, how they are evaluated and the prevailing models for such analysis and evaluation, followed by an exposition of the model developed by Bogetoft and Wang (2005) which is to be the method of choice in this study, and finally analysis and evaluation of the results generated.

### 4.2 Merger Analysis Literature

### 4.2.1 Introduction

Incentives for mergers in the private sector (and in higher education) can be financial, a firm is looking to protect itself from collapse (Ripoll-Soler and de-Miguel-Molina, 2014), expand market share and benefit from economies of scale (Teixeira and Amaral, 2007) or enter a different market. In the case of banks, mergers have been used to prop up failing institutions and prevent bank failure. In light of the recent banking crisis many have asked if banks are too big to fail. Exploration of the mergers within higher education look first to Government restructuring of the higher education system, but Fazackerley and Chant (2009) explore the issue of failing institutions and what the results would be, asking a question similar to that of banks in the recent crisis: Are universities too important to fail? The paper discusses a range of difficulties that may occur in this area, for example, institutions established by Royal Charter (most of the pre-1992 group) would require an Act of Parliament to close, though later institutions are limited companies and therefore closing would be easier. It goes on to discuss a range of mergers that have happened within the UK higher education sector such as, the successful merger of University of Manchester Institute of Science and Technology with the Victoria University of Manchester resulting in the highly successful University of Manchester, and the unsuccessful where Imperial College London took over and subsequently dissolved Wye College.

More traditional (within the higher education sector at least) mergers are those that come
about through Government restructuring of the higher education sector, sometimes with a view to reducing the number of institutions (Norway Kyvik (2002), Canada Curri (2002), and South Africa Botha (2001)), or improving academic competitiveness within institutions Finland Tirronen and Nokkala (2009). Intuitively there is an understanding of what a merger constitutes, however this review begins with a deeper examination of an important question: what is a merger? There are several ways in which the output of two universities can be combined. Harman and Harman (2003) show the full spectrum (page 30), which ranges from informal collaboration to merger with unitary structure, and give detailed explanations of each combination. They further discuss a number of issues which can affect the tone in which the merger type activity is effected, whether it is voluntary or involuntary, single or cross-sector, two or more universities merging, and whether or not they have similar academic profiles.

However these distinctions are academic, and in practice a merger will typically consist of the latter two options of the spectrum (merger with federal structure and merger with unitary structure). It is more specifically defined by Harman and Meek (1988) and Goedegebuure (1992) as a situation where two or more separate business entities come under the control of a single management board, including assets, liabilities and responsibilites. A very similar definition is supplied by Higher Education Funding Council for England in report into collaborations and mergers within the higher education sector (Higher Education Funding Council for England, 2012) (Page 4).

Merger: two or more partners combining to create a single institution, which may retain the name and legal status of one of them or be an entirely new legal entity. In the 'holding company' model, one institution can have subsidiaries that retain separate names, brands and operations, to varying degrees. Federations can be seen as a more flexible version of full merger.

Efficiency measurement applied to merger analysis can be split into two distinct segments, before and after (Bogetoft and Wang, 2005); such separation will be utilised in the discussion which follows.

### 4.2.2 Before Bogetoft and Wang (2005)

Prior to the 2005 paper the majority research into mergers was based around event studies and narrative commentaries of lessons learnt over a particular time period. Many of these would focus on issues such as why the mergers came about, how they worked on an operational level, and whether people were happy with them (Harman and Harman, 2003). The nature of this research meant that it was primarily qualitative.

One such study by Rowley (1997) conducted a survey of 83 questions with 35 institutions believed to have been involved in a merger in a seven year period from 1984. Her study covers issues of process, motive, and feelings toward the merger following the event. Whilst many of the comments suggest that the merger process was fairly successful there were additional costs that were not expected. Such costs would have increased the resources needed to consolidate services. It also highlights that in several cases the merged partner was experiencing financial difficulty which made decision makers certain that the costs required to build a sustainable collaborative partnership would not be viable.

Another study which considers the success or failure of mergers from a strategic, business view is that of Skodvin (1999). Once again however the focus of the work is on qualitative questions such as who initiated the merger and whether they were forced or voluntary in the eyes of the smaller entity. He notes that in Great Britain both voluntary and involuntary mergers had taken place, but were divided into two time periods, the polytechnic reform of the 1960's and 1970's were the involuntary mergers and the voluntary came later in the 1980's - 1990's. He suggests once more that it is perceived gain in terms of economics of scale and scope that typically drives mergers. In terms of post merger analysis, the author focuses on three distinct areas; economic, governance, academic. Many mergers see improvements whether voluntary or not, however he is careful to note that it is of particular benefit in a merger scenario of one of the partners is substantially larger as this avoids any issues where there is not a clear orchestrator of the merger. Fielden and Markham (1997) consider similar lessons to be learned from mergers in higher education but as there is little difference in methodology it will not be
covered in detail.

As Harman and Meek (2002) observe that government led restructuring of the higher education sector has occured in many countries, Canada, UK, Germany, the Netherlands, Norway, Sweden, Hungary, Vietnam, New Zealand, and Australia highlight several examples. They additional proffer a number of drivers for governments to engage in such restructuring such as increasing efficiency and effectiveness, dealing with non-viable institutions, widening access, and increasing government control of the higher education system.

Botha (2001) turns its attention to South Africa, following up on the Size and Shape report given to the Minister of Education. Within the report there was a recommendation to reduce the number institutions through merger rather than closure. Following an evaluation of different definitions of merger and the different structures that can be arrived at (similar to Harman and Harman (2003)) the paper concludes that whilst merging is fraught with risk and opportunities for calamity, it can also generate considerable success if done correctly (though Harman and Meek (2002) suggests these benefits may take at least five years to emerge). The paper then offers a process flow for merging (assumed voluntary) so that the risks might be mitigated as far as possible. It also raises very clearly the issue of the cost of a merger both financially and in terms of staff time which could lead to a reduction in the quality of core service provision.

Curri (2002) focuses on the Canadian higher education sector where increasing pressure was being placed on institutions by politicians and the public over the costs incurred and duplication of effort. The paper looks at the Australia example as discussed in Harman (2000), where HEI were forced to merge following legislation passed in 1988 reducing the number of higher education institutions, five years after the mergers had taken place to see what lessons could be learned and what parallels could be drawn. The paper highlights, once again, that there are additional costs associated with merging that are not always considered pre-merger. In this instance they include the additional costs in terms of travel, disparate location of a centralised service, as well bureaucracy and slower communication. It also becomes apparent from discussions with merging institutions that in many cases there were no distinguishable differences between the pre and post merger institutions; they continued to act as two separate
institutions - this may be more specific to Australia as there is considerable geographic distance between some mergers. Importantly the paper concludes that the data suggests efficiency may actually fall as a result of a merger rather than increase.

Kyvik (2002) considers the Norwegian higher education sector following the implementation of a forced restructure much like Curri (2002). The Norwegian higher education sector had a large number of specialist colleges (98) with 26 state colleges being formed by the end of the process. The aim by the government was to create stronger units with savings across administrative and infrastructure (library and ICT) functions which could be centralised. Following a qualitative study amongst a range of staff within the affected institutions the authors conclude that whilst some of the aims (notably fewer institutions and improved administration and leadership) have been met, many of the aims around increased quality of teaching and research have not been met.

Norgard and Skodvin (2002) also conduct a study on the Norwegian higher education sector, though theirs is focused on one state-college in particular, Telemark College, and how it has performed since the merger. Based on a variety of interviews with those involved in the process, the study find that there were a number of difficulties from an initial culture of resistance to geographical distance. However, despite these difficulties there were definite improvements to budgeting and administration facilitated by improved network infrastructure that was well executed (with financial assistance from the government). The area of most difficulty for Telemark college was social and cultural integration. It seems that the geographical separation of original campuses, which became the faculties, and the subsequent lack of co-location left little opportunity for staff to become familiar with each other and begin to work together.

### 4.2.3 After Bogetoft and Wang (2005)

A disadvantage of prior efforts is that there is little in the way of quantitative, absolute measurement of a merger such that a researcher may compare one with another, or indeed merged with unmerged units. A recent effort which makes particular advance in this regard is Johnes (2014). Within this paper the author takes a 13 year panel data sample including merged and
non-merged institutions. They then estimate a variety of both parametric and non-parametric models (random effects, stochastic frontier analysis, dea) to examine differences between premerger, post-merger, and non-merging institutions. The results demonstrate a significant difference in mean efficiency of those merging and not, with those merging having a higher mean efficiency. Though a strong caveat is given that there is no way to be certain that the increased efficiency comes from the process of merger and not from underlying fundamentals, it does ask an interesting question as to whether this would transfer to other institutions.

Mao et al. (2009) conduct a study of Chinese institutions that is similar in its statistical nature. Their focus lies in the efficiency of mergers in improving what they call knowledge production, but is more commonly called research. To establish how effective mergers were in this regard they conducted a factor analysis that weighted various aspects of research from number of faculty to per capita number of papers, and then used these to calculate a Z-score for those who had merged. This was then plotted to determine whether the merger was leading to increases or not. Their conclusions were that following the merger a short term "honeymoon period" exists where research outcomes are increased and then decline gradually year on year. They go on to say that mergers are painful and as such benefits can sometimes take nearly a decade to come to light.

### 4.2.3.1 The General Efficiency Model

The lack (until very recently) of more statistical methods for analysing mergers and, more specifically, an apparent inability or unwillingness to evaluate potential mergers was seen as an area of considerable weakness. A new method developed by Bogetoft and Wang (2005) served to strengthen that weakness. In the introduction to their paper the authors note that they deviate in their analysis of the merger in three key ways; they estimate gains prior to the merger rather than analysing them post completion, they utilise a multi-input, multi-output production model rather than a simpler cost model, and allow the decomposition of the potential gains into several options which relate to specific strategic objectives.

The authors continue with an exposition of their model, which shall be recreated here with
heavy reference Bogetoft and Wang (2005) (a similar exposition is given in Gourlay et al. (2006) and so this is also referenced). It is worth noting before beginning the exposition of the model that it considers the private benefit to be secured from a merger. It does not determine the societal costs and benefits, nor the private costs. The implications of these limitations and how one might use the results of the model to determine whether a merger would be socially beneficial will be discussed in the conclusion of this chapter.

Commencing with a statement of the production set and the model assumption gives a set of decision making units(DMUs) ${ }^{1}, n$, which produce $q$ outputs from $p$ inputs to give a production possibility set $T$ i.e.

$$
\begin{aligned}
D M U^{i}, i \in I & =[1,2, \ldots, n] \\
\text { Inputs : } x^{i} & =\left[x_{1}^{i}, x_{2}^{i}, \ldots, x_{p}^{i}\right] \in R_{0}^{p} \\
\text { Outputs : } y^{i} & =\left[y_{1}^{i}, y_{2}^{i}, \ldots, y_{q}^{i}\right] \in R_{0}^{q}
\end{aligned}
$$

Production possibility set : $T=\left[(x, y) \in R_{0}^{q+p} \mid \mathrm{x}\right.$ can produce y$]$

A standard set of assumptions are then made which determine the shape of the production set:

- Convexity:

$$
(x, y) \text { and }\left(x^{\prime}, y^{\prime}\right) \in T \rightarrow \mu(x, y)+(1-\mu)\left(x^{\prime}, y^{\prime}\right) \in T, \quad \mu \in[0,1]
$$

- Strong disposability:

$$
(x, y) \in T \rightarrow\left(x^{\prime}, y^{\prime}\right) \in T \quad \text { where } x^{\prime} \geq x, y^{\prime} \leq y
$$

- Returns to scale:

1. Constant returns to scale (CRS)

$$
(x, y) \in T \rightarrow k(x, y) \in T, \quad k \geq 0
$$

[^15]2. Increasing returns to scale (IRS)
$$
(x, y) \in T \rightarrow k(x, y) \in T, \quad k \geq 1
$$
3. Decreasing returns to scale (DRS)
$$
(x, y) \in T \rightarrow k(x, y) \in T, \quad 0 \leq k \leq 1
$$

Bogetoft and Wang (2005) then introduce another assumption which is "less common but very relevant" (page 148), that of super additivity. Super additivity holds that for all $x^{\prime}, x^{\prime \prime} \in R_{0}^{p}$ and $y^{\prime}, y^{\prime \prime} \in R_{0}^{q}$, if:

$$
\left(x^{\prime}, y^{\prime}\right) \in T \text { and }\left(x^{\prime \prime}, y^{\prime \prime}\right) \in T \rightarrow\left(x^{\prime}+x^{\prime \prime}, y^{\prime}+y^{\prime \prime}\right) \in T
$$

The benefit of this assumption is its intuitive nature, if two DMU's with inputs $x^{\prime}, x^{\prime \prime}$ produce outputs $y^{\prime}, y^{\prime \prime}$ then it follows that the very least a combined unit with $x^{\prime}+x^{\prime \prime}$ inputs should be able to produce is $y^{\prime}+y^{\prime \prime}$ outputs as it could act as two independently governed units producing as before. Ideally, however, the combined unit would be able to either produce more output with the same set of inputs $\left(x^{\prime}+x^{\prime \prime}, y^{\prime}+y^{\prime \prime}+y^{\prime \prime \prime}\right), y^{\prime \prime \prime}>0$ or produce the same set of outputs with less input $\left(x^{\prime}+x^{\prime \prime}-x^{\prime \prime \prime}, y^{\prime}+y^{\prime \prime}\right), x^{\prime \prime \prime}>0 .{ }^{2}$

The proportion by which a combined unit is able to achieve either of these objectives is typically cited as its efficiency. Farrell (1957) introduced his own measures which capture this more elegantly;

$$
\begin{align*}
& E^{i}=\operatorname{Min}\left[E \in R_{0}^{+} \mid\left(E x^{i}, y^{i}\right) \in T\right]  \tag{4.1}\\
& F^{i}=\operatorname{Max}\left[F \in R_{0}^{+} \mid\left(x^{i}, F y^{i}\right) \in T\right] \tag{4.2}
\end{align*}
$$

where $E^{i}$ represents the lowest possible proportion of summed original inputs able to achieve the same production of output by the combined unit as the sum of the individuals. $F^{i}$ represents the

[^16]greatest proportion of outputs that can be achieved by the combined unit whilst maintaining the level of inputs used by the individual units.

The difficulty with a practical application of this theoretical measure is knowledge of the production possibility set $T$. Usually the exact nature of the possibility set $T$ is unknown and must be estimated from the data at hand, in Bogetoft and Wang (2005) this estimation is achieved through the application of DEA. A full exposition of DEA is available in Charnes et al. (1978). For this purpose a description and formal statement of the linear programs are sufficient.

To conduct DEA a linear programming approach is applied which produces enveloping frontier around the smallest subset of inputs, $p$, and outputs, $q$, which contain each individual inputoutput mix for all units. This gives an estimate of $T, T^{*}$ which can them be used as a substitute for $T$ in the Farrell (1957) measures to estimate efficiency in either the input or output plane. The formal statement of a constant returns to scale DEA model (Charnes et al., 1978) is as follows,

$$
\begin{align*}
\max \left(\begin{array}{ll}
q_{i}^{\prime} & \mathbf{0}
\end{array}\right)\binom{u}{v} & =q_{i}^{\prime} u \\
\text { subject to, } \quad-\boldsymbol{X}^{\prime} v+\boldsymbol{Q}^{\prime} u & \leq 0 \\
X_{i}^{\prime} v & \leq 1, \\
u, v & \geq 0 \tag{4.3}
\end{align*}
$$

which is equivalent to the following optimisation (Rao et al., 2005; Walter and Cullmann, 2008):

$$
\begin{array}{ll}
\min _{\theta, \lambda} \theta, & \\
\text { subject to, } & -q_{i}+Q \lambda \geq 0, \\
& \theta x_{i}-X \lambda \geq 0, \\
& \lambda \geq 0 . \tag{4.4}
\end{array}
$$

which can be extended to give a variable returns to scale model (Banker et al., 1984) with the addition of an extra constraint,

$$
\left.\begin{array}{rl}
\min _{\theta, \lambda} \theta, \\
\text { subject to }, & -q_{i}+Q \lambda
\end{array}\right)=0, ~ \begin{aligned}
\theta x_{i}-X \lambda & \geq 0, \\
I 1^{\prime} \lambda & =1, \\
\lambda & \geq 0 .
\end{aligned}
$$

The I 1 term is an $I$ x 1 vector of ones which builds into the $I 1^{\prime} \lambda=1$ constraint. It cuts closer to the data than the original CRS model would ensuring that firms are only benchmarked against those of a similar size. Additionally, units will present more closely to the frontier than in the CRS model and as such will reported greater than (or equal) levels of efficiency to that of the CRS model (Rao et al., 2005) (page 172).

With the base model criterion, assumptions, and estimators set the changes that take place during a merger will now be examined. A number, $J$, DMU's are merged ${ }^{3}$ to create the merged unit $D M U^{J}$. This merged unit will, initially, use the total inputs $\sum_{j \in J} x^{j}$ of the original units to create their total outputs $\sum_{j \in J} y^{j}$ representing a situation where they produce as individuals within a larger umbrella type business environment. This newly merged unit can then be plotted against the previously generated frontier $T^{*}$ to easily see where efficiency gains can be made.

If there are potential efficiency gains to be made mergers should end up well within the frontier created by $T^{*}$. This may seem initially confusing though a moment's careful reflection on Figure 4.1 will clarify. Firms $A$ and $B$ are the pre-merger entities along with their efficiency plotted against the frontier $T^{*}, M_{A B}$ shows the efficiency level of the merger. With the merger inside the frontier it could either maintain output production and reduce inputs by moving to

[^17]

Figure 4.1 Potential Gains from a Merger
$E$ or it could expand output to $F$ whilst using no additional resources. This is the situation where there are gains to be made from the merger in both perspectives. If the resulting merger was already on the frontier then there would be little point to it as the improvements could be made to the individual units (Firm $B$ ) and result in the same benefit, without any cost of merging. The gains are calculated via equation 4.6 and 4.7.

$$
\begin{equation*}
E^{J}=\operatorname{Min}\left[E \in R_{0}^{+} \mid\left(E\left(\sum_{j \in J} x^{j}\right), \sum_{j \in J} y^{J}\right) \in T\right] \tag{4.6}
\end{equation*}
$$

where $E^{J}$ is the smallest proportion of combined original resources that the merged unit can use whilst still maintaining pre-merger total output, or an increase in outputs,

$$
\begin{equation*}
F^{J}=M a x\left[F \in R_{0}^{+} \mid\left(\sum_{j \in J} x^{j}, F\left(\sum_{j \in J} y^{J}\right)\right) \in T\right] \tag{4.7}
\end{equation*}
$$

where $F^{J}$ is the largest proportion of combined original outputs the the merged unit can make
whilst utilising only the pre-merger level of inputs.
Of course, the values of $E^{J}$ will determine whether a merger is costly or beneficial. Should $E^{J}<1$, for example 0.45 , then it is a beneficial merger; the inputs could by reduced to $45 \%$ of their original level whilst maintaining output. The obvious alternative is where $E^{J}>1$, say 1.12 , requiring a reduction of inputs to $112 \%$ of their original level, which is of course an increase in resources required and hence a costly merger. In the output space is the converse relationship, should $F^{J}<1$ ( 0.8 for example) then the total outputs of the merged unit can be increased to $80 \%$ of the original value, again a decrease in realised output, whilst a value of $F^{J}>1$, for example 1.4, suggests that the output of the merged unit could be increased to $140 \%$ of the original total, $40 \%$ growth in output, and a beneficial merger.

Though ideally the merged unit will find its production point within the frontier, there is a possibility that unfavourable scale conditions or specificity of inputs or outputs will cause the merged unit to fall outside the frontier (Point D in Figure 4.1). Such an option is infeasible, and so Bogetoft and Wang (2005) make a particular point of addressing it (page 151-153). The main thrust of their address is that the super additivity assumption invoked earlier in the exposition can be used to show that a merger is weakly advantageous and feasible if:

$$
\sum_{j \in J} T \cong T
$$

where the possibility of producing $y^{j}$ outputs with $x^{j}$ inputs, $j \in J$, allows for the possibility of producing $\sum_{j \in J} y^{j}$ outputs with $\sum_{j \in J} x^{j}$ inputs.

### 4.2.3.2 Decomposition of Potential Gains

Gains from merging have typically been summed to give one value, labeled"Efficiency gains", suggesting that they are simple scale efficiencies, a merged unit is bigger so it must do better. However, the actuality is that, these efficiency gains are made up of several different elements; scale efficiencies, though these are not always a guaranteed outcome, efficiencies from improved techniques of doing business learned from one of the merger partners, and changes in the
input/output mix which can be in a more productive range than the separate individuals. Bogetoft and Wang (2005) are quick to highlight that more accurate estimation of merger gains requires this decomposition as should all the gains come from improving technique of business there is actually no real gain from the merger that could not be achieved by simply improving the orginal units. The different efficiency effects are named; technical, improvements in business technique, scale, improvements from increased scale of production, and harmony, from amalgamation of input-output mix leading to a more productive set.

Technical Efficiency Within a set of merging units it is likely that there will be inefficiency (specifically technical inefficiency) which is then captured in the potential benefits of the merger ( $E^{J}$ and $F^{J}$ ). If there were only technical efficiency gains to be made then a merger would be far too costly and time consuming, particularly as alternatives are available such as training, knowledge sharing, and licensing. Ideally any analysis of a merger would be able to identify these effects so that they can be discounted when deciding whether a merger is the appropriate course of action. In order to do this Bogetoft and Wang (2005) propose adjusting each of the merging units by the efficiency factor of the merged unit $E^{J}$, which creates a new spread of points within the production set $T$. After these adjustments to the standing input-output mixes of the merging units the minimisation process is effected once more giving us a new measure $E^{* J}$ which is the reduction (expansion) in inputs (outputs) that could be achieved by the most efficient merged unit following the merger. This reveals the technical efficiency gains that can be made purely through a merger and not any licensing or knowledge sharing.

Formally:

$$
\begin{equation*}
E^{* J}=\operatorname{Min}\left[E \in R_{0} \mid\left(E\left(\sum_{j \in J} E^{j} x^{j}\right), \sum_{j \in J} y^{j}\right) \in T\right] \tag{4.8}
\end{equation*}
$$

where $\left(x^{j}, y^{j}\right)$ have been moved to $\left(E^{j} x^{j}, y^{j}\right)$, and $E^{j}$ is the standard efficiency score for the single $D M U^{j}$. Using the merger reduction score $E^{J}$ and the newly formed adjusted reduction score $E^{* J 4}$ we can define a new variable,

[^18]\[

$$
\begin{equation*}
I^{J}=\frac{E^{J}}{E^{* J}} \tag{4.9}
\end{equation*}
$$

\]

where $I^{J} \in[0,1]$ represents the the potential for improvements in the individual merging units ${ }^{5}$. Having dealt with the gains that can be achieved by making the individual units better the rest of the potential gains can now be considered, and represent the more interesting elements of the merger. These gains are made from improving input/output mix, harmony effects, or improving the scale of production, scale effects, which can be thought of as economies of scale and scope.

Harmony Effects Mergers can also be beneficial in allowing different input/output mixes to be used, allowing for movement along the isoquant (Point A and Point B move to Point D in Figure 4.2), which can give potential savings from production closer to the average of the two individual units than either extreme. ${ }^{6}$ The harmony effect can be seen from two perspectives. Firstly, with a similar consideration as with scale effects and technical effects, an average of the two units will move the output point to $\mathrm{C}^{7}$ showing that with an even mix $A$ and $B$ could produce the same level of output $L(y)$ with only half the inputs. Projecting this to Point $G$ shows the production possibility of the merged unit with the full amount of original input being utilised, resulting in expanded output, $L(F(2 y))$. Here the output of the merged unit is proportionally larger (by factor of $F$ ) than the sum of the two individuals $L(2 y)$. It is also worth noting that the merged unit could produce the same output as the two individuals with a lower proportion of inputs (by a factor of $H$ ), shown at point $E$.

Secondly, and perhaps more easily seen, Figure 4.2 shows that a straight line drawn between A and B will bisect the 45 degree line at point $D$. Point $D$ has an input/output mix of $\left(\frac{1}{2} x^{1}+\frac{1}{2} x^{2}, y^{1}+y^{2}\right)$ represents a direct average of the two, however, readers will note that the previous isoquant is below the level of the straight line AB . The size of this difference represents

[^19]the Harmony Effect, $H$, the potential gains that can be made through average production rather than polarised production.


Figure 4.2 Harmony Effects

Once again to capture the pure benefits of the merger the minimum value of $H$ that could be achieved by any of the merging units is taken, noting that averages are used because of the assumption of similarity between the merging units. Formally, the harmony effects of the merger are found as follows:

$$
\begin{equation*}
H^{J}=\operatorname{Min}\left[H \in R_{0} \mid\left(H\left(|J|^{-1} \sum_{j \in J} E^{j} x^{j}\right),|J|^{-1} \sum_{j \in J} y^{j}\right) \in T\right] \tag{4.10}
\end{equation*}
$$

Here $|J|$ represents the number of elements in J. Following the same reasoning as on Page 103, a value of $H<1$ is beneficial and gains will be made through the merger, whilst $H>1$ will
indicate a poor merger were losses will be made.

Scale Effects The merger of two individual units will allow for production at a larger scale than before. The effects of this, and hence the benefits or disadvantages, cannot be given as an absolute answer, the researcher will require more information about the type of returns to scale that are found within the industry. Here two polar cases are illustrated. Figure 4.3a shows positive scale effects (increasing returns to scale), such examples may be a public utility merging regional sub-units, and Figure 4.3b shows negative scale effects (decreasing returns to scale), such examples would be a typical manufacturing firm.

In both cases we have original units A and B with input/output mixes as follows; $A=\left(x^{1}, y^{1}\right)$ and $B=\left(x^{2}, y^{2}\right)$. As demonstrated by their position on the output frontier they are efficient units, however following the merger of these units, and an invocation of the Additivity assumption, the resultant combination typically does not appear on the frontier. In the case of increasing returns to scale it will appear below and conversely so with decreasing returns to scale, there is then the opportunity to alter the level of inputs or outputs to move the merged unit onto the frontier. In Figure 4.3a this is clearly beneficial, either a lower amount of input is utilised or higher amount of output produced, whereas in Figure 4.3b an increase in inputs would be required to maintain the level of output, or lower level of output is produced.

With these differences in mind the potential gains from production at full scale, as opposed to the average scale considered by the harmony effect, can be directly examined and formulated. Here again the units for estimation are those that have been modified by the technical efficiency of the merged unit, harmony effects are then applied and finally scale effects are the last component of the the merger gains. The Scale effect will be the minimum scale factor displayed by any of the individual units, i.e.

$$
\begin{equation*}
S^{J}=\operatorname{Min}\left[H \in R_{0} \mid\left(S\left(H^{J} \sum_{j \in J} E^{j} x^{j}\right), \sum_{j \in J} y^{j}\right) \in T\right] \tag{4.11}
\end{equation*}
$$

Again the scale efficiency factor indicates potential gains from a merger if $S<1$ and losses


Figure 4.3 Differing Returns to Scale
from a merger should $S>1$.

Putting the Components Together It was initially determined that the gains from merger (represented by a reduction in inputs whilst producing the same output) can be represented by $E^{J}$ which was subsequently found to contain possible gains from improvements to the individual units (without the need for merger), $I^{J}$, and the additional gains that would be captured via a merger $E^{* J}$. When decomposing $E^{* J}$ two elements were considered, harmony effects, $H^{J}$, and scale effects, $S^{J}$, which form a multiplicative decomposition of the merger gains. Hence, algebraically:

$$
\begin{align*}
& E^{J}=I^{J} \mathrm{x} E^{* J}  \tag{4.12}\\
& E^{* J}=H^{J} \mathrm{x} S^{J} \tag{4.13}
\end{align*}
$$

and, substitution of $E^{* J}$ gives:

$$
\begin{equation*}
E^{J}=I^{J} \times H^{J} \times S^{J} \tag{4.14}
\end{equation*}
$$

This useful equation allows for a detailed examination of the effects of a merger to better understand whether they are beneficial or not, which is particularly useful for authorities and regulators who have used, and continue to use, mergers as a way of protecting industries and improving efficiency. Further, as Bogetoft and Wang (2005) discuss (pg 158), there are a number of different approaches that can be adopted to capture similar gains; the obvious example being the technical component, $I^{J}$. If the majority of the gains from the merger are found in the technical component, a more socially optimal approach could be to simply engage in knowledge transfer or licensing so that the individual units can improve. This avoids the cost of a merger which can be significant and allows the firms to continue competing and benefiting the public. Alternatively, in the extreme case, all the benefits of merger come from either the harmony or scale effects of the merger. Should this be the case then a merger may, again, be suboptimal.

In the case that all gains are available from the harmony effects then a re-shuffle of inputs and outputs between firms via licensing agreements could prove more cost effective; service teaching such as visiting lecturers are a prime example of this type of licensing agreement already working in practice. It is likely however that this sort of service teaching occurs only where there are small numbers of students engaging in the licensed course (as an optional module on a course), were the course to be offered as a programme then it would seem more likely that the teaching would be done primarily in-house. Similarly, unless the scale effects are caused by an operating environment that prohibits expansion, then expansion by the individual firms may prove more socially beneficial, maintaining two working firms instead of one.

### 4.2.3.3 Bogetoft and Wang (2005): Applications and Extension

Bogetoft and Wang (2005) go on to apply their newly devised measure in the same paper by looking at Danish Agricultural Advisory Services during 1994 and 1995. They investigate a number of potential mergers of regional offices and break down where the gains (or losses) would come from in these mergers as well as providing some clear insights that will translate across a number of industries. Overall the levels of technical efficiency amongst the different branches are between $80 \%$ and $90 \%$, which is contrary to the initial expectations of the authors who expected higher levels of efficiency in the individual units due to the similarities in technology and the culture of collaboration and sharing found within the entire group.

The scale efficiencies were, in all but one case, above 1 suggesting that the merged units would move into the decreasing returns to scale portion of the output curve. It is noteworthy that the size of these inefficiencies was as high as $17.9 \%$ in some situations, and so, though small levels of scale inefficiency are typical and expected following a merger, here the magnitude should strongly discourage such mergers from taking place. Counteracting this negative perspective on the scale effects is the lack of large units that were in the original sample. Without these, the authors note, there cannot be wholly precise estimates of larger unit normal outputs and hence harsher estimates of scale effects are likely. The harmony efficiencies are however moderate across the sample with up to $21 \%$ gains possible, which was more in line with the authors
expectations. A more average output set would enable the merged units to better react to sudden changes in demand based on fluctuations in weather and market conditions affecting the farmers.

The favourable light in which a number of the mergers are portrayed is counter-balanced by a trait of DEA which gives an "inner approximation of the underlying production possibility set" (page 150) the result being that the reported estimates are "therefore optimistic and the potential input savings and output expansions are underestimated" (page 150). The optimism originates in the slight difference between the true production possibility set (a curve) and the DEA approximation (a joining of points). The DEA frontier will lie inside the true frontier therefore the reported efficiency will be slightly better (higher efficiency) than those that would be presented by the actual frontier. In terms of the actual figures this is an important point for the researcher to note when applying the model and reporting their results, though relatively, in terms of the overall message and comparisons between data, it is less of an issue. The effect applies across the decomposed effects, and their estimates, and hence the relationship between the different mergers will remain the same with more attractive mergers continuing as such, even though the potential input savings or output expansions by the merger are "in general downward biased" (page 150).

Regionalised public services and utilities are common subjects of efficiency analysis as well as merger examination because their non-private nature makes them prone to x -inefficiency. Walter and Cullmann (2008) apply this type of thought to German public transport provision which is introduced as a fragmented offering with 60 associations representing 800 individual companies. As in Bogetoft and Wang (2005) the main prerequisite for merger candidates are geographical proximity; it is unlikely that any merger gains will be forthcoming from mergers of Public Transport systems in disparate provinces of a country as large as Germany. They would, for all practical purposes, remain two non-merged entities. This paper develops the Bogetoft and Wang (2005) model as normal and gives formal criterion for their mergers; that there be more than one operator for a network before and only one after the merger, and that the merger makes geographical sense. Once these criterion are taken into account 14 possible
mergers result, and are then analysed. As one would expect in many of the mergers significant gains (up to $12 \%$ ) can be made, however, more interestingly there are some mergers where there will be losses. Closer inspection of these results reveal that the synergistic benefits that are typically accrued by mergers are not present, due to the significant differences of the pre-merger units. ${ }^{8}$

This brings to the fore the importance of having some similarities in the production of the merging units. Without such production similarities there is little chance that there would be any benefit to the merger; scale gains would be unlikely as all that would grow is the parent companies employee count, harmony gains would be unlikely as the products would be too different to produce at an "'average" level and still satisfy demand, and technical gains would be difficult to find as processes would be so different that no transferrable technologies could be found.

The regionalised, provincial nature of German public system and public service provision allows for merger investigation in a number of different areas, much like Walter and Cullmann (2008) with public transport provision, Zschille and Walter (2012) focuses his study on water utilities. He uses a cross section for 2006 which, after standard adjustments for erroneous and omitted data, leaves observations for 264 companies. The author finds scope for large efficiency increases with low estimates for the pre-exisiting efficiency, however, the findings differ from those of Walter and Cullmann (2008) and Bogetoft and Wang (2005) in that the majority of these increases are from improvements to the efficiency of the original units. Further, many of the mergers would exhibit low harmony gains (mean of $4.1 \%$ ) and in some cases even losses, suggesting that it is highly likely any merger gains would be significantly outweighed by the costs involved.

Kristensen et al. (2010) focus their study on hospitals in Denmark, which present very similar characteristics and conditions to those of the studies in Germany, the only difference being the motivation. The motivation of this study follows directly from a regulatory decision to reform

[^20]the health care sector and reduce the number of hospitals from 42 to 20 over a 10 year period. This decision sped up the process for a number of hospitals and the study focuses on those left, particularly those which are due to close or have specialised departments; mergers in these cases can just be those where specialist sections are moved from one hospital to another, or are full mergers. Here again the authors results suggest that there are significant gains to be made through merger of the hospitals, citing 5 specific examples. It would appear that the hospitals pre-merger were at an effective scale as the mergers suggest potential scale losses from the merger with a mean of $4.5 \%$. Harmony effects are present within most of the mergers and contribute up to $3.5 \%$ improvement from the individual units, but the most substantial gains come from improving the technical efficiency of the individuals which could result in up to a $32 \%$ boost to the hospital performance without the need for the merger. Like Zschille and Walter (2012) it is arguable that in these cases many of the mergers should be approached carefully so as to not waste some potential benefits through overscaling (as the goal is still to reduce overall hospital numbers), though ideally a knowledge share system would be more appropriate.

The final application to be looked at within this analysis of the literature is a study of bank mergers in India by Gourlay et al. (2006). Their application, extending previous literature to look at several years after merger and the time effects it has created, is much like the other papers considered herein. However, the authors devote a much larger portion of their analysis to formal testing of the results and whether there are differences between returns to scale, whether there are indeed technical efficiency gains, and finally present a measure to allow for graphical presentation of the two criterion for a "successful merger".

Initially the scale inefficiency of the sample is tested using a Kolmogorov-Smirnov test which is used to determine whether there are significant difference between the variable returns to scale and constant returns to scale assumptions of DEA. The null hypothesis is no significant difference, whilst the alternative determines that scale inefficiences are found within the sample. The Kolmogorov-Smirnov test is conducted as follows:

$$
\begin{equation*}
D=\max \left|F^{G_{1}}\left(\ln \hat{\theta}_{j}\right)-F^{G_{2}}\left(\ln \hat{\theta_{j}}\right)\right| \tag{4.15}
\end{equation*}
$$

This statistic is used to differentiate between two cumulative distributions, here the distributions are of efficiency scores under two different models of banking. It does this by calculating the greatest vertical distance (so as to compare like with like) between the two distributions. Inference is then conducted based on the value of D , which is inversely related to p values; a high D is accompanied by a low p , and hence indicates that the distributions are significantly different to one another. Gourlay et al. (2006) note that this could be carried out using just the efficiency scores and would return similar results. ${ }^{9}$

Following determination of the correct distribution the focus changes to the evolution of the merger over time. The authors note that whilst initial gains by a merger are a usual result, these gains may not be sustained or may be improved upon, which makes it important to determine accurately and precisely which situation holds true. In order to do this a Mann-Whitney test is conducted with hypotheses as follows (page 16):

- $H_{0}$ : No significant difference in TE Change between merged banks and control group
- $H_{1}$ : The TE Change of the merged banks significant differs from that of the control group
- $H_{2}$ : The TE Change of merged banks exceeds that of control group

The first year following the merger is designated the base year for comparison against a control group of non-merging units and, to give a value for TE Change, the authors then find the difference between the merged bank and the average technical efficiency of this control group. This is an important additional test as if firms which don't merge make superior gains to the merged firms in future time periods then it would not be worth wasting resources merging. It is noted additionally that the speed of the adjustment process following the merger would necessitate the use of VRS DEA rather than the more typical CRS.

[^21]This metric builds into a formal method for determining the success or failure of a merger and provides a very useful tool for future research and for the readership. The metric is a simple graphical analysis (Page 15) of the results of the Bogetoft and Wang (2005) model and the evaluations against the control group as conducted with previous test. These results are mapped onto an $(x, y)$ space graph which is then broken down into four quadrants as shown in Figure 4.4.


Figure 4.4 Success of a Merger

The positive - positive quadrant is deemed a complete success, the merger has captured the potential gains estimated by application of Bogetoft and Wang (2005) and displays efficiency gains over non-merging counterparts, and these results hold throughout the period of assessment. The positive-negative and negative-positive quadrants are deemed partial successes as the merger either captures the potential gains or exceed the efficiency of their non-merging peer units. Finally the negative-negative quadrant is deemed wholly unsuccessful, failing to capture any potential gains or to exceed efficiency of other units. In utilising this metric on their own results the authors find their results congregate in either the positive-positive or positive-negative quadrants with a few results in other areas. This suggests that on the whole the mergers studied were successful and beneficial to the firms.

The analysis over time does give a particularly interesting insight. In two polar cases the
results show; one merger which initially is in the negative-negative quadrant indicating a fully unsuccessful merger but evolves into the positive-negative/positive-positive quadrants, and in a second case a merger which begins in the positive-positive quadrant before eventually ending in the negative-positive quadrant. The first case indicates that the merger gains simply took times to be realised, perhaps because of initial difficulties bringing two units together, whilst the second case showed immediate improvements which tapered off as time continued suggesting perhaps that the culture of the business fell back to old habits after an initial boost from additional capacity. These are both interesting cases, indicating clearly that merger gains are not necessarily instant or permanent, which remains an important facet of the investigation of actual mergers.

### 4.2.3.4 Issues and Complications

As with any methodology there are some tendencies or weakness of construction that create bias or make it vulnerable to particular situations. DEA is no exception to this though, fortunately, the scope and scale of research using DEA has necessitated and facilitated solutions for most of the problems that confront the researcher.

An observation made by both authors investigating German public utilities (Walter and Cullmann, 2008; Zschille and Walter, 2012) is that, given the DEA process at the heart of the methodology, a significant downward bias will be caused on the estimators, the process will be sensitive to outliers, and, in addition, the environment may affect the production process which is not accurately reflected in the estimation of the DEA Frontier.

Bias Correction and Bootstrapped Estimators To combat bias both authors propose using the bootstrapping process developed by Simar and Wilson (1998) which follows from work conducted by Efron $(1979,1982)$ and utilises a simulation of the Data Generating Process (DGP) to approximate the asymptotic sampling distribution of the envelopment estimators in question. The model builds as follows:

- The original data $X_{n}$ is caused by a DGP, $P\left(X_{n}\right)$, with true efficiency $\theta$.
- Knowledge of the production possibility set, $\psi$, and the probability density function, $f(x, y)$, allows full characterisation of this DGP.
- $\hat{P}\left(X_{n}\right)$ is assumed to be a consistent estimator of the DGP.
- The envelopment estimator is estimated as $\hat{\theta}(x, y)$.
- The true values of $P, \psi$, and $\theta(x, y)$ are unknown.

Of course, given that real world data is to be used, the researcher cannot know the true values and so must estimate them. This is achieved through the bootstrapping process which takes a sample from $P\left(X_{n}\right)$ to give $\hat{P}\left(X_{n}\right)$ with an efficiency 'true' efficiency $\hat{\theta}(x, y)$, and computes an estimate $\hat{\theta}^{*}(x, y) . \hat{\theta}^{*}(x, y)$ is an estimate of $\hat{\theta}(x, y)$. The sample is then replaced and the whole process repeated. Following a large number of repetitions an estimator the sampling distribution of $\left[\hat{\theta}^{*}(x, y)-\hat{\theta}(x, y) \mid \hat{P}\left(X_{n}\right)\right]$ is approximately distributed as $\left[\hat{\theta}(x, y)-\theta(x, y) \mid P\left(X_{n}\right)\right]$. Naive bootstrapping utilised the median of each bootstrapped estimate, which when combined with all the median from the other bootstraps would generate a sampling distribution which could be used as described earlier. However, there are issues of bias in using this method which must be addressed for more accurate application. The authors of Walter and Cullmann (2008) use a method found in Simar and Wilson (1998) and known as smoothed homogenous bootstrap to effect their correction. This method used a smoothed kernal density for estimation of the sampling distribution, and corrects for bias as demonstrated in equations 4.16 and 4.17. The bias formed in the construction of DEA estimators is the difference between the expected value of the estimator and the true value: $B I A S(\hat{\theta}(x, y))=E(\hat{\theta}(x, y))-\theta(x, y)$. This relationship is the same as for the bootstrap estimate of the bias:

$$
\begin{equation*}
B \hat{I A} S_{B}(\hat{\theta}(x, y))=B^{-1} \sum_{b=1}^{B}\left(\hat{\theta}_{b}^{*}\right)(x, y)-\hat{\theta}(x, y) \tag{4.16}
\end{equation*}
$$

It then follows that the bias corrected estimator of $\theta(x, y)$ is found by solving,

$$
\begin{align*}
\tilde{\theta}(x, y) & =\hat{\theta}(x, y)-B I A S(\hat{\theta}(x, y)) \\
& =2[\hat{\theta}(x, y)]-B^{-1} \sum_{b=1}^{B}\left(\hat{\theta}_{b}^{*}\right)(x, y) \tag{4.17}
\end{align*}
$$

which gives the distribution to be used for the estimation.

Influential Observations Zschille and Walter (2012) dedicates a lot of time to discussing the detection of influential observations. The sensitivity of DEA to these extremes requires "validation of the data" (page 10) to maintain accuracy and robustness. Typically this is done via the super-efficiency method. Rao et al. (2005) and Thanassoulis et al. (2008) describe the concept of super-efficiency in their respective books, crediting the seminal work to Andersen and Petersen (1993), as the simplest and most practical way to detect and remove outliers.

To determine super-efficiency of a particular DMU the researcher must simply recalculate the linear program omitting the DMU in question, this removes its influence on the frontier and hence alters the resulting placement of the frontier. This is easily seen in Figure 4.5 , where the solid lines show before and dashed line shows after removing a super-efficient DMU from the estimations.

In terms of the notation used in Figure 4.5 the efficient frontier is initially calculated including all points which results in Points $\mathrm{A}, \mathrm{B}$, and C placing on the efficient frontier. Point B is then omitted from the calculations altering the placement of the frontier, which can allow point B to operate above the efficient frontier. The efficiency of Point B is then found as usual by dividing the radial distance from the Origin to Point $\mathrm{B}^{\prime}$ by the radial distance from the Origin to Point B on the new frontier $\left(\frac{O B^{\prime}}{O B}\right)$, and will result in a value greater than 1 . This process is repeated sequentially to get a super-efficiency score for all DMU's; it is typical for several to have super-efficient scores (greater than 1) if they originally formed part of the frontier.

The results of the super-efficiency analysis will indicate the most appropriate manner to proceed. If the scores are not far above 1 or there are insufficient observations to permit removal from the sample, the researcher may decide to keep them in the sample. Alternatively, if it


Figure 4.5 Graphical Representation of Super Efficiency
is decided that they should be removed, then one of two methodologies are typically utilised to guide the removal process. One is to set a threshold level of efficiency, above which values will be discarded as outliers; though some authors have expressed caution in following this rule rigidly. The second is to decide upon a maximum proportion of DMU's to be removed, which maintains integrity of the study Thanassoulis (1999). An atypical alternative is to use one of several averaging measures proposed in Wilson (1995).

To make this process a little more visually appealing Zschille and Walter (2012) uses graphical analysis to detect extreme outliers and remove them from the sample, and it does have an impact. After detection of outliers (between 4 and 11 depending on model), there is up to a seven percentage point shift in minimum efficiency. The super-efficiency approach can be extended to factor in operating environment by only allowing peers within a chosen bandwidth around $z_{i}$, where $z_{i}$ is the matrix of environmental variables of the $D M U$ in question, to be considered in determining super-efficiency. By considering only those in a local bandwidth (with similar characteristics) the researcher avoids finding a firm to be super-efficient because
its production mix is markedly different to those against which it is compared.

Accounting for the Operating Environment In his study of German water providers Zschille and Walter (2012) notes that the characteristic differences of the area in which the company operates can have a significant impact on its effectiveness; an obvious example is rural vs urban providers. Conceptually speaking it is a realistic argument though it does complicate somewhat the calculations that are required to estimate the efficiency of each DMU.

Perhaps the most important reason to make some accommodations for operating environment ${ }^{10}$ in any efficiency estimation is for acceptance by firms and regulatory bodies. Failure to take account of these factors can lead to rejection of the real world applicability of results which will defeat the purpose of many such studies. Given the consequences of failing to deal with operating environment for efficiency studies it is little surprise that several methods, and iterations upon those methods, have been created to condition efficiency estimates upon the operating environment that firms face.

Rao et al. (2005) describe four methods for including environmental variables within a DEA estimation of efficiency, crediting authors of the seminal works for particular methods and giving a number of examples. This examination will be restricted to a description of the methods used, and particular authors, but refer those interested in more examples to Chapter 7.4 of Rao et al. (2005).

Ordering Method This approach, as suggested by Banker and Morey (1986), relies on being able to order the effects of the environmental variable on the DMU's i.e. $D M U_{i}$ is affected more negatively by the environmental variable than $D M U_{j}$, which is more negatively affected than $D M U_{k}$. If this is possible then the researcher simply restricts any comparison between the subject $\mathrm{DMU}, D M U_{i}$, to those DMUs that are affected more negatively, thus ensuring that there are no units with a more favourable environment being compared with the subject. A typical example of this may be sales in rural, suburb, and urban areas, where the effects can

[^22]be easily ranked because location is known and the relationship between sales and levels of urbanisation can be easily determined as positive or negative.

Three Stage Method Unfortunately there is not always an obvious ranking system that can be applied, and different styles of ownership are common here; private, board, shareholder, charity, etc. To overcome this issue Charnes et al. (1981) suggest that some subdivision of the sample is used, forming subsets which contain only those DMUs affected by the environmental variable in question, i.e. all those which are owned by shareholders. With the subsets formed, the DEA linear program is solved for each subset in turn, the observed data points are then moved to the respective frontiers and these new points are used to resolve a single DEA frontier. The researcher can then compare the two subsets using a Banker (1996) parametric test to determine if there are any differences, looking particularly at mean efficiency.

Inclusion in Linear Program Method A more direct manner in which to consider these environmental variables is to include them within the linear Program that forms the basis of DEA, good examples can be found in Bessent and Bessent (1980) and Ferrier and Lovell (1990). The particulars of doing this are fairly straight forward, a separate term for the environmental variable is added allowing the efficiency term $\theta$ to only be affected by those variables under the control of the firm. The enabling decision to be made before this method can be implemented is whether the environmental variable has a positive, negative, or neutral effect on the firms in question. With that decision made an inequality is added which relates the vector of environmental variables affecting $D M U_{i}, z_{i}$, to the full sample of firms, shown in equation 4.18.

$$
\begin{align*}
& \min _{\theta, \lambda} \theta, \\
& \text { subject to , } \quad-q_{i}+Q \lambda \geq 0, \\
& \theta x_{i}-X \lambda \geq 0, \\
& z_{i}-Z \lambda \geq 0, \\
& I 1^{\prime} \lambda=1, \\
& \lambda \geq 0 . \tag{4.18}
\end{align*}
$$

The additional constraint $z_{i}-Z \lambda \geq 0$ ensures that only those DMUs that are no better than $D M U_{i}$ are used as comparators. This inequality changes to $-z_{i}+Z \lambda \geq 0$ if the environmental variable is deemed to have a negative effect as in equation 4.19,

$$
\begin{align*}
& \min _{\theta, \lambda} \theta, \\
& \text { subject to , } \quad-q_{i}+Q \lambda \geq 0, \\
& \theta x_{i}-X \lambda \geq 0, \\
& -z_{i}+Z \lambda \geq 0, \\
& I 1^{\prime} \lambda=1, \\
& \lambda \geq 0 . \tag{4.19}
\end{align*}
$$

and finally $-z_{i}+Z \lambda=0$ if it is thought to have a neutral, or unknown, effect as in equation 4.20 .

$$
\begin{align*}
& \min _{\theta, \lambda} \theta, \\
& \text { subject to , } \quad-q_{i}+Q \lambda \geq 0, \\
& \theta x_{i}-X \lambda \geq 0, \\
& -z_{i}+Z \lambda=0, \\
& I 1^{\prime} \lambda=1, \\
& \lambda \geq 0 . \tag{4.20}
\end{align*}
$$

The exact equality used here is much stronger than the weaker equalities used elsewhere and restricts comparison to those which have an identical operating environment thus restricting any bias; however, the number of comparators is then markedly reduced which is not ideal for such empirical work as it may lead to larger efficiency estimates than in the alternative scenarios.

Regression Method This two stage method involves estimating the DEA model normally and extracting the efficiency scores generated. These efficiency scores are then regressed on the environmental variables within the model. Signs on the coefficients of the regression will indicate positive and negative effects, whilst the strength of the effects can, of course, be determined by significance testing. This model is supported by McDonald (2009) who remarks that the efficiency score generated during DEA is simple a "fractional or proportional" (pg 792) measure and as such Ordinary Least Squares estimation of the efficiency score as an independent variable with environmental variables as dependent variables is in fact a more appropriate way to test for the effects of operating environment that more complex two stage estimators suggested by other authors such as Daraio and Simar (2007). A strongly written counter argument was presented in Simar and Wilson (2011) states that for a number of reasons including the correct assignment of random or stochastic error in the second stage and the restrictive assumptions required for an OLS regression at the second stage, that treating the efficiency measures as fractional and seeking second stage relationships on that premise
is inappropriate and will not allow for inference to be conducted on the results. Adjusting the previously reported scores for these environmental variables is typically done by using the estimated coefficients to alter the reported efficiency scores and move them towards a common environment.

Daraio and Simar The methods suggested so far suffer from several key issues; the need for prior decision about the direction of the variables influence, inability to deal with more than one variable (in some cases), and a greatly reduced comparison set. These issues prompted authors to continue in their search for alternative methods to cope with environmental variables in their studies and utilise all of the information provided.

Daraio and Simar were two authors who published several significant papers on this topic. They suggest that even more important than issues of reduced comparison sets and prior decisions about the direction of variable effects, is that in normal circumstances the multistage approaches discussed in Rao et al. (2005) rely on the "separability condition between the input and output space used in DEA and the space of environmental variables z" (Zschille and Walter, 2012) (page 8), which contradicts the reality of typical markets; therefore circumvention is required (Daraio and Simar, 2005, 2007).

The main goal within their proposed measure is to generate a scenario where only peers which face similar operating environments will be considered in the efficiency analysis. Zschille and Walter (2012) is able to create that by following the approach of Daraio and Simar (2005). In order to create this scenario the environmental variable vectors for each unit are differenced and placed within chosen distribution, if it falls within the given thresholds it is included. This gives a new group for estimating conditional efficency, which is then compared with the original efficiency to create a density plot through which a trend line can be drawn. To perform this process the following steps are taken by Zschille and Walter (2012):

1. A matrix of structural variables is formed for the DMU under consideration, $z_{i}$, and all other DMU's, $z_{k}, k=(1, \ldots, K)$;
2. The z variables are smoothed via the estimation of a Kernel Function $K($.$) where K(u)=$
$0,|u|>1, u=\frac{\left|z_{i}-z_{k}\right|}{h}$. An Epanechnikov kernel is chosen as the distribution function $K$;
3. The bandwidth, $h$, is chosen using the k -NN method ( k Nearest Neighbour) approach to the Likelihood Cross-Validation Method;
4. Those neighbours chosen are used to estimate a new efficiency score for $D M U_{i}, \theta_{D E A^{i}}(x, y \mid z)$ i.e. those for which $|u|>1$ have a $K(u)$ value of 0 and hence are not included;
5. This is done for each DMU in turn;
6. A ratio of the esimates of both the conditional and unconditional DEA efficiency scores are then created and regressed against a particular environmental variable to give a scatter plot. ${ }^{11}$

It is important to take note of stages 2-4 as this is where the researcher can impact the results of their analysis the most. In stage 2 the structural variables matrix of the DMU in question and another DMU are differenced which will give a value. The question is then, should this DMU be included in the set for defining the new frontier? One option may be to create a histogrammatic representation of all the values generated by this process and then determine threshold values that would give the most appropriate neighbours, however, this could lead to step changes in inclusion which are not ideal. This is where the kernel function is used.

A kernel function generates a symmetric distribution around 0 and depending on the researchers choice can take a variety of shapes. The shape chosen here, the Epanechnikov kernel, gives a symmetric dome shaped distribution and importantly takes a value of 0 should $|u|>1$ this gives a definitive, repeating, objective method for a researcher to reject the inclusion of a particular DMU in generating a new frontier.

The bandwidth selection in stage 3 is arguably the most important part of any kernel estimation function as it can drastically change how many other DMU's are included in the estimation of the new frontier by making changes to the value of $u$ much slower with regard to changes in $z_{k}$. It is important for the researcher to choose bandwidth specifically and carefully as different values can have significant effects on the smoothness of the resulting distribution.

[^23]Stage 4 is where the neighbours chosen are utilised in an estimation of the new frontier. Much like the super-efficiency method, this then gives a comparator to be used with the original scores. A regression of the ratio between this conditional measure and the unconditional measure against the level of the environmental variable gives a scatter plot through which trend lines can be drawn indicating the particular relationship that the environmental variable has with efficiency. Zschille and Walter (2012) determines that, at least in the case of his study, an increasing trend indicates an unfavourable relationship between the variable and efficiency.

With this different inclusion criterion it is necessary at this stage to specify the particulars of the conditional DEA model that will be used to estimate the new frontier:

$$
\psi_{\overline{D E A}}^{\hat{z}}=\left[(x, y) \in R_{+}^{p+q}\right.
$$

given that

$$
\begin{aligned}
& y \leq \sum_{k \mid z_{i}-h \leq z_{k} \leq z_{i}+h} \lambda^{k} y^{k}, \\
& x \geq \sum_{k \mid z_{i}-h \leq z_{k} \leq z_{i}+h} \lambda^{k} x^{k}, \\
& \left.1 \leq \sum_{k \mid z_{i}-h \leq z_{k} \leq z_{i}+h} \lambda, \quad \lambda \in R_{+}^{K}\right]
\end{aligned}
$$

Note that in this model, taken from Zschille and Walter (2012), the final conditions $\lambda \geq 1$ makes this a non-decreasing returns to scale model; returning to a variable returns to scale model would require simply altering this condition to be $\lambda=1$.

Bandwidth selection and kernel function estimation are complex undertakings, particularly in the context of estimating efficiency. Due to this complexity, and their tangential nature to the focus of this study, they will not be examined in further detail. Interested readers are however pointed to Daraio and Simar (2005) and Daraio and Simar (2007), which serve as excellent texts on the particulars of both.

### 4.2.4 Conclusion

What began as a qualitative, inexact field of research has evolved into a highly technical, empirically focused manner, lending itself to continued application across areas, disciplines, and the world. The model of potential merger gains with decomposition into component elements, as proposed by Bogetoft and Wang (2005), was a turning point in the study of mergers that has been implemented successfully by several authors. However these authors have also noted a number of issues, some technical, some not. The technical issues have been described and methods to overcome provided, however there are more abstract questions that follow in application to real world events i.e. why do some mergers fail to capture the gains that analysis suggests are there? Obviously the potential gains captured in these models are developed absent any consideration for the cost of implementing such a merger; the human elements that must come together and feel appreciated before they will perform at optimum levels, the financial cost of the legal support, and all associated costs with moving people together, IT infrastructure, re-branding, the list goes on. This brings into sharp focus the different parts of merger analysis, before and after. Many applications of the Bogetoft and Wang (2005) approach consider just the before, the potential in a sector that may only be considering mergers, providing a valuable insight into what could be achieved. Other implementations such as Gourlay et al. (2006) are able to examine the benefits of the merger and their evolution over time which provides a much clearer picture of how mergers may work in a real world context.

### 4.3 Methodology

### 4.3.1 Introduction

In the discussion of related literature in this field it became clear that application of Bogetoft and Wang (2005) can vary in complexity from a straight forward application, to a more complex enterprise involving bias correction, modification for operating environment, and removal of extreme, influential values. It will be the aim of this section to reframe these issues in the context of the higher education sector and the potential for merger gains that may exist there,
whilst remaining mindful that this application will represent an initial exploration into the viability and applicability of merger analysis in the sector. As such, complex kernel density estimations will be avoided.

### 4.3.2 Main Model

As a central tenet of contemporary merger analysis this study will utilise the Bogetoft and Wang (2005) model. However, this initially requires an estimation of the efficiency of merging units which lends itself to either stochastic frontier analysis (SFA) or data envelopment analysis (DEA). Whilst Chapter 3 argued in favour of SFA, so as to represent a contribution to literature, here the estimation of efficiency is itself a simple stepping stone to decomposing the potential merger gains.

The approach taken by Kristensen et al. (2010) will be the one mirrored here as they utilise an estimated cost function along with DEA to form their efficiency measures. Section 3.8 demonstrates that some environmental variables have an effect on the efficiency of a HEI and these lessons can be applied to merger analysis. As to the choice of DEA, the authors cite advantages of easier use and absence of required assumptions for justification and the same reasons are viable here. A brief exposition of the DEA model is given in equation 4.4 and equation 4.5 (pages 100 and 101).

Characterizing the production process within a university is conceptually simple; creation of knowledge (through research) and transfer of knowledge (through teaching). As well described in Johnes et al. (2008) universities are considered to also some form of community output which includes "storage and preservation of knowledge and skills; the provision of advice and other services to business; and the provision of a source of independent comment on public issues". The paper does not go on to account for the third mission in their paper and this research shall follow that lead as this is still a developing area in terms of both estimation and data collection and, crucially, for the period under consideration no data is available. It is important to remain mindful that this omission may lead to some bias in the results presented in later sections.

There is considerable debate on how to best measure the inputs and outputs that go into the creation and transfer of knowledge. Despite a growing literature in the area there is no consensus on the choice and measurement of the inputs or outputs, which is made more challenging as there are no direct measures to choose from. Proxy variables are used to closely represent either an input or an output, however, by their very nature they are not perfect substitutes and so alternatives are numerous.

### 4.3.3 Inputs

The teaching portion of an institution's mission and the factors that go in to enabling the teaching process to occur are staff and capital. Staff provide the teaching and capital expenditure on premises and facilities allow for a space where the staff can work. These two inputs are common and are utilised in a number of studies ${ }^{12}$, though there still remains choice over how to measure the quantity of each. Choices are mostly divided between a simple count of the number of staff ${ }^{13}$ and the use of full time equivalent ${ }^{14}$ number of staff. Studies using either measure offer no explanation as to their choice, though a possible reason could be a simple data availability restriction. Reasoning offered by the QS Intelligence Unit ${ }^{15}$ suggests that the use of full time equivalent measures overcomes any extremes of part time employment (high or low) and possible prevents some bias. Some authors (Flegg and Allen, 2007; Johnes et al., 2008; Abbott and Doucouliagos, 2003) advise that distinctions between the quality of inputs found at each institution cannot be measured as there is no data published in this area and so whilst not a major concern it should be borne in mind when considering results.

Turning now to capital, Glass et al. (1995) make a fairly strong point that preceding papers had lacked an adequate measure for capital which would likely have biased their results, to compensate for this they included a measure for both capital and labour. Lecture theatres

[^24]and exam halls in which the teaching take place form part of the capital stock, as do any libraries and computer labs, representing a major input into the transfer of knowledge and many authors agree: McMillan and Chan (2004) viewed capital as important enough to mention in their study despite having no data for it, Carrington et al. (2005) considered it too complex but noted a number of options, whilst Bonaccorsi et al. (2006) use number of spaces in lecture halls as yet another proxy.

Carrington et al. (2005) discuss a number of issues with measuring capital which prevented them from even attempting to represent it. The first is that capital is highly heterogenous "in type, value and age. It consists of land, buildings, plant and equipment etc." (pg 152), which causes difficulty in deciding what should count as capital. Although there are different types of capital there is likely to be some kind of accounting metric which gives an overall value and would allow for comparison. They suggest a problem with value comparisons in that, though the usefulness of capital stock is assumed rather than observed (and assumed to be in some way proportional to the stock), different accounting structures and valuations can make comparison very complex. Further they suggest that due to the way capital is typically priced, annual depreciation, the value of a new purchase divided by the expected life span, gives a value of practically zero on older buildings though they still provide services in some way or another. ${ }^{16}$ Glass et al. (1995) confirm the issue with differing accounting practices for capital, but suggest that they are primarily due to location in the US and that no such problems are encountered in the UK (footnote 5).

Moving to research, it is fairly straightforward to identify the inputs, staff and capital, which are mostly shared with teaching; as an example libraries can be used for teaching and research, whilst many academic staff within a university have a joint contracts which stipulates both teaching and research responsibilities (Abbott and Doucouliagos, 2003). ${ }^{17}$ Hence, studies which consider a multi-output system Stevens (2005) have made no effort to separate those staff who do research from those who do teaching because of dual contracts and the inherent complexity separating time spent on each factor to avoid double counting.

[^25]
### 4.3.4 Outputs

Measuring the output of knowledge creation (research) and knowledge transfer (teaching) presents a much less certain spectrum of choice than the inputs. Though a consensus seems to be that the teaching output is related in some way to students and research output in some way to publications, there is great division about which measures most accurately proxy these two outputs. Additionally, unlike the inputs into the process, the outputs are very distinct and are not shared, which creates further difficulty for an aspiring researcher.

### 4.3.4.1 Teaching Output

An initial option for representing the teaching output of a university is the number of graduates. This seems to be a logical option and is utilised in several studies (Stevens, 2005; Flegg et al., 2004; Athanassapoulos and Shale, 1997). The advantage of the number of graduating students is that it represents a complete package, the teaching is finished and the output is something that the market desires. This option draws helpful parallels to an intermediary firm such as a furniture factory which takes in the lumber output from a lumber mill and delivers an improved product in furniture, where A-Level students are lumber and graduates the furniture ready for firms to take in as raw materials to their production process. Though in this case the A-Level student, or even the graduate, can be both an input and an output when looking at the entire system, in the isolated higher education sector this is not the case and each type of student (A-Level or graduate) acts either an input or an output. In such a model it is difficult to assign value to a student who drops out before completing their course as there will be no demand for such students.

This approach has been criticised by several authors (Avkiran, 2001; Carrington et al., 2005; McMillan and Chan, 2004) who take issue with the lack of value placed on situations where students have dropped out. All argue that despite non-completion the university has still expended resources in teaching the student and the student has still received some education suggesting that a portion of the teaching process has occurred. Hence should be given some value as an output to correctly assign the inputs that have gone into the creation of a partial
completion. They further argue that this would unfairly bias results against newer institutions with lower entry grades which will typically have higher dropout rates and will penalise them for accepting students from wider backgrounds and abilities, and offer student enrollments as the appropriate choice.

Placing abstract fairness to one side momentarily, the financial implications of students dropping out part way through a course are difficult to represent. Failure to adequately provide for this may leave an institution with misrepresented costs and revenues; a student leaving after their registration has been processed but before payment of fees has occurred will incur costs but provide no revenue stream, alternatively, payment of fees and not taking part in the course or utilising student accommodation may allow for additional revenues to be acquired through clearing or reassigning student accommodation. Further, there is a considerable difficulty in using student graduates; the allocation of costs and revenues. Costs are incurred for three years prior to the awarding of a degree and there is no way to accurately distribute the costs or revenues to each individual and hence, accurately establish the efficiency with which that graduate was produced. This could become an issue if recruitment takes a sudden jump, or grows particularly quickly. There will be much increased cost in that year but as the new students will only be in their first year, and the graduates will be from a smaller intake year, there could be larger costs for smaller a number of graduates, misleading the results.

In addition to which type of student will form the teaching load (total or graduate), a great deal of thought and discussion has centred around a distinction between students taking arts subjects or those taking science based subjects. Most authors (Johnes, 1996a; Stevens, 2005; Flegg et al., 2007) find that a separation is entirely justified with both returning significant results in estimations. Once again the logic behind such a formulation is clear; arts based students can be more easily taught in lecture theatres with little specialist equipment or resources by fewer members of staff, science bases students on the other hand require a great deal more resource in terms of chemicals, laboratories which are inherently more expensive than lecture theatres, and supervision.

### 4.3.4.2 Research Output

Measuring the research output of a HEI is perhaps the most debated subject within the literature and there is even less consensus than with teaching output. As mentioned by Abbott and Doucouliagos (2003) it is essential to capture not only quantity of research but also quality. Since quantity and quality of research are interrelated issues both are discussed here.

Avkiran (2001) suggests a number of popular alternatives, number of publications, number of citations, impact, and reputational ranking, though there is a fifth option which has been used more recently by Stevens (2005) and Flegg et al. (2004) which is research income. Johnes (1992) provides a comprehensive discussion of the measurement of research output the key points of which we will now elaborate on.

Publication Count A simple count of the number of publications created by a researcher, department, or institution is the common starting point for any discussion on measuring research output though Johnes (1992), and many others, challenge this as too simplistic. They suggest that simply counting each leads to a situation where top four-star journals are considered equal to one-star journals, though it is common knowledge that this is not the case. Further difficulty is encountered when attempting to include different categories of research within the same count i.e. books chapters as opposed to journals.

Proposed modifications to this simple count include narrowing the field of count or assigning weights to particular journals or types of publication. Narrowing the field of counting to higher ranked journals, much like only counting a first or upper-second class degree, can, as Johnes (1992) notes, increase the possibility that specialist works will not be counted as higher ranked journals prefer to appeal to a wider range of audience. Adding weights to particular types of output or specific journals carries its own set of problems. An example, Johnes (1990) finds that, in a study of economics departments, the weightings assigned to the different types of publications hugely affected the efficiency rankings.

Both of these alternatives require a decision to be made on which journals to count or which weightings to give to each type of publication creating an abstract problem as Carrington et al.
(2005) note, decisions will all be incredibly subjective and results would be sensitive to the decision maker, whilst Johnes (1992) summarises the issue concisely, "arbitrary weighting rules [...] lead to arbitrary outcomes" (p27).

Supplementary problems with a simple count are considered by Johnes (1992), the age and size of a department. The size of a department will have a fairly apparent effect, a straight count of publications will be larger in larger departments. As with all size related data issues a normalisation process is applied to remove the bias towards larger departments, however, it can be difficult to accurately determine the number of staff in a department, particularly in terms of contribution to the research efforts. This difference in size and level of resourcing is found to be a significant factor in Johnes (1988) which suggests that over half the variation of output was caused by different levels of resourcing. Young departments, with a number of new members of staff, are also likely to be hindered in a straight count as it is easier for older, more experienced members of staff to publish regularly.

Different disciplines will also publish in completely different cycles with some subjects publishing frequently and others less frequently (Avkiran, 2001). By way of example, subjects like business, economics and finance have a tendency towards high volume publication, whilst subjects like medicine require a great deal of initial research and experimentation, leading to a much longer publishing cycle.

Research, as many famous authors have found, is a first past the post system. It is very unlikely that the second person to publish will receive as much credit for the work and so it is highly plausible that huge differences in measured output could actually represent very minor differences in actual output (Johnes, 1992).

Perhaps the most difficult problem to circumvent is that of the time lag involved. It would take an incredible centralised investment to carry a real time count of all of the publications and research output of the nations institutions. The best that a researcher can do currently is use outdated counts or private databases.

Citation count Mindful of the issues with publication counts an alternative suggestion is a citation count, though such a count only tackles a few of the problems mentioned and indeed
creates some of its own. Initial inspection of a citation count would suggest that they overcome the impact and quality issue of work by virtue of the fact that those which are cited most frequently are highly impactful and clearly of superior quality. However, the opposite can very well be true, it could be the case that a piece of research is obviously wrong or has significant drawbacks and as such many authors cite it as the wrong way to do it, yet still this would give a positive result to research output (Johnes, 1992).

Additional problems with this can be the lack of a centralised database and the bias that can occur given the cumulative nature of citation counting. The lack of a centralised database was a significant problem in the early part of the century (Johnes, 1992), and more importantly as some still find, if a researcher writes under their own name and then a married name, or includes a middle name, it can frequently give inaccurate returns on citations. Moreover, there are now a number of different citation scores (including Google Scholar or H-Index) which make comparison difficult particularly in an interdisciplinary setting. The cumulative nature of citation counting can potentially lead to a bias in favour of older departments or those that are more male dominated (as career breaks are less frequent) as opposed to those departments with a higher proportion of younger, or female, researchers. Citation circles, where a group of colleagues or researchers cite each others work frequently so as to boost the number of citations, are also a concern (albeit for the cynical researcher) in the use of this measure.

The final problem, much like a publication count, is the necessary time lag that occurs between the research output and a citation count reflecting the output. Many works can take up to a year before they are accepted and published in a journal, and then after that stage another author has to write a paper in a similar field which cites the initial output. This could take some time, even a famous contemporary idea like the Nash Equilibrium was not fully appreciated for some time after it was written; a citation count would only begin to value it after that period of time.

Peer Review An alternative to both of these methods is one of peer review and this is the process by which institutions are currently ranked, as a result of the Research Assessment Exercise, or RAE, now called the Research Excellence Framework, or REF. There are considerable
benefits to this type of assessment in that it is less mechanical and therefore likely to give a better consideration of the overall output rather than just the statistics (Johnes, 1992). Drawbacks to this system are congruent with any measurement where humans are directly involved and are fairly obvious in that judgements are necessarily subjective and so can favour those departments which publish in the reviewers chosen area.

Most importantly for a practical application, peer review is exceptionally expensive and slow, making it unlikely for any researcher on their own to utilise it as a method of rating research unless, of course, they use the RAE or REF scores. However these scores will be the same for a given 5-6 year period, which does not allow for any measurement of research output growth, making it less helpful in that regard.

Research Income The final measure to be considered is perhaps the most controversial: research income. This has been used by Flegg et al. (2004) and Stevens (2005) as it can be deemed a price that governing bodies and private institutions are willing to pay for a universities research, thus taking into account quantity and quality. Further, it is a more up to date method than publication or citation counts, reflecting annual changes in quantity or quality.

Many authors, particularly Johnes (1992) and Avkiran (2001), suggest that research income is quite clearly an input and so is an inappropriate choice for an output measure. These objections are noted by Flegg et al. (2004) however they realise that it is the only real option they have as it is the only proxy for which data is readily available and up to date (Johnes, 2006; Flegg and Allen, 2007; Flegg et al., 2007; Izadi et al., 2002; Stevens, 2005; Johnes et al., 2008; Worthington and Lee, 2008; Johnes, 2014) agree and uses research funding as a measure of research output also suggesting it balances quality and quantity). A further, similar, argument to that of citations can be levelled against use of research income. Often the success of an institution in receiving research income is in part determined by previous success, by its track record in a particular area, thus a similar situation to that of older departments and citations occurs. Newer, younger departments find it difficult to attract funding and so may be unfairly biased in comparison to older more established departments.

### 4.4 Model Variables

There has been considerable discussion about the array of options available to a researcher when estimating the efficiency of institutes within the higher education sector. In this section the options chosen for use in this study will be presented (forming the inputs and outputs).

### 4.4.1 Inputs, Outputs

## Inputs

Though there seems to be a consensus that staff and capital represent the two main inputs into the university production process, there is some difference of opinion as to how best to measure these inputs.

Staff Input Staffing input is typically measured by either staff number (a simple count) or full time equivalent. In this study we will use staff numbers ${ }^{18}$ broken down into the academic and non-academic components. .

Capital Capital has caused some concern for other studies because differing accounting methods give way to volatile measurements for capital across the sector, however, recalling Glass et al. (1995) words on the subject the issues are only because of American Accounting styles which vary widely, this will not occur in UK studies as"UK universities employ uniform accounting practices" (Footnote, Page 62, (Glass et al., 1995)). Hence, the choice in measuring capital is made confidently. Further, in an approach borrowed from banking literature ((Kenjegalieva et al., 2009)), the measurement of capital stock will be done via a valuation of total fixed assets, an easily available and accurately measured facet of HEI. ${ }^{19}$

[^26]
## Outputs

Teaching Teaching output in this study will be measured by two individual student enrollments, those for science students and those for non-science students as in Johnes (1996a); Stevens (2005); Flegg et al. (2007). Science students are termed as total students doing Medicine and Dentistry, Veterinary Science, Subjects allied to Medicine, Biological Sciences, and Physical Sciences. This options provides the most balanced way to consider the total teaching output of a university, rather than considering only the completed teaching in terms of the number of graduates. An additional benefit of using the number of student enrollments as opposed to the number of graduates is that the costs and revenues involved will be temporally congruent; the revenues and expenditures will match with the number of students enrolled, whereas numbers of graduates would match with revenues and expenditures from $3-5$ years previous dependent on the course studied.

Research Reflection upon the current crop of measures of research output highlights the fact that most are difficult to use, out of time with more up to date data, or inappropriate for use over a panel set with several years of data. Due to these difficulties, and in seeking a complementary price, a new measurement of research output was constructed for use in this thesis. This new measure of research output was formed through a two stage process.

Each research council reports the total funding given to Institutions as well as the number of outputs generated by this funding. $\frac{\text { ReportedFunding }}{\text { ReportOutputs }}$ gives an average price for an individual piece of research for a single research council. Creation of an equally weighted average across all research councils presents an overall price of research faced by each Institution in each year $\left(\frac{\text { Sumof Average ResearchPricesacrossallCouncils }}{\text { NumberofCouncils }}\right)$. From this the total research income of each institution could be divided by the appropriate years price of research to give an approximation of the the number of outputs. A similar method of forming an output proxy was suggested in Boone (2008) should data for outputs not be readily available.

This measure has not been found in any previous literature but offers a number of advantages.

It allows for the use of research income in a manner of speaking, which although considered by some to be an input, remains a very good indicator of both quantity and quality of output. It allows for a price to be externally determined which resembles the actuality more closely: research councils will have varying levels of funding and be stricter in some years than others which will require more research for less funding i.e. a lower price. Finally, it overcomes many of the issues found in publication counts or citations such as time inconsistency, citation circles, quality measures etc. This method also fits an intuitive understanding of the production of research whereby unit price multiplied by units sold render total revenue, this is translated in the research setting to unit price multiplied by research output rendering research income.

The input-output mix of each university will therefore be as follows:

- Inputs

1. Academic Staff: Captured by the Total Number of Academic Staff
2. Non Academic Staff: Captured by the Total Number of Non Academic Staff
3. Capital: Captured by Total Fixed Assets

- Outputs

1. Science Teaching: Captured by the Number of Student Enrollments in Science based subjects
2. Non-Science Teaching: Captured by the Number of Student Enrollments in NonScience based subjects
3. Research: Captured by a variable derived from Research Income

With DEA as a method by which the efficiencies will be estimated there are further decisions to be made regarding returns to scale, bias correction and operation environment. These differing returns to scale assumptions lead to slightly different models, the VRS model typically punishes extremes of size, the CRS is more easily used but potentially less accurate. An additional difficulty is posed in making this choice when considering the environmental variables that will be included. The inclusion of environmental variables will add a number of constraints to the
linear program which will make it infeasible for a majority of mergers if using a VRS model, hence, a CRS model will be used in the estimation.

Correcting for bias is typically achieved through a bootstrapping process, and with many uses by a number of authors it has formed a regular part of DEA estimations. However, in noting the comments made by Rao et al. (2005) in their book on efficiency and productivity (page 203), sometimes bootstrapping is actually not required. The particular situations where this is the case are those where the research is utilising census data and hence the frontier estimated must be the true frontier; it is measured rather than estimated. This argument extends to the research conducted in this study as all HEI in England and Wales feature in the raw dataset, therefore no bootstrapping will be conducted.

The next issue pertaining to the empirical application of DEA is that of environment in which the DMU conducts business or operating environment which is represented by environmental variables. Operating environment is perhaps the most complex aspect of DEA estimation to deal with and sometimes omitted (Kristensen et al., 2010). The preferred method for accounting for operating environment is inclusion within the linear program (as discussed on Page 121); it is relatively straightforward to accomplish, and allows for the inclusion of as many variables as required. To that end, the efficiency results which were determined in Section 3.8 are used to indicate whether an effect was positive or negative; those positive effects were added to the output variable matrix as is, those negative effects were multiplied by minus 1 before being added to the output variable matrix. This new output matrix with environmental variables will be the one utilised for estimation of the merger gains. Note, though the Russell Group dummy variable was deemed significant in the initial efficiency estimation, it is not used in the merger matrix as it is assumed a merger between a Russell Group and a non Russell Group institution would be a takeover by the Russell Group, resulting in non-optional membership. There is then no reason to seek to maximise it within the linear program. For the same reasons, dummy variables for university grouping, location in London or Wales, and offering of particular courses (medicine and associated courses or law) are also omitted. Locations will not be flexible, mergers will not take place across area boundaries and so cannot be minimised,
and any course offerings could not immediately be withdrawn as students would need to finish their courses before they could be wound up.

Correcting for outliers will be the final stage in estimation of the initial efficiency of the units. As discussed earlier in the Chapter the detection of outliers is vital to the robustness of results of any study as DEA is particularly sensitive to extreme values. The super-efficiency method will be utilised, but more important is the choice of whether or not to remove a super-efficient DMU. There are several options however in the interests of objectiveness a proportional threshold option will be utilised. This will mean that having set a threshold of $130 \%$ efficient, any units which exceed this threshold will be removed until a pre-determined proportion (10\%) have been removed, thus striking a balance between bias and inclusivity. Of course, should there be insufficient super-efficient units for either threshold to be binding, then all super efficient units will be removed.

This methodology will present a robust, well conditioned DEA frontier and estimations of base level efficiency. The merger model Bogetoft and Wang (2005) applied using the R software package (R Development Core Team, 2008) estimates all relevant efficiency scores, including the before merger efficiency and a breakdown of the component efficiencies. This will give the important decomposition values that will allow for determination of the merger benefits.

Selection of the merging units will be done in a similar method to that of Zschille and Walter (2012), using geographical proximity such as University of York and York St John or University of Southampton and Southampton Solent University. A maximum radius for this was set at 10 miles (16 kilometres), approximately one third of that used in Bogetoft and Wang (2005) so as to ensure that mergers would be practicable. Additionally those HEI which displayed low efficiency in previous estimations will be considered as merger candidates with other proximal poorly performing units. This process results in 62 Mergers. ${ }^{20}$

If these mergers were real, then it would also be necessary to designate a control group of non-merging units so as to give a comparator for the implementation of the (Gourlay et al., 2006) model. As they are merely hypothetical mergers it would be inappropriate to implement

[^27]their model and as such no control group is needed.

### 4.5 Data

The Higher Education Statistics Agency ${ }^{21}$ (HESA) track information on a huge range of variables across HEI and tabulate the information for purchase. The tables purchased for this work were: Resources of Higher Education institutions (2004/05 through to, and including, 2008/09), Students in Higher Education institutions (2004/05 through to, and including, 2008/09), HE Finance Plus (2004/05, through to, and including, 2008/09). The financial data drawn from HE Finance Plus was deflated using a GDP Deflator supplied by HM Treasury. ${ }^{22}$

After some data processing to make the different years compatible it became apparent that some institutions were particularly specialised or had anomalous characteristics such as, having no reported value of total assets in the case of the Royal College of Nursing, receiving no government funding for teaching in the case of Homerton College, having a completely unique provision of teaching as well as a very large size in the case of The Open University, or having no undergraduate students as in the case of The Institute for Cancer Research, London Business School, London School of Hygiene and Tropical Medicine, and the Royal College of Art. As in Johnes et al. (2008) institutions with these characteristics were removed, as were a cumulative entries for the UK, Wales, and England. Despite these removals the sample which remained contain observations for 139 institutions for a period of up to 5 years, creating 669 individual observations.

[^28]

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University ID | University IDNumber | HESA assigned <br> for code  <br> (consistent across <br> name changes)  | 669 | $9.883 \mathrm{E}+01$ | 57.568 | 7.000 | 209.000 |
|  |  |  |  |  |  |  |  |
| year id | Year ID Number | Number for academic year 04-05 to $08-09$ | 669 | $2.996 \mathrm{E}+00$ | 1.414 | 1.000 | 5.000 |
|  |  |  |  |  |  |  |  |
| Total.Academic. | Number of Aca- | Count of Academic | 669 | 1048.117 | 939.25 | 30 | 5075 |
| Staff | demic Staff | Staff in a given academic year |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Total.Non Aca- | Number of Non- | Count of Non- | 669 | 1200.994 | 1054.797 | 30 | 5995 |
| demic.Staff | Academic Staff | Academic Staff ina given academic year |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| DefFixedAssets | Deflated Fixed | Value of Fixed Assets | 669 | 135924.4 | 166303.8 | 0.88613 | 1441082 |
|  | Assets | in current Academic |  |  |  |  |  |
|  |  | year, deflated to give |  |  |  |  |  |
|  |  | constant prices |  |  |  |  |  |

Table 4.1 －continued from the previous page

| $\underset{\sim}{x}$ | $\begin{aligned} & \text { N } \\ & \stackrel{\circ}{\dot{~}} \\ & \text { in } \end{aligned}$ |  |  |  |  |  | $\stackrel{\stackrel{8}{7}}{\stackrel{-}{+}}$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \vec{P} \\ & \stackrel{1}{0} \\ & i \end{aligned}$ |  |  |  |  |  | $\begin{aligned} & \infty \\ & \stackrel{\infty}{\gtrless} \\ & \underset{\sim}{\infty} \end{aligned}$ |  |  |  |  |  |  | $\begin{aligned} & \not \approx \\ & \ddagger \\ & \vdots \end{aligned}$ |
| $$ | $\begin{aligned} & \text { n} \\ & 0 . \\ & 0 \end{aligned}$ |  |  |  |  |  | $\begin{array}{r} 104 \\ \\ \end{array}$ |  |  |  |  |  |  |  |
| $\stackrel{\text { Ĩ }}{\substack{\pi\\}}$ | $$ |  |  |  |  |  | $\begin{aligned} & 0 \\ & 1 \\ & 1 \\ & 2 \\ & \vdots \\ & 0 \end{aligned}$ |  |  |  |  |  |  |  |
| $\frac{0}{0}$ | \％ $0_{6}$ |  |  |  |  |  | $\ddot{\theta}$ |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | $\begin{aligned} & \dot{0} \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & 0 \\ & \# \\ & 0 \end{aligned}$ |  |  |  |  |  |  |  |
|  |  | \＃ 0 0 0 0 |  |  |  |  |  | \＃ 0 0 0 0 0 0 |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.1 - continued from the previous page

Table 4.1 - continued from the previous page

Table 4.1 - continued from the previous page

| Variable | Name | Description | Obs | Mean | Std Dev | Min | Max |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| PropPTNon Aca- | Negative propor- | Total Part Time | 669 | $-3.409 \mathrm{E}-01$ | 0.106 | -0.753 | 0.000 |
| demicStaffneg | tion of Non Aca- | Non-Academic Staff |  |  |  |  |  |
|  | demic Staff that | divided by Total |  |  |  |  |  |
|  | are Part Time | Non-Academic Staff |  |  |  |  |  |
| PropPTStaff | Proportion of To- | Total Part Time Staff | 669 | $1.257 \mathrm{E}-17$ | 0.133 | -0.372 | 0.424 |
|  | tal Staff that are | divided by Total Staff |  |  |  |  |  |
|  | Part Time |  |  |  |  |  |  |
| PropEU | Proportion of HE | Total EU Students di- | 669 | -6.804E-18 | 0.039 | -0.051 | 0.203 |
|  | Students from EU | vided by Total Stu- |  |  |  |  |  |
|  | Domiciles | dents |  |  |  |  |  |
| PropNonEUneg | Negative propor- | Total Non-EU Students | 669 | -1.639E-18 | 0.080 | -0.545 | 0.101 |
|  | tion of HE Students from Non- | divided by Total Students |  |  |  |  |  |

### 4.6 Results

### 4.6.1 Bootstrapping and Correlation

Before applying the Bogetoft and Wang (2005) merger procedure to the data, an initial Data Envelopment Analysis was conducted without the effect of environmental factors to enable comparison with other studies. This would provide an initial check on the model, ensuring that it would give sensible results. The initial values were very much in line with the results of the stochastic frontier model presented in Chapter 3, showing a majority of high performing institutions with a small cluster whose performance was worse. These results also echo those found by Johnes (2014) suggesting that they are indeed sensible results. A second estimation was also conducted factoring the environmental effects which was also in line with the general finds (predominantly high levels of efficiency with some lower efficiencies). These results are, in and of themselves, important. They agree with the results of the the earlier work in Chapter 3 and support the proposition that environmental factors do have an effect on the efficiency of particular institutions and are thus important to include within efficiency estimation work.

Mindful of the tendency for DEA to introduce bias, a bootstrapping procedure was implemented utilising the benchmarking package within R (Bogetoft and Otto, 2015; R Development Core Team, 2008). This returned estimates of the efficiency, bias corrected efficiency, bias, and confidence interval for each institution in each year. The full results of this bootstrapping, run using 2000 samples, are reported in Appendix B.4. Here, it suffices to note that there is a high correlation between the biased and unbiased efficiencies (of the group including environmental factors) confirmed by a Spearmans Rank coefficient of 0.993 and a graphical comparison of the data (Figure 4.6). This high level of correlation suggests there would not be significant relative or rank differences between the biased and unbiased scores and so further analysis can proceed. Further, a graphical representation of the confidence intervals is given in Figure 4.7 and confirms the similarity of these findings to those of the stochastic frontier model and those of Johnes (2006).

The high levels of efficiency for the majority of institutions would initially seem odd given
a perceived lack of profit motive by institutions, however there has been increasing exposure to market forces through the early 2000 's. This pressure has focused institutions towards revenue maximisation and cost minimisation particularly around the introduction of increased fees, and in combination this will produce a pseudo profit maximising unit. Additionally, it is also important to note that by contrast to stochastic frontier models, DEA provides relative measures of efficiency comparing each institution against the best of the group. The high levels of efficiency shared by most suggests that they are as efficient as each other in a relative sense, not specifically that they are efficient in an absolute sense and so the scores presented may be generous (Johnes, 2006). This is an important caveat to remain mindful of when considering the results.

(
Figure 4.7 Bootstrapped Confidence Intervals

### 4.6.2 Merger Results

With confirmation that the model produces sensible results the merger analysis can now be conducted. The richness of the dataset used in this study allows for the mergers to be considered over the course of 5 years. The practical method for doing this is to estimate 5 separate cases of a single merger which happen in each period under examination, hence Table B. 3 found in the Appendix (Page 257) is substantially larger than the 62 mergers might suggest. It shows the efficiency for each merger over each of the 5 years and broken down into each of the effects shown in (Bogetoft and Wang, 2005) where; Overall Efficiency is the basic DEA efficiency of the merged unit where the input and output amounts are simply summed, and the Corrected Overall Efficiency is the efficiency calculated after the original un-merged inputs have been projected onto an efficient frontier and then summed.

Before delving into the results it is important to consider at this stage that the discussion to follow is based on theoretical mergers. These mergers have not taken place to be examined after the fact, they are simply theorised to demonstrate where benefits may be drawn through mergers within the higher education sector. It is also important to remember that mergers which return values of less than 1 the learning, harmony, or scale categories are desirable as they give the opportunity for efficiency improvement as opposed to those close to or above 1 which suggest the opposite.

Consider now Table B.3, which is included within the Appendix and has the full results of each proposed merger across each time period. Across the table there are common themes that can be drawn out. There are in general, very high levels of the scale and harmony factors. The harmony factor results produced a minimum of 0.77 (for Merger 60 in 2006-2007) and the scale factor a minimum of 1 (achieved by all mergers).

Recalling the earlier discussion on the meaning of the different factors, the harmony factor represents the benefits to efficiency that can be drawn from combining resources to produce a more average set of outputs. In terms of institutions within the higher education sector this can be more intuitively understood as the benefits drawn by bringing together an institution
which is heavily science focused with one that is non-science focused.
An example of this is merger 26 between the University of Leicester, a more science focused institution which included medicine, and De Montfort University, a more arts and humanities based institution. This merger returns a harmony value of 0.93 suggesting the possibility of a 7 percentage point rise in efficiency through merging. In general however, the efficiency gains to be realised through the harmony factor are less than 7 percentage points. An average value of 0.976 suggests that in fact the it would be unlikely for most of the mergers to secure more than a percentage point increase in efficiency through the averaging of output.

This outcome whilst initially a little unexpected is easily to reconcile when considering the geographical constraint placed upon the mergers. The mergers were not selected to maximise the harmony factor, they were selected to be geographically feasible (within 10 miles), and as such many of the institutions within each merger are fairly similar. Mergers 23 (Coventry University and the University of Warwick), 31 (Staffordshire University and The University of Keele) are two examples of a fairly common theme. Given the fairly homogenous nature of the institutions involved in each merger it is not unsurprising to find there are only small gains to be made within this factor.

Turning now to the scale factor. The results show that there are no gains to be made in terms of achieving greater economies of scale through any of these mergers. This would suggest that all institutions are currently near to, or on, the constant returns to scale portion of their scale curves. Such a suggestion overlooks a potential difficulty introduced by the dataset being used. The data being used has only the institutions within England and Wales which, in terms of scale, are not particularly large (Leeds Metropolitan is the largest with an average of 40,000 students).

Though in itself the merger of two large units is not an issue, the difficulty in gaining a feasible solution for the linear program is that there is no comparable reference unit to draw on as all of the reference units will be significantly smaller and so the program cannot easily determine whether it is efficient or not. A similar problem was faced by Bogetoft and Wang (2005) who posit that the lack of larger units provides no measure of "production norms" (Page 166)
for merged units above a certain size. It is therefore not certain that these mergers would not produce, or indeed have the potential to produce, efficiency gains, but at this stage it is impossible to suggest that they could.

Whilst the harmony and scale factors proved unfruitful in potential efficiency gains, considerable potential gains present themselves within the learning factor. The learning factor describes the improvements to process and production that can be brought about through changes in technology or methodology; within manufacturing that might be the implementation of a new pieces of software or different approach to production process, whilst in higher education that could simply be a visiting lecturer providing access to a high quality course that was otherwise not a provided option for the students. It can also be collaboration in research which allows for a much greater output given the experience and reputation of some researchers.

The learning factor average is a much lower than either harmony or scale at 0.504 , suggest that there is the opportunity for approximately 50 percentage points of growth in efficiency through the merger of these units. Such an example is Merger 6 (The University of Birmingham, University of Central England in Birmingham, Aston University, Newman College of HE, and Birmingham College of Food, Tourism and Creative Studies), with a learning factor score of 0.509 . Here there is a clear leader in terms of capability, process, and effectiveness in The University of Birmingham, which could do a great deal of "teaching" in terms of course provision or research support to the other institutions to help them improve.

Whilst there is the capability to improve through merger with regard to the learning factor this is, unlike with scale or harmony, not the only way. As in manufacturing with the license of a process or technology, institutions can engage in knowledge transfer helping their peers to improves, engaging in collaborative research, or providing visiting academics to smaller institutions all without merger. Instead a simple licensing agreement or reciprocal arrangement can be made. There are a number of benefits to this, including but not limited to, speed of implementation (much quicker than a merger) and cost (there is just a little contract wrangling rather than lengthy merger process).



These overall results are made particularly clear in Figures 4.8 and 4.9 which shows the level of learning and EStar efficiency (harmony multiplied by scale) achieved by each of the mergers. Estar is used on the x -axis as all values are 1 and it represents the gains specifically achievable through merger as opposed to the learning factor on the y-axis which is specifically from an improvement in practice and so can be achieved through merger or licensing. Figure 4.9 has been amended to have a shorter axis to spread other the point for easier viewing; this will of course make the possible increases in harmony and scale seem larger than they actually are.

In either case, scores approaching the top right hand corner of the graph suggest no potential gains for merger. Those approaching either of the axes suggest potential for improvement, either in terms of harmony and scale (for those closer to the y axis) through merger or in terms of learning (for those closer to the x axis) through merger or otherwise. As this research is focused on mergers the preferred area to find points in would be the left half of the graph as this would indicate increases in efficiency only achievable through merger, however, we find most are towards the right hand boundary (as confirmed by the numbers discussed earlier).

Such results may suggest that there is in fact little scope for gains through merger in the higher education sector, however it is important to remember the points made by Bogetoft and Wang (2005) regarding the reference units for larger scale mergers. This is an necessary caveat when considering the overall results.

Importantly for this research Table B. 3 shows that the only mergers to not show any signs of potential gains, whether it be through learning or through harmony and scale were those which produced infeasible results (Merger 61, periods 1 and 2). In all other cases there was the possibility of at least small gains in efficiency available only through merger. The results of this paper are supported by Johnes (2014) which found that there were significant improvements to efficiency in merged units.

Another aspect of the results to consider is that of time. Gourlay et al. (2006) found that some mergers would demonstrates changing benefits over time, some starting off with considerable improvements and then tailing off as they honeymoon period wore off, and others building the benefits more slowly to end up with much improved efficiency. Within the harmony factor, the
changes over time ranged from 0.109 to -0.11 . These translate to a potential for increase in potential gain of 11 percentage points (from 1 to 0.89 ) to a reduction of potential gains of 11 percentage points ( 0.854 to 0.964 ).

Careful thought on these results can be quite revealing. A reduction in potential gains from the harmony factor would come about if the two institutions were drawing closer in terms of the types of resources they were using; a merger would therefore benefit only in terms of scale rather than averaging outputs. The alternative, where the potential for gains from the harmony factor increases, suggests that the opposite is occurring and the two institutions are becoming more divided in their offerings. The biggest increase was for Merger 49 (Liverpool Hope University and Liverpool Institute of Performing Arts) which suggests that Liverpool Hope was moving toward more traditional and science based making it more different from the arts based subjects offered by Liverpool Institutes of Performing Arts. The biggest drop in potential gains was for Merger 57 (Ravensbourne College of Media and Communication and Trinity Laban) which fits well with the intuition since both are very arts focused institutions and would stand to gain little in terms averaging resources following a merger.

### 4.7 Conclusions

The research conducted in this paper has also confirmed the work of authors such as Stevens (2005) and work conducted in earlier chapters of this thesis (Section 3.8) in demonstrating the significance of environmental factors in determining the efficiency of institutions. Confirmation from a second methodology provides an additional sensitivity test to these works and whilst the specifics of the results are slightly different (to be expected from different models), there is a clear pattern of a cluster of nearly full efficiency and some clusters of lower efficiency. Whilst supporting the results of previous work it does also raise a question of whether performance measurement through efficiency is a useful exercise within the higher education sector given the clustering of high efficiency that is a common theme of such work. If there is little difference in terms of efficiency, how can one usefully generate policy to encourage the right behaviors using efficiency scores?

This empirical work provides a contribution to the current body of literature through a novel application of the Bogetoft and Wang (2005) merger model to HEI over the period 2004-2005, to 2008-2009, and supports the results of other authors in the area (Johnes, 2014). It builds on results presented in Section 3.8 which revealed some significant efficiency changes for those HEI which had merged. 62 different mergers are presented all of which demonstrate the at least some potential for growth in efficiency following the merger. The mean harmony score is 0.976 indicating the possibility for a $2-3$ percentage point increase in efficiency through merging. The mean learning factor score suggests there is much greater potential for growth in improving process and technology (moving toward best practice) for the institutions.

That the majority of potential for gains comes from the learning factor raises important questions as to whether mergers would indeed be the best course of action. In the majority of cases examined in this research it would actually be more beneficial to arrange for knowledge transfer through research collaboration, consultancy, or visiting lectureships to help those institutions not utilising best practice. This would enable a much quicker capture of the potential gains. Moreover it would avoid the costs of merging.

The costs of a merger have not be considered within this research and as such for a critical caveat of the results. If mergers were costless the harmony factor gains suggested, though slight, would be worth merging to capture. Additionally with the institutions now joined there would also likely be a capture of the majority of the learning factor gains, providing a large increase in efficiency for many institutions. Indeed it is the implicit assumption within the Bogetoft and Wang (2005) model is that any cost of merging would be shown in the levels of cost that are presented to the model. However, in the case of hypothetical mergers such as in this research it is not the case. The results shown here act as if the merger process is instant and costless which, whilst ideal, is in no way realistic. An extension to this work would be to re-estimate the model with the addition of a merger cost function.

The results also demonstrate a similar trend to those found in Gourlay et al. (2006) where the gains from mergers changed over time. Here those gains are potential and the mergers theoretical but they still vary over time, with a considerable range of change (from -11 to +11
percentage points). These results suggest that any future work on mergers, including policy, should be very careful to not place too much emphasis on immediate improvements as doing so could dramatically over or understate the gains that will be made. It is worth considering the points made by Mao et al. (2009) who found there was a definite "honeymoon" period within their results, and that even where such a period was present mergers were still painful and the full effects of would not be stable and visible for approximately a decade.

Not only is the passage of time a factor in examining these mergers, but the period of time under consideration is also important. The time period used within this research could be argued as a relatively prosperous time in the higher education sector. Whilst tuition fees were introduced during the period, there was still a considerable increase in funding and in student numbers. More recently the funding environment has changed dramatically, including cuts of up to $80 \%$ of teaching budgets and a concentration of research budgets (Richardson, 2010). An application of this research technique to an updated dataset of the current higher education sector, in this state of funding woe, would likely yield considerably different results to those produced within this research and be hugely beneficial in shaping policy towards the policy on failing institutions; whether to let them fail, or to impose mergers on poorly performing units much like the Danish hospital example in Kristensen et al. (2010). It is of course not necessarily straight forward to let an institutions fail if established via Royal Charter (requiring an act of parliament) which would increase the likelihood of merger should such an institution fall into difficulty.

An examination of potential mergers within the higher education sector does raise an additional question: is fewer, broad institutes preferable to more, narrow institutes? Typically competition is viewed as a positive for consumers, leading to falling prices and improving standards. If the number of sellers is high, competition is high, and the higher education sector is no different. If there were a number of mergers to provide greater efficiency there is a risk that competition may then decrease leading to falling standards and increasing prices. This risk is weighed against the current state of the sector, if it is not very competitive the outcome of mergers and competition falling further may be substantial, whereas if the sector is very competitive, a small
decline in the number of institutes through merger would not likely lead to significant falls in standards or increases in price. This question warrants an examination of the competitiveness of the higher education sector, which forms the basis for Chapter 5 .

## CHAPTER 5. Competition within Higher Education

### 5.1 Introduction

Competition is a favoured topic amongst many different stakeholders; academics wish to analyse it, regulatory bodies want to stimulate it, and consumers like to reap the benefits. It would appear initially as though competition is a fairly simple entity to grasp, and to quantify, but as academics and regulators have proven, it is anything but. Markets provide an ideal base unit of analysis, small enough to gain meaningful results and large enough to make recommendations about future moves, however sectors provide a much richer source of information and are of greater importance for policy - particularly in public (or semi-public) services such as the National Health Service and the higher education sector. The National Health Service has been subject to ongoing study by Carol Propper and associates (Propper, 1996; Propper et al., 2004, 2003), and Maynard (1994) with frequent empirical analyses. The higher education sector is without such a weight of investigation and has only been the topic of some essays and thought based work by Marginson (Marginson, 1997, 2004).

Measuring Competition, as has already been remarked, is a complex business and several competing models, all with a good deal of support, vie to become the chosen model. These models, the Structure-Conduct-Performance (SCP) model ((Bain, 1968)), the New Empirical Industrial Organisation (NEIO) family of models ((Bikker and Haaf, 2002; Casu and Girardone, 2009; Hay and Liu, 1997; Klette, 1999)), and the Relative Profit Differences model (Boone, 2008; Gourlay et al., 2006; Schaeck and Cihak, 2010), all have merits, particularly in reference to their compatibility with efficiency studies (a central focus of this thesis), and all have disadvantages.

### 5.2 Is Competition Desirable?

When considering competition it is important to first discuss what the point of competition is, and whether it would benefit a particular sector or society. Competition is typically presented as a desirable situation for several reasons, more choice for consumers, less profits for big business, more efficient production and lower prices. These reasons centre on the conflict between private and social welfare; companies vs people. An easy way to see where higher prices occur though a lack of competition is in a diagrammatic exposition of the two ends of the competitive spectrum; perfect competition and monopoly (Figure 5.1).

Perfect competition is a market where:

- a large number of producers produce the same good
- both consumer and producers are perfectly informed on market conditions (demand and prices)
- the large number of producers and perfect information drives price to be equal to marginal cost
- consumers are utility maximising
- producers are profit maximising
- market prices are determined by consumer demand rather than producer supply

If it further assumed there are no externalities (impact on society through the private consumption of the good), either positive or negative, then perfect competition represents the end of the spectrum with the greatest social benefit.

Monopoly, by contrast, is a market where:

- a single producer produces one good
- the producer has greater information on market conditions than the consumer
- monopolies are profit maximising and so produce where marginal cost is equal to marginal revenue
- price is then set to generate demand at that level, typically leading to lower production and a higher price

Once again, if it is assumed that there are no externalities this is the end of the spectrum with the smallest social benefit. Figure 5.1 clearly shows the differing pricing mechanisms. The perfectly competitive firm prices at price equals marginal cost which leads to output at $Q_{c}$, whilst the monopoly firm prices where marginal revenue equals marginal cost leading to output, $Q_{M}$, at price, $P^{M}$. With perfect competition the consumer surplus (an indicator of the social benefit) would be areas A, B, and C. In a monopoly, the price is higher reducing consumer surplus to A, transferring B to the monopoly in profits, and wasting C as a dead weight loss.


Figure 5.1 Benefits of Competition

Of course this initial, and very simplistic, diagram does not fully capture the benefits (or disadvantages) of differing levels of competition. It is the final assumption regarding externalities
which introduces additional complexity. Externalities have already been defined as an impact on society through private consumption of the good and they can be positive or negative. A negative externality is something such as pollution caused through the consumption of petrol for driving, the private benefit is a functioning car, the private cost is the cost of fuel, the societal cost is pollution. A positive externality is something such as a vaccine, the private cost is pain and perhaps money, the private benefit is immunity from a particular disease, and the societal benefit is slowing / preventing the spread of disease. A general graphical representation (Figure 5.2) of these scenarios makes comparison easier.

In the case of positive externality there is a higher benefit to society (MSB) than privately (MPB). This leads to a situation where output is lower ( Qp ) than socially optimal and would need to be artificially boosted to move to preferred levels (Qs). In the case of negative externality the social cost (MSC) is higher than the private cost (MPC) and so there is higher output ( Qp ) than society would prefer (Qs) unless it is artificially restricted. In both scenarios deadweight loss (DWL) is incurred to society through over or under production.

The latter is particularly relevant to the higher education sector as there is a clear positive externality to broad higher education amongst the workforce. Two key positive results of higher education within the workforce are higher productivity for firms and greater competitiveness with overseas labour. Consider again the positive externality (Figure 5.2a) and the resulting underproduction because the full benefits are not received by the producer. Here it is clear that the enhanced output levels of a competitive market are preferred to the lower levels of monopoly production. Importantly the competitive environment would still not produce sufficient to meet the socially optimal level, however it would be closer than the monopoly production and therefore capture more of the positive externality.

The real life applicability of these models is, as always when theory meets practice, less than perfect. Rarely will pure perfect competition or a pure monopoly be found, in fact legislation exists to prevent the latter. In reality the two ends of the spectrum are competitive, where a number of firms compete with fairly similar products (clothing for example) and oligopolistic, where few firms dominate the market (desktop computing). The relationship between the two


Figure 5.2 Externalities
is similar to that of perfect competition and monopoly, though there are specific differences.
A competitive market is not always an easy one to define. One would typically see the airline industry as almost an oligopoly, there are quite a few companies, though in the real arena of competition, flight routes, there is little direct competition. However, it has been argued by some ((Burgess, 1988)) ${ }^{1}$ that a more important factor is how easy it is to enter the market to capture any abnormal profits. In the case of the airlines industry this is actually fairly easy, planes maintain their value and most other costs are variable dependent on level of sales (staff) or easily resold (terminal space and flight path permits), which allows new entrants easy access to the market if there are profits to be made.

The primary difference between these different types of competitive markets are barriers to entry. Typically if a market is returning super-normal profits then another firm will see this (with perfect information) and enter the market to take its share of the profits. This process will continue until only normal profits are made and the market more closely resembles a perfectly competitive one. However, if there are barriers to entry this process doesn't function efficiently which allows firms to continue making super-normal profits and, dependent on the type and size of the barriers, can lead to oligopoly or monopoly situations.

These entry barriers typically take the form of either significant economies of scale or high levels of sunk costs (Burgess, 1988). Economies of scale will naturally disadvantage a new entrant who will be unable to produce at the same level as the incumbent firm. In such a situation the average cost of the incumbent will be lower than that of the entrant; in a friendly situation this leads to greater profits for the incumbent, in unfriendly scenarios this can enable predatory pricing by the incumbent which will price below the average cost of the entrant, forcing them to sustain losses or leave the market. Similarly if there are high levels of sunk costs ${ }^{2}$, for example the washing detergent industry (with high levels of advertising spend), then the levels of profits that would be required to motivate entry to the market is much higher than an industry when

[^29]the initial investment can be recouped upon exit i.e. airline industry (Burgess, 1988).
Though typically monopolies are perceived as "bad", there are several examples of monopolies which end up benefiting the consumer, referring of course to natural monopolies created by utilities, research and development expenditure, and international competitiveness.

Utility natural monopolies benefit from such incredible economies of scale that the majority producer has a significantly lower average cost and can pass these savings onto consumers. Of course, once in a monopoly position the possibility of raising prices is controlled by regulatory bodies. The pricing controls imposed by regulators are designed to simulate the level of pricing that would occur within a competitive market. In order for regulatory bodies to be effective in this endeavor, they must be able to accurately determine the level of competition that currently exists within the market. This will enable the adjustment of policies so that a competitive environment, with its efficient production and lower prices, is created without being too restrictive and stifling businesses or being too relaxed and allowing abuse of monopoly position.

Monopoly power also enables firms to earn super normal profits (beyond those expected within the market). This creates additional reserves that can be invested into research and development which can create new and exciting products or substantially improve processes. That cost can then be recouped through sales of new products and licensing of new processes, thus reinforcing and rewarding the initial investment. Industries such as utilities, manufacturing, technology, and pharmaceuticals all benefit from monopoly power giving enough extra profit to be put into research and development; obvious topical examples include the driverless car by Google ${ }^{3}$ or research into providing internet access to third world counties via drones ${ }^{4}$.

Monopoly power can also enable a firm to grow to sufficient scale that they can compete with large overseas producers. Though this is still not always the case given recent reports on the problems faced by British Steel (West, 2015), it is far more probable that monopoly scale within the UK would be able to compete with overseas producers. A fragmented production

[^30]such as that of perfect competition would ensure, by definition, that no one producer would have sufficient scale to grow beyond a local market.

Some of these examples apply to HEI and can give pause to reconsider whether large scale competition is actually desirable within the higher education sector. Larger institutions are better able to be globally competitive (University of Cambridge, University of Oxford, University College London, and Imperial College London all enter in the top 10 global universities) ${ }^{5}$ but no small scale specialist institutions are visible even moving into the top 100 and beyond. Further the larger scale can give reduce costs of production which, whilst not being passed on to the consumer due to the unique nature of pricing, does give larger reserves for investment in new facilities, improving the products they deliver (in terms of teaching and research), and driving stronger innovation in research.

There is then a conflict over the preferred market structure for higher education. From an externality or social benefit perspective there is a preference for a competitive environment with a large number of producers to move closer to the level of output that is socially preferred. However, given the wider advantages that come from larger scale institutions there is also a preference for a more concentrated market structure enabling greater inward investment and stronger international comparison. Whilst it is not the intention of this research to discuss and conclude upon the most desirable structure for the higher education sector it is important to be mindful of these arguments in the context of the estimations and results to be presented in later sections.

### 5.3 Empirical Models

### 5.3.1 Structure Conduct Performance

One of the earliest models by Bain (1968) has formed the base for much of the competition analysis since its creation. The SCP model establishes a causal link from structure, through

[^31]conduct, to performance in any market. It hypothesizes that in situations where, for example, there are few firms in the market (structure), it is easy for them to collude on price (conduct), and then achieve oligopoly profits (performance). In taking a closer look at this model, its assumptions and application, Church and Ware (2000) is drawn upon heavily for their clear and structured exposition.

The assumptions of the model are as follows (Church and Ware, 2000) (pg 425-426):

- A sustained relationship in which structure causes conduct which is turn causes performance.
- This relationship is considered to hold across all industries, where the structural variables (considered later) will exercise the same average effect.
- Market power can be calculated using available accounting data.
- Conduct cannot be directly observed and so structural variables are identified which are observable, measurable and linked to the market power or collusion.
- Following the establishment of a relationship between these structural variables and market power the inference of the SCP model is that these variables will facilitate the exercise of market power which will bring differing assumed conduct.
- Market power is then an inverse proxy for competition i.e. high market power comes with low competition.

The aim of the SCP framework is to establish a relationship between market power and a set of structural variables (typical examples include concentration, advertising spend, etc) which are created so as to capture the ability of firms to exercise market power. The techniques for establishing and examining these relationships are relatively straightforward; a simple regression of the chosen structural variables against market power. A typical example might display as in equation 5.1 (Church and Ware, 2000) (pg 426):

$$
\begin{equation*}
\pi_{i}^{2}=\alpha+\beta_{1} \text { Conc }_{i}+\beta_{2} B E_{i}^{1}+\beta_{3} B E_{i}^{2}+\cdots+\beta_{N+1} B E_{i}^{N} \tag{5.1}
\end{equation*}
$$

Here $\pi$ represents market performance, $\alpha$ a constant, Conc a measure of the concentration within the industry and the various $B E$ terms to represent various barrier to entry. The equation, in itself, is simple; empirical application is not. Difficulties arise from the very first step. The equation is built to find a relationship between specific variables and market power, but as many authors have discovered there is no simple choice for representing market power, seller concentration, and other aspects of the market (Church and Ware, 2000; Cabral, 2000; Bikker and Haaf, 2002; Schmalensee, 1989).

### 5.3.1.1 Market Power

As noted in model assumptions, conduct is difficult to observe and so it is replaced with observable, measurable alternatives. Market power has similar issues as it is completely intangible. Fortunately, the exercise of market power has some visible characteristics which can be used as proxy variables in empirical estimations. These options are typically based on accounting variables such as profits, price, costs and stock valuations. The favoured options are; economic profits or rates of return, Lerner index or price cost margins, and Tobins q (Carlton and Perloff, 1994).

Profit seems a sensible option for considering market performance, higher profits would suggest better performance and greater power in an easily identifiable manner. However, one should exercise caution here, as the option is not simple profit but economic profit, which is different in a subtle but important way; it measures the difference between revenues and the opportunity cost of all inputs. Importantly there is not an equality between profit and economic profit, sometimes firms can have one without the other i.e. they earn profits (through market power) but no economic profit. The use of profit does present an absolute vs relative complication, some industries may have lower profits across the board given the nature of the industry, and so rates of return are favoured in this instance for comparability. In general a rate of return is the earnings of the investment divided by the investment value. This will naturally return a proportion which is then compared against the return of the next best alternative to discover the "competitive rate" which could well be putting the money
into savings. If the realized rates of return are above the competitive rate then the firm is performing above that of a competitive firm.

An alternative is the Lerner index of market power, a famous theoretical measure of market power, which is simply a ratio of price minus marginal cost to price (Cabral, 2000).

$$
\begin{equation*}
L=\frac{P-M C}{P} \tag{5.2}
\end{equation*}
$$

The higher the value of the index, the higher the market power of the firm. A value of zero indicates that a price equals marginal cost strategy is being followed which will only occur for long periods of time in a perfectly competitive market. A value approaching unity gives a situation where price is inflated so far beyond marginal cost that the effect of marginal cost is negligible. In such a situation the firm in question would require considerable market power in order to maintain that level of price markup. The Lerner index has found usage in antitrust investigations which typically use it to give evidence as to the possible abuse of market power and in academic investigation of "past and current levels of competition" (Bolt and Humphrey, 2010) (pg 1808).

A final, less common approach is to use Tobin's Q . It is more focused on investor determinations about a particular company's profitability. Specifically it is a ratio measure of the current market value of the firm against its replacement value. The valuation of a firm is a summation of its outstanding stock and debt, whilst the replacement value is the total cost of the firms assets. Carlton and Perloff (1994) suggest that one of the significant advantages of Tobins Q is that there is no need to estimate potentially complex rates of return or marginal costs.This ratio can, and for some companies does, exceed unity (several industries in a study by Lindenberg and Ross (1981)).

### 5.3.1.2 Seller Concentration

An additional aspect of the structural variable equation that is typically estimated is the concentration of sellers within the market. The normal presumption is that an increase in
concentration within a market (through a lower number of firms) will lead to an increase in market performance by those remaining. This positive relationship is justified through an intuitive explanation; fewer firms makes it easier for the incumbents in the market to prevent new entrants, and to engage in price coordination, leading to increased performance for all incumbent firms. Alternatively the same relationship is explained through Oligopoly Theory using a profit maximising condition (Church and Ware, 2000) (pg 428).

The profit maximising condition for a firm (equation 5.3), where $P(Q)$ is the demand, $M C\left(q_{j}\right)$ is the marginal cost of the firm, and $\epsilon$ is the conjectural variation ${ }^{6}$ :

$$
\begin{equation*}
P(Q)+\frac{d P}{d Q}(1+\epsilon) q_{j}-M C\left(q_{j}\right)=0 \tag{5.3}
\end{equation*}
$$

Substitution for market share $s_{j}$ and market elasticity of demand $\varepsilon$ returns equation 5.4:

$$
\begin{equation*}
\left(\frac{P-M C_{j}}{P}\right)=\frac{s_{j}(1+\epsilon)}{\varepsilon} \tag{5.4}
\end{equation*}
$$

This clearly shows a positive relationship between market power (as represented by the formulaic statement of the Lerner Index) on the left and market share (amongst other variables) on the right. With intuitive explanation supported by theoretical derivation for the link between market power and market share, it is reasonable to assume that it will appear in empirical work (or a proxy), an accurate determination then becomes important.

Two leading measures of seller concentration are used in the analysis of markets, Herfindahl Hirschman Index and concentration ratios (Burgess, 1988). The Herfindahl - Hirschman Index is simply a sum of the squares of market shares for the firms in the industry. Over a market of N firms the Herfindahl - Hirschman Index is (Cabral, 2000):

$$
\begin{equation*}
H H I=\sum_{i=1}^{n} s_{i}^{2} \tag{5.5}
\end{equation*}
$$

[^32]The index is valued between 0 and 1 , where obviously a value of 1 indicates the full market share of a monopoly and value moving towards 0 suggests smaller market shares indicative of a greater number of firms. There exists an alternative specification which makes later comparisons to concentration ratios slightly easier. Noting that market shares are rarely equal amongst firms, an alternative specification of the HHI is proffered which includes a term for variation (Church and Ware, 2000):

$$
\begin{equation*}
H H I=\frac{1}{N}+N \sigma^{2} \tag{5.6}
\end{equation*}
$$

The presence of the variation term, $\sigma$ as well as the number of firms allows the Herfindahl Hirschman Index to reflect more accurately the change in number of firms or spread of concentration. This makes intuitive sense when considering that the goal of the index is to measure seller concentration, a greater variance in firm size would suggest a greater concentration (in favour of the larger firms).

The second measure, concentration ratios, is slightly more specific. Once the market shares of the firms are acquired they are placed in descending order with the largest followed by the second largest and so on. This leaves the firms in an order such that:

$$
\begin{equation*}
s_{1} \geq s_{2} \geq s_{3} \geq \ldots s_{i} \geq \ldots s_{N} \tag{5.7}
\end{equation*}
$$

It is then left to the researcher to decide on the appropriate number of firms to be used in the sample e.g. if an industry seems to be dominated by 3 major firms it might be prudent to take a 3 firm concentration ratio. The formula for the concentration ratio is as follows:

$$
\begin{equation*}
C R_{m}=\sum_{i=1}^{m} s_{i} \tag{5.8}
\end{equation*}
$$

So for the 3 firm concentration ratio one would simply sum the market shares of the greatest 3 firms which should also be the first 3 in the ordering sequence.

### 5.3.1.3 Conditions of Entry

Seller concentration is only one facet of a market which, without others, will not necessarily lead to abuse of position and higher prices (Carlton and Perloff, 1994). Consider, for example, an industry with 3 major firms would seem in a perfect position to collude and drive up industry prices. Assume that they do so and that prices now significantly exceed marginal cost resulting in abnormal profit for the firms (price equals marginal cost is a perfect competition pricing condition which leaves firms making normal profit) ${ }^{7}$. A non-active firm (one that does not currently sell in the market) would want to enter the market to produce and capture some of the abnormal profit. If it is easy for the firm to enter and compete in the market then they will do so, which will reduce prices (through larger output) and share the industry profits amongst more firms leader to lower individual profits. Non-active firms will continue to enter the market until profits are brought down to a level such that profits for the next firm to enter would be negative.

This example shows that there is not necessarily a link between concentration and profits. Indeed for a few sellers to abuse the concentration of the market and make use of their market power they must be to able to discourage or prevent other firms for entering and capturing some of the market profits. This prevention is enabled by barriers to entry, which make it more difficult for new entrants to compete than for incumbents. Some are a natural feature of the market, such as economies of scale, whilst others are created by the incumbent and their actions, such as advertising. Bain (1965) considers the height of a barrier to entry to be given by the increase in price above average cost that can be maintained by the incumbent firms. Normally any increase over average cost would encourage a new entrant into the market. He defines 3 types of barrier into which the majority of specific examples will fit.

Economies of Scale Economies of scale describe the considerable fall in average cost that occur with increasing production. Considering a new entrant into a market; the new entrant will have to produce at a similar scale to the incumbents otherwise their average cost will far

[^33]exceed that of the other firms and hence face reduced margins and lower profits. If they do produce at a similar level to the incumbent firms it will flood the market with goods and depress prices leading to reduced profits all round which an unestablished firm would be less able to absorb. Additionally industries with such economies of scale position the incumbent firms to be more aggressive in discouraging competition. Upon entry the incumbent firms can reduce prices to their lower average cost which will require the entrant to absorb not only the fixed costs of entry but also the losses on output until it reaches the same level of output as the other firms, which it is unlikely to do.

Product Differentiation In some markets, such as washing detergents, all products perform the same function, which leaves the majority of competition between different suppliers to be based on marginal differences. This type of market is swayed heavily by brand loyalty of consumers and firms spend a great deal of money trying to build and maintain it. This acts as a significant barrier to entry for new producers as overcoming this brand loyalty will require either; a better value proposition, through lower price, better quality, etc, or through a significant advertising spend. Both options represent additional costs that will make entry into the market less profitable and therefore less attractive.


#### Abstract

Absolute Cost Advantage Incumbents within a market will hold a natural advantage over any potential entrants simply by virtue of being established in the market. They will have a solid customer basis, established production lines, and ongoing research and development of product and process. Unless the product is very simple or the production processes well known, these advantages will give the incumbent an absolute cost advantage; it will cost them less to make the product. Similarly the history they have built within the market will enable them to gain finance more cheaply to expand capacity. These cost advantages will create a more hostile entry environment for any firm considering the market and create a disincentive.


Additional Barriers to Entry Though these three were those defined by Bain (1965) there are other variables that have since been identified as important considerations in the analysis of competition within a market. The strength and penetration of Unions within a given work force can determine how well market power can be abused to increase market performance. In highly unionised markets high levels of market power are more likely to be translated into improved contracts and higher wages for workers than into profits. The converse can also be said, low levels of unionisation will allow the firms to capture most of the market power in terms of improved profits. Additionally it is important, for completeness, to consider the levels of buyer concentration to offset the effects of seller concentration. Just as a single seller in the market can increase prices through lack of alternatives for consumers, a single buyer can decrease prices within a market as the sellers have no alternatives and therefore cannot exercise any market power they may have.

### 5.3.1.4 Benefits of the Structure - Conduct - Performance (SCP) model

Bolt and Humphrey (2010) remark that the SCP model is attractive to academics and regulatory bodies alike due to its simplicity, theoretical grounding, and ease of application. It is of particular attraction to policy makers because it follows a relationship that they can affect. Under the structure conduct performance model it is fairly simple for regulators to control the market shares available to companies and sanction any collusion. If equitable market shares are maintained and collusion is prevented competition should thrive in the market and continue to provide greater social benefit than private benefit. An alternative where such legislation would not be effective is unlikely to be as popular with regulators.

### 5.3.1.5 Disadvantages of the SCP

Whilst the SCP model has advantages and seems to follow a logical sequence to draw its causal relationship, there are a number of issues that have generated a great deal of academic criticism. Church and Ware (2000) categorise the main criticisms into two distinct areas, measurement and concept, and such segmentation will be utilised here also.

## Measurement Issues

Market Power Profitability was posited as a key variable for the SCP model as it is seemingly the only way to determine market performance and hence, market power. There are several alternatives for an appropriate measure of profitability; rates of return, price cost margins and Tobin's Q. Whilst they represent good measures of monetary profit, their suitability for the theoretical model is not always as good. ${ }^{8}$

Rates of return are a calculated measures of monetary value, which leaves them open to a number of vulnerabilities during the calculation process. These vulnerabilities include the appropriate way; to measure depreciation (accounting convention is typically to use straight line depreciation which causes varying rates of return), to include intanglible assets such as customer loyalty (which have no monetary value), to account for inflation, and to consider capitalisation of market power. It is also important to realise that accounting rates of return are not the same as economic rates of return. Accounting rates of return measure a ratio of accounting profits to book value and are influenced by a number of factors which causes a divergence from the true economic rate of return, which would leave to an inaccurate statement of market power.

A second alternative for measuring profitability and hence market power is the price - cost margin which is the more direct approach and approximates the Lerner index. The Lerner index uses the difference between price and marginal cost to determine the extent to which a firm can exercise its market power for additional profit. In the past, marginal cost data was incredibly difficult to find and so approximations were made using average total cost.

Introduced by Collins and Preston $(1968,1969)$, price cost margins are an attempt to address the lack of marginal cost data by substituting marginal cost for average variable cost in an aggregated formula (Church and Ware, 2000), typically:

[^34]\[

$$
\begin{equation*}
P C M=\frac{(\text { Sales Revenue }- \text { Payroll Costs }- \text { Costs of Materials })}{\text { Sales Revenue }} \tag{5.9}
\end{equation*}
$$

\]

This option initially presents as a substitute for the true Lerner index. However, as noted within the discussion of rates of return, an imperfect substitute will necessarily generate measurement error and cause issues with the estimation. Substitution into this approximation of the appropriate variables and comparison with the true Lerner index quickly highlights a definite bias within the equation which could be quite large ((Schmalensee, 1989)).

$$
\begin{align*}
& \frac{P-M C}{P}=\frac{P-\nu-(\rho+\delta)\left(\frac{K}{Q}\right)}{P} \\
& \frac{P-M C}{P}=\frac{P Q-\nu Q}{P Q}-(\rho+\delta) \frac{K}{P Q} \tag{5.10}
\end{align*}
$$

Here $P$ gives price, $Q$ gives output, $K$ gives dollar value of capital employed, $\delta$ is depreciation, $\rho$ the competitive rate of return, and finally $\nu$ the variable cost per unit. The second part of the equation, containing $\rho$ and $\delta$, provide us with the bias, or measurement error, associated with using a price cost margin rather than the Lerner index.

Corrections for this bias can be made through the addition of assets adjusted for revenue into the equation, however strong assumptions are made by the use of this method and the addition of the adjusted asset variable. The assumptions are that, a correct valuation of capital can be made so as to give a value for $K$, and that depreciation and risk free rates are equal across all industries.

However, modern firms can, and regulary do, estimate their marginal cost data with accurate forecasts of input prices and demand. It may be more difficult for an individual researcher to have access to the same predictions which renders use in empirics slightly more challenging than simple payroll and materials costs which are more typically reported in financial statements.

Tobin's $q$ is a method of valuing a company that is typically used in financial markets. It is market value of a firm adjusted by the replacement cost of its assets. Strictly, in a fully
competitive situation the value of Tobin's q should be 1 , therefore values greater than 1 are reflections of the financial markets beliefs about the firms ability to earn abnormal profits, a result of the exercise of market power. As a measure of profitability for application to the SCP model Tobin's $q$ is not without its own problems which fall mainly into the category of correctly measuring the $q$ value. Much like rates of return, Tobin's $q$ is vulnerable to inaccurate inclusion of intangible assets (such as investment in research and development, training, and advertising), to inaccurate valuation of assets (inflationary adjustments are stepped rather than continuous and there may be no efficient secondary market for the assets held by the company), and failing to account for Ricardian rents (the use of a superior input or production process that could sold or licensed for higher values than the standard inputs and processes).

Conceptual Issues Whilst a number of proximal problems have been identified with measurement and application of the SCP model, there are more distal issues at play which go to the very foundation of the model.

The typical assumption of the SCP model equation is that the variable coefficients speak to the relationship between market structure and long run profitability. Under such assumptions firms may make short term economic profits (even without exercising market power) and those exercising market power may not necessarily make additional profits. Salinger (1990) points out however, that this only applies if indeed the firms are in long run equilibrium. The suggestion is then that a more appropriate application is to use the equation to determine the relationship between short run profitability (price cost margin in this case) and market structure. He supports this by arguing that in the short run capital costs are sunk and so average variable costs become a very good proxy for marginal cost (even though it is expected that marginal cost will strictly exceed average variable cost).

An additional assumption seems to be that if certain structural variables are related to performance (and hence market power), then they can also be said to cause them. The SCP model has in comparative study (Weiss, 1974) been called the differential collusive hypothesis
after the focus on exploitation of market power to increase profits. Demsetz (1973) and Demsetz (1974) presents a different perspective of the causes of market power and seller concentration. The core argument of his model is that in a market with asymmetric firm efficiencies those that have the greatest efficiencies will have lower costs and therefore be able to secure greater market share and capture higher profits. As some firms have larger market shares and also greater profits there will be a positive correlation between concentration and profits even though in truth both are correlated with a third variable, lower costs. Obviously in this situation there is not a market wide increase in profits, increases in concentration lead to higher profits for the larger firms but not the smaller ones. This model is known as the differential efficiency hypothesis due to its focus on the efficiency of firms rather than the concentration. Whether the differential efficiency model is an acceptable alternative or whether it too has problems matters not; it demonstrates that there is not a single explanation for the effects on profitability found in markets.

The primary assumption of the SCP model is that of a causality chain progressing uni-directionally from structure to performance and thus we get the empirical estimations with profitability as the dependent variable with concentration and several barriers to entry variables as independent variables (Cabral, 2000). The simplicity of the model in this sense is its strength and its weakness. Researchers, (Church and Ware, 2000; Cabral, 2000), find that the simplicity is a much greater weakness than strength; intuition would more strongly agree with a bi-directional model. Consider, for example, a firm that has a slight efficiency advantage in production; it will have better margins and a greater profit, this will lead it to grow and gain market share, which in turn will force some smaller firms out of the market, leading to a more concentrated industry. This is an entirely plausible chain of events, however it works in the opposite direction to the assumed causality chain of the SCP model. Not only does this represent a conceptual issue it also represents a practical issues. If the independent variables are not exogenous and are in fact endogenous within the model then any estimations will be very biased (Verbeek, 2004). Biased estimates in this way will make the validity of any results highly suspect and in most cases would be safer to disregard.

Lastly the SCP model assumes industry symmetry, that the effects of any given variable hold across all markets and that anything which causes a difference across markets is included as an explanatory variable. There are a huge number of variables that will affect the performance of a firm within a market, even given the narrow scope of the causal relationship central to the SCP model. The huge number of variables are also likely to interact in different ways in each industry, especially when one considers the differences in age, composition, and historical relationships. Further, it is unlikely all of the relevant factors in Industry A would be relevant to Industry B. Therefore, it is difficult to conclude that the explanatory variables will have symmetric effects across all industries. It is also typical for only a small number of explanatory variables to be used in empirical estimations due to difficulties with data and constraints on degrees of freedom. Such small numbers of explanatory variables make it difficult to concur that all of the contributory effects are included leading to misspecification within the model.

### 5.3.2 Structure Conduct Performance: Concluding Remarks

The SCP model is a fairly old model with the seminal work originating with Bain (1965). The empirical model itself is fairly simple and can enable a researcher to investigate a number of potential barriers to entry as well as considering the effect of concentration on the profitability of a market. The benefits of the SCP model are strong, particularly for use in research or regulation applications (Bolt and Humphrey, 2010). Its easily understood reasoning and implications make it a very good introduction to industrial organisation empirical work, however, it is, as frequently documented and extensively examined, a model built on shaky foundations.

The measurement issues themselves render the model weak and the addition of the conceptual issues only serve to seal the fate of the model and consign it to the academic past. Though the measurement issues are numerous, the conceptual issues which have been considered here are arguably more important. Of particular concern is the ease with which a intuitive and theoretical argument can be made against the linear, uni-directional causality
assumption of the model. It is very difficult to overlook the significant disadvantages of the model in terms of potential data collection, inaccuracy or unreliability of results, and refuted assumptions to conclude that the SCP model is usable; especially as other models are developed which cover many of the weaknesses of this model. One such new model, or in this case family of models, is the new empirical industrial organisation models which improve upon the SCP model through reliance on theoretical models of oligopoly and the assumption that marginal costs information is unobservable.

### 5.3.3 The New Empirical Industrial Organisation Model

### 5.3.3.1 Introduction

The New Empirical Industrial Organisation (NEIO) model evolved over several studies and addresses a number of the key weaknesses of the SCP paradigm (Bain, 1968). The focus of this evolution was to build a more theoretical robust model. Bresnahan (1989) introduces a lot of the works that have contributed to the evolution and presents the key options and choices a researcher must make in conducting a NEIO based study.

More a family of models rather than a particular example, the NEIO model allows the weaknesses of the SCP paradigm to be overcome in three key areas; accounting data, industry symmetry, and firm behaviour. Building from strong theoretical grounding regarding firm behaviour allows simple, defensible models to be constructed and, in addition, gives validity to any direct hypothesis testing of degrees of market power.

The problems derived from use of certain accounting data caused a number of problems for the SCP model, becoming the source of many criticisms. NEIO models avoid this issue by acknowledging that no useful measures of marginal cost will be obtained rendering obsolete any observations of price - cost margin based measures such as the Lerner index or alternative options using variable cost. Once acknowledged, the model is developed without reliance on any such data which shields it from the problems faced by the SCP model.

Industry symmetry was another key feature of the SCP model that attracted a great deal of
criticism in academic works. Bresnahan (1989) notes that industries are idiosyncratic and that practitioners in the NEIO area are skeptical of inter industry comparisons unless the industries are particularly closely related. To that end, the NEIO model focuses instead on individual markets avoiding the need to make strong assumptions about the symmetry of industries.

Discussion of the SCP model centres around the choice of variable used to represent the different barriers and the profitability parts of the equation rather than the formation of the equation itself. The NEIO model is quite the opposite where the majority of discussion is dedicated to building the model to be estimated from basic foundations and overcoming econometric issues. As the model is built, external factors such as the identification problem (Bresnahan, 1982), variable or constant marginal cost, and identification of market power are examined.

### 5.3.3.2 The Model

Convention begins with a simple statement of the inverse demand and cost functions as follows,

$$
\begin{align*}
& P=P(Q, Y, \delta) \\
& C=C\left(q_{i}, W, \tau\right) \tag{5.11}
\end{align*}
$$

where $Q$ is total output, $q_{i}$ is the output of the individual firms, $Y$ is an aggregate term for variables which shift the demand curve (exogenous demand shocks such as floods or financial crisis), and, $\delta$ and $\tau$ are parameters to be found.

These foundation equations allow us to access those which are more important to the estimation process, marginal revenue and marginal cost. marginal cost is found as a simple differentiation of the cost function and marginal revenue as a differentiation of total revenue (price multiplied by quantity). Both of these identities are found below, note marginal cost is
simpler than marginal revenue as price must be multiplied by quantity which necessitates differentiation of a product rather than a simple fraction.

$$
\begin{gather*}
M C\left(q_{i}, W, \tau\right)=\frac{d C\left(q_{i}, W, \tau\right)}{d q_{i}} \\
M R(Y, \delta, \lambda)=P+\frac{d P}{d Q} q_{i} \lambda_{i} \tag{5.12}
\end{gather*}
$$

$\lambda$, which can also measure the conjectural variation approach of oligopoly theory ${ }^{9}$, measures the conduct within the particular market. As a simple example, in a perfectly competitive market $\lambda$ would be equal to 0 which collapses the marginal revenue equation to price as expected. Applying the profit maximising condition where marginal cost is equal to marginal revenue generates equation 5.13 which can be rearranged in terms of price.

$$
\begin{align*}
M C\left(q_{i}, W, \tau\right) & =M R(Y, \delta, \lambda) \\
M C\left(q_{i}, W, \tau\right) & =P+\frac{d P}{d Q} q_{i} \lambda_{i} \\
P & =M C\left(q_{i}, W, \tau\right)-\frac{d P}{d Q} q_{i} \lambda_{i} \tag{5.13}
\end{align*}
$$

The theoretical ideal measure for market power is the Lerner index, equation 5.14,

$$
\begin{equation*}
L=\frac{P-M C}{P} \tag{5.14}
\end{equation*}
$$

Upon careful inspection of equation 5.13 , it is easy to see that a simple rearrangement will give price minus marginal cost and we need only make a two additional transformations to both sides of the equation to generate a very neat, comparable equation which demonstrates the key role $\lambda$ plays. Dividing by $P$ and multiplying the right hand side by $\frac{Q}{Q}$ produces:

$$
\begin{equation*}
\frac{P-M C\left(q_{i}, W, \tau\right)}{P}=\frac{d P}{d Q} \frac{1}{P} \frac{Q}{Q} q_{i} \lambda_{i} \tag{5.15}
\end{equation*}
$$

[^35]Rearranging this expanded equation gives some more familiar identities:

$$
\begin{align*}
& \frac{P-M C\left(q_{i}, W, \tau\right)}{P}=\frac{d P}{d Q} \frac{Q}{P} \frac{q_{i}}{Q} \lambda_{i}  \tag{5.16}\\
& \frac{P-M C\left(q_{i}, W, \tau\right)}{P}=\frac{s_{i} \lambda_{i}}{\epsilon} \tag{5.17}
\end{align*}
$$

The simplification seen between equations 5.15 and 5.16 present readers with the more recognisable quantities of market share $\left(s_{i}\right)$ and elasticity of demand $(\epsilon) . \lambda$ can now clearly be seen to proportionately related to the Lerner Index (which is given in basic term form on the left hand side). Noting that a solution simply requires finding the equilibrium between all buyers and sellers, the variables of interest are those representing the unknown shifting parameters $\delta$ and $\tau$ as well as the conduct parameter $\lambda$.

The Identification Problem The identification problem features in all econometric work as a fundamental consideration as to whether there is sufficient information contained within the model to estimate any unknown parameters; in this case the conduct of the firms. Church and Ware (2000) spend a little time on this issue, considering the supply and demand relationships in aggregate and graphical fashion. However it was Bresnahan (1982) whose seminal work in this area presents the method for establishing identifcation of the oligopoly equation which is referenced by Church and Ware (2000) and closely followed over the next few paragraphs of chapter. The problem can be summarised intuitively in that, with two endogenous variables in quantity and price, should one exogenous variable exist in either function that is not in the other, then the model will be identified and a solution will be possible.

The Order Condition and Discovering Market Power An identified model does not guarantee that the parameters of interest within the model, $\lambda$ and $\tau$, can be disentangled from the function as a whole. Separating the specific effects of these parameters requires some additional thinking. The main focus of the model is the investigation of market power which
leads to an important question; will firms behave different if they have market power to those which do not? With the answer to this question it is then possible to separate competitive markets from those where market power is present.

Intuitively markets where there is market power will behave differently to those which are competitive. In particular they will react differently in terms of price setting behaviours, including reaction to external shocks. With these intuitive statements a model can be exposed which details the different responses and allows the identification of market power. Though a similar model was presented by Carlton and Perloff (1994) the model below is credited to Church and Ware (2000) and is used as an exemplar.

Taking a demand curve in form of equation 5.18,

$$
\begin{equation*}
P=\delta_{0}+\delta_{1} Q+\delta_{2} Y_{1}+\delta_{3} Y_{1} Q+\delta_{4} Y_{2} \tag{5.18}
\end{equation*}
$$

with deltas as the parameters to be estimated, $Y_{1}$ a substitute price, and $Y_{2}$ measuring income. $Y_{1}$ appears twice affecting the position of the curve through the $\delta_{2} Y_{1}$ term and affecting the slope of the curve through the interaction term $\delta_{3} Y_{1} Q$. Simple differentiation gives:

$$
\begin{equation*}
\frac{d P}{d Q}=\delta_{1}+\delta_{3} Y_{1} \tag{5.19}
\end{equation*}
$$

In addition a simple linear marginal cost curve is assumed:

$$
\begin{equation*}
M C=\tau_{0}+\tau_{1} Q+\tau_{2} W \tag{5.20}
\end{equation*}
$$

Here the $\tau$ parameters and exogenous variable $W$ complete the first order conditions for this market. Aggregation of the supply relationships for the whole industry gives a slight change to equation 5.16, instead of several $q_{i}$ terms there are now $Q$ terms, where $Q=\sum q_{i}$. Substitution of the derived first order conditions into the aggregate supply relationship presents equation 5.21,

$$
\begin{equation*}
P=\tau_{0}+\tau_{1} Q+\tau_{2} W-\left(\delta_{1}+\delta_{3} Y_{1}\right) \lambda Q \tag{5.21}
\end{equation*}
$$

Collection of terms leaves,

$$
\begin{equation*}
P=\tau_{0}+\left(\tau_{1}-\delta_{1} \lambda\right) Q-\delta_{3} \lambda Y_{1} Q+\tau_{2} W \tag{5.22}
\end{equation*}
$$

equation 5.22 and the demand curve specified at the start of this section, equation 5.11 create the system of equations that will be used in the determination of the unknown conduct parameter. The order condition is clearly satisfied as $Y_{2}$ and $W$ are both exogenous and unique to one of the equations. However, whilst estimation of the model may give parameter values, these will be combined and not component values i.e. for $\delta_{3} \lambda$ rather than $\delta_{3}$ and $\lambda$.

The keen eye will note that there is a saving grace in the demand function, where estimation would give a parameter value for $Y_{1} Q$ which is solely represented by $\delta_{3}$, hence, division of the supply relationship parameter for $Y_{1} Q$ by this estimate of $\delta_{3}$ will reveal the conduct parameter. The interaction term proves crucial as without it no identification of the conduct term can occur.

Initially the use of $\delta_{1}$ might be considered and could be applied by following a similar process as with $\delta_{3}$, however, closer inspection reveals that the counterpart parameter $\tau_{1}-\delta_{1} \lambda$ would not allow a simple process of division to give the answer required. Rather, it would require further estimation of a different equation to give a value for $\tau_{1}$ also. This creates a more complex system and defeats the original goal. ${ }^{10}$

Intuitively, the perfectly competitive industry would respond to any changes to the system by restoring a price equals marginal cost level of output, a monopolist on the other hand would respond by shifting to where marginal cost equals marginal revenue, this would obviously not be in the same place as price equals marginal cost. The difference in responses would then suggest price taking or price making behaviour and can be clearly seen in a graphical

[^36]representation (Figure 5.3). Without $\delta_{3}$ and the interaction between $Y_{1}$ and $Q$, any changes in $Y_{1}$ will simply shift the demand curve to a new equilibrium whether the firm is competitive or monopolistic. With a non-zero value of $\delta_{3}$ and some effect of the interaction term the demand function will rotate rather than shifting which will leave the perfectly competitive equilibrium unchanged but change where marginal cost cuts marginal revenue and hence alter the profit maximising output for the monopoly firm.

Problems with the NEIO Model Family Though the NEIO set of models have significant benefits over the SCP paradigm in terms of their more rigorous foundations, they do struggle with one common problem: they are focused on a price - cost margin. It would seem that the attention given to more accurate modelling through theoretical development has focused on the relationship between price, cost and profit. Boone (2008) suggests that the theoretical foundations of price-cost margin based measures still lack robustness as measures of competition. He goes on to cite a number of authors (Amir, 2002; Bulow and Klemperer, 1999; Rosenthal, 1980) whose work shows increases in competition intensity lead to higher price cost margins rather than the converse which is to be expected.

Concluding Remarks The NEIO set of models presents a significant advancement over the SCP paradigm as developed by Bain (1965). These advantages arrive via; a more considered development of the model from theory, the use of data that is available rather than that which must be estimated or assumed (marginal cost), and no need for troubling assumptions such as industry symmetry. It does still, however, suffer from a base of price cost margin as estimation for the market power of each firm, which Boone (2008) has suggested could produce illogical results.

### 5.3.4 The Boone Models

Having suggested the inadequacies with price cost margin based models citing the illogical results found in several papers who found increasing competition led to greater price cost

(a) Not Identified

(b) Identified

Figure 5.3 Identification of Market Power (Church and Ware (2000)
margins (Amir, 2002; Rosenthal, 1980; Stiglitz, 1989), Boone (2008) sets about creating a new method for analysis of competition over periods of time. The method utilises two distinct measures, the first is an elasticity measure whcih simply requires that profit be positively related to efficiency $(\pi(\mathrm{Eff})>0)$. This measure is then used as a basis of the second measure relative profit differences, which compares a group of firms operating within a market. In creating this model his aim was to derive a "theoretically robust" measure which did not "pose more stringent data requirements than price Cost Margins" (Boone, 2008) (page 1246).

Further, he cites a desire to allow "a comparison between the new measure and price cost margin for a number of industries over time" (page 1246). This is an important step after identifying that in some examples the results would be unlikely to agree, as it is then necessary to test the extent to which this new measure would disagree with studies previously conducted. If, as mentioned, only $1 \%$ of the instances disagree then it is of little consequence and can be put down to empirical error, if, however, $20 \%$ are in disagreement then it would represent a significant concern as to the validity of the new and the old models.

### 5.3.4.1 Conceptual Foundations

The relative profit difference model focuses on efficiency and profits generated by firms within a particular market. Consider the following scenario. Three firms A,B,C have different efficiency levels $1,2,3$ (larger numbers represent greater efficiency). In a normal situation where competition is based on output, and therefore follows a Cournot specification, it is easy to give rank to the firms based on their efficiency which would be C (efficiency of 3 ), B (efficiency of 2), A (efficiency of 1).

Any change to the market which intensifies competition, such as a switch to competition based on price (Bertrand specification) or a disruption in the market which frees up consumer choice (comparison website), will have an asymmetric effect on the firms. Greater intensity of competition will typically result in a price lowering (whether Bertrand or Cournot) by one firm so as to capture greater shares of the market; in our example prices will be reduced by one firm e.g. firm B.

Firms A and C will follow this by reducing their price to the same level so as to regain a level footing. This is where the differing efficiency levels take effect: greater efficiency results in lower costs. Firm C will be better able to deal with a lower price as it has lower costs, firm A on the other hand will find its margins squeezed much more tightly than those of C and so will struggle more greatly under this increased competition. Of course, firm C could cut its price further to a level such that firms A and B would make negative profits and therefore could not continue to compete. In doing so buyers will shift their custom to firm C and the weight of market output will increase for firm C.

The Boone model takes this intuitive series of events and looks for the effect to suggest the intensifying of competition; starting at the end and working back. The model suggests that reallocation of output or reduced prices will be detrimental for the less efficient firms and benefit the most efficient firms. To that end his model proposes a comparison between the relative profit difference (in our example) between firms C and firm A, with that of the relative profit difference between firm $B$ and firm $A$. If competition increases the value returned by the relative profit difference equation will increase.

The General Model This section will closely follow that in Boone (2008) to build his model and discuss the principles under which it has been developed. As with all models Boone begins with setting the situation,

- There are $I$ firms which either compete in the market or are available to enter
- Individual firms, $i$, are ranked where lower $i$ represents higher efficiency leaving:

$$
n_{1} \geq n_{2} \geq \cdots \geq n_{I}
$$

- Each firm chooses a vector of strategic variables; $a_{i} \in \mathbb{R}^{\mathbb{K}}$
- $a_{i}$ will be positive if firm $i$ is active within the market in question
- These choices result in an output vector for each firm, $q\left(a_{i}, a_{-i}, \theta\right) \in \mathbb{R}_{+}^{\mathbb{L}}$
- $a_{-i}$ represents the strategic variable choice of all other firms i.e.
$a_{-i}=\left(a_{1}, \ldots, a_{i-1}, a_{i+1}, \ldots, a_{n}\right)$
- $\theta$ represents firm conduct, specifically how aggressive they are, and could be related to the availability of acceptable substitutes or the type of competition within the market (Cournot and Bertrand)
- The strategic variable choices also lead to a price vector for firm is output, $p\left(a_{i}, a_{-i}, \theta\right) \in \mathbb{R}_{+}^{\mathbb{L}}$
- Cumulatively, the costs of production for firm $i$ are then $C\left[q\left(a_{i}, a_{-i}, \theta\right), n_{i}\right]$ where $n_{i} \in \mathbb{R}_{+}$

The key first order conditions associated with a given output vector are as follows:

$$
\begin{align*}
\frac{d C(q, n)}{d q_{l}} & >0 \\
\frac{d C(q, n)}{d n} & \leq 0 \\
\frac{d\left(\frac{d C(q, n)}{d q l}\right)}{d n} & \leq 0 \tag{5.23}
\end{align*}
$$

They hold for each output vector, $l$, such that $l \in(1,2, \ldots, L)$ where the second order condition is strict for at least one combination of $q$ and $l$. These conditions are intuitively self-evident when considering the observations made before specification of the model.

The first condition simply gives higher costs for higher levels of production. The second condition states that as efficiency increases costs will decrease (or at least remain the same). This can be extended to compare between firms where a more efficient firm will produce the same output for a lower cost than a less efficient firm. The third condition states that increasing efficiency will result in a falling, or non-increasing, level of marginal cost.

This can again be used as a relative comparison; a more efficient firm will produce the same output at the same, if not lower, marginal cost than a less efficient competitor. ${ }^{11}$ Having laid out the situation prior to increases in competition analysis now moves to the conditions firms will use to decide upon entry, and which set of strategic variables to choose so as to maximise profit.

$$
\begin{gather*}
\max _{a_{i}}\left[p\left(a_{i}, \hat{a}_{-i}, \theta\right)^{T} q\left(a_{i}, \hat{a}_{-i}, \theta\right)-C\left(q\left[a_{i}, \hat{a}_{-i}, \theta\right], n_{i}\right)\right]-\gamma_{i}<0 \quad \text { implies } \quad \hat{a}_{i}=0 \\
p\left(a_{i}, \hat{a}_{-i}, \theta\right)^{T} q\left(a_{i}, \hat{a}_{-i}, \theta\right)-C\left[q\left(a_{i}, \hat{a}_{-i}, \theta\right), n_{i}\right]-\gamma_{i} \geq 0 \quad \text { for } \quad \hat{a}_{i} \neq 0 \\
\arg \max _{a}\left(p\left(a_{i}, \hat{a}_{-i}, \theta\right)^{T} q\left(a_{i}, \hat{a}_{-i}, \theta\right)-C\left[q\left(a_{i}, \hat{a}_{-i}, \theta\right), n_{i}\right]\right)=\hat{a}_{i} \tag{5.25}
\end{gather*}
$$

The keen eye will note the addition of $\gamma_{i}$, this term represents the entry cost of the market. The first two arguments give the list of possible actions for any of the firms. Obviously the first argument is simply a zero profit function; should the firm be unable to cover costs of production and recoup their entry costs then they will choose the 0 value action $\left(\hat{a}_{i}=0\right)$ and not enter the market. The second argument states that for all strategic variable sets that give a positive return (including the cost of entry) are considered as viable options which cause the firm to remain in, or enter, the market. The final condition denotes a profit maximising strategy as employed by the firms i.e. they will choose the strategic variables set which maximising their standard profits (revenue - costs). Assuming symmetry of the equilibrium outcome Boone then proposes that the following price and quantity functions should be applicable for this new competition model in its empirical form:

$$
\begin{align*}
& p(n, N, \mathcal{I}, \theta) \\
& q(n, N, \mathcal{I}, \theta) \tag{5.26}
\end{align*}
$$

$N$ is an aggregate efficiency index which is a function of individual firm efficiencies $n_{i}=\left(n_{1}, \ldots, n_{l}\right)$ and $\mathcal{I}$ is the set of firms whose choice satisfies the first condition and

[^37]therefore enter the market. To ease understanding it is assumed that each firm in the market produces only one product and faces a demand curve determined by its output as well as that of the other firms within the market as in equation 5.27,
\[

$$
\begin{equation*}
p\left(q_{i}, q_{-i}\right)=a-b q_{i}-d \sum_{j \neq i} q_{j} \tag{5.27}
\end{equation*}
$$

\]

The firm also faces constant marginal costs that are inversely proportional to its efficiency i.e. $\frac{1}{n_{i}}$. With these functions in mind the firm, firm $i$, then chooses its output level, $q_{i}$, so as to maximise profit, which will solve equation 5.28:

$$
\begin{equation*}
\max _{q_{i} \geq 0}\left[\left(a-b q-i-d \sum_{j \neq i} q_{j}\right)-\left(\frac{1}{n_{i}}\right) q\right] \tag{5.28}
\end{equation*}
$$

Variable conditions for this equation are that:

$$
\begin{align*}
a>\frac{1}{n_{i}} & >0 \\
0 & <d \leq b \tag{5.29}
\end{align*}
$$

Simple differentiation then presents the Cournot Nash Equilibrium (a standard first order condition),

$$
\begin{equation*}
a-2 b q_{i}-d \sum_{j \neq i} q_{j}-\frac{1}{n_{i}}=0 \tag{5.30}
\end{equation*}
$$

Boone goes on to assume that all I firms produce positive levels of output, which enables for a solution to the $I$ first order conditions to be found and aggregated into a market output function. This function (equation 5.31) includes the defined variable $N$, which is equal to a summation of the firm level marginal costs i.e. $N=\sum_{j=1}^{I} \frac{1}{n_{j}}$.

$$
\begin{equation*}
q\left(n_{i}\right)=\frac{\left(\frac{2 b}{d}-1\right) a-\left(\frac{2 b}{d}+I-1\right) \frac{1}{n_{i}}+\sum_{j=1}^{I} \frac{1}{n_{j}}}{[2 b+d(I-1)] l\left(\frac{2 b}{d}-1\right)} \tag{5.31}
\end{equation*}
$$

equation 5.31, gives the aggregate equilibrium output of the firm and has been specified as a function of its own efficiency and an aggregate efficiency index, which can be considered in a functional format $q(n, N, \mathcal{I}, \theta)$ as was proposed in equation 5.26 (Page 194). This allows Boone to respecify the firms profit equation in terms of this new notation:

$$
\begin{equation*}
\pi\left(n_{i}, N, \mathcal{I}, \theta\right) \equiv p\left(n_{i}, N, \mathcal{I}, \theta\right)^{T} q\left(n_{i}, N, \mathcal{I}, \theta\right)-C\left[q\left(n_{i}, N, \mathcal{I}, \theta\right), n_{i}\right] \tag{5.32}
\end{equation*}
$$

Each firm that enters the market will face two costs, that of entry $\gamma_{i}$, and that of production $C\left(q, n_{i}\right)$. An important distinction is made between these two costs; entry cost, $\gamma_{i}$, is able to vary positively and negatively with rising efficiency, $n_{i}$, whereas production costs, $C\left(q, n_{i}\right)$, vary in a weakly negative manner (they either stay the same or fall) with rising efficiency. This distinction stems from the possibility that firms could either be more efficient at both entry and production or, in the alternative where it varies positively (higher efficiency leads to high costs), the firm may have invested in additional research and development, capital or larger factories so as to improve production technologies or take advantage of economies of scale.

Boone (2008) confirms the validity of the model through two key conditions which demonstrate an increase in competition. There are two ways in which this occurs, increasing entry from outside firms (typically due to lowered entry costs) or more aggressive competition between firms (such as a shift from Cournot to Bertrand Competition). The proof applies the envelope theorem to the defined profit function and this in turn allows for the definition of these competition effects whereby positive movements of either theta or epsilon $(\delta \theta>0)$ or $(\delta \epsilon>0)$ will bring about greater competition if the follow equations are increasing in $n_{i}$.

$$
\begin{align*}
& \frac{d \ln \left\{-\left.\frac{\delta C\left[q\left(n_{i}, N, \mathcal{I}, \theta\right), n\right]}{\delta n}\right|_{n=n_{i}}\right\}}{d \theta}  \tag{5.33}\\
& \frac{d \ln \left\{-\left.\frac{\delta C\left[q\left(n_{i}, N, \mathcal{I}, \theta\right), n\right]}{\delta n}\right|_{n=n_{i}}\right\}}{d \epsilon} \tag{5.34}
\end{align*}
$$

equations 5.33 and 5.34 are representatives of the output reallocation effect discussed on Page 191 of the paper where, in times of more intense competition, output shifts from less efficient firms to more efficient firms. The only slight difference here is that they are done where $q(\cdot, n)$ is a vector. Simpler restatements are available in Boone (2008) (page 1251) but need not be repeated here.

What is important is how to best represent the reallocation effect. An obvious suggestion would be in terms of the products that are reallocated, however, as Boone (2008) points out "[I]if goods are not perfect substitutes, $\frac{q\left(n^{*}\right)}{q(n)}$ is not well defined (dividing apples by oranges)" (page 1251), which leaves monetary valuations as the best option. A monetary valuation of the reallocation effect could be made via either revenue or cost calculations.

Revenue is quickly discounted as competition is likely to alter prices as well as efficiency which does not allow for examination in isolation. Valuation via cost does however allow for such analysis and becomes the variable of choice. This leads to a fairly simple and intuitive ratio which will allow for direct comparison and analysis of how competition affects any two firms within the market. Along with the conditions (equations 5.23) this means that for a rise in competition, ratio 5.35 will increase; the more efficient firm will have a greater reduction in costs than the less efficient firm.

$$
\begin{equation*}
\frac{-\left.\frac{\delta C\left[q\left(n_{i}, N, \mathcal{I}, \theta\right), n\right]}{\delta n}\right|_{n=n_{i}}}{-\left.\frac{\delta C\left[q\left(n_{j}, N, \mathcal{I}, \theta\right), n\right]}{\delta n}\right|_{n=n_{j}}} \tag{5.35}
\end{equation*}
$$

### 5.3.5 The New Model

Having built a general model and modeled some of the interactions between the firms (entry and exit) Boone (2008) introduces the addition that form the core of his model. The addition is to measure competition intensity by relative profit differences. The function (equation 5.36) is shown as a robust measure for changes in both $\theta$ and $\epsilon$ (conduct and entry) by equation 5.37.


Figure 5.4 Graphical Representation of Intensifying Competition

$$
\begin{gather*}
\frac{\pi\left(n^{* *}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}{\pi\left(n^{*}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}>0  \tag{5.36}\\
\frac{d\left[\frac{\pi\left(n^{* *}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}{\pi\left(n^{*}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}\right]}{d \theta}>0  \tag{5.37}\\
\frac{d\left[\frac{\pi\left(n^{* *}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}{\pi\left(n^{*}, N, \mathcal{I}, \theta\right)-\pi(n, N, \mathcal{I}, \theta)}\right]}{d \epsilon}>0 \tag{5.38}
\end{gather*}
$$

Whilst the algebraic exposition and resulting figures are useful, graphical representation makes intertemporal competition much easier to observe. Figure 5.4 ((Boone, 2008) pg 1252) is an exemplar showing changing competition the axis of normalised efficiency against normalised profits. Normalisation is done by adjusting the firms efficiency or profit by the lowest efficiency or profit and dividing that result by the range of profit or efficiency.

As can be seen in Figure 5.4 (Boone, 2008) an increase in similarity between goods sold in the market (an increase in substitute competition shown by a higher value of $d$ ) leads to a curve that lies below the initial curve at all values. This indicates more intense competition and, in general, any results which produce a curve that lays below another curve will indicate an increase of competition.
equation 5.37 provides us with 2 distinct advantages. It shows that the results specified (Figure 5.4 and equations 5.36 and 5.37 ) will hold for any three firms, and the graph showing one curve lower than another indicating increased competition, is a robust way to measure competition. This allows the researcher to use relative profit differences to create a graphical representation of the competition for a subset of firms within an industry and be confident that the results will hold for the whole industry.

An important additional note is made: sometimes the curves will not lie everywhere below or above each other (e.g. sometimes they will intersect). If the curves do not intersect then ordering can be done very simply, if they do intersect then the comparison is made through the numerical values of the areas under the curves, found through integration.

### 5.3.5.1 Application Considerations

Though the paper does not contain an application of the new measure, thought is given to particular variables or data that would make for better estimations. These include a discussion of what costs should be part of the cost function and which should form part of the cost of entry to the market and what alternatives are available when a research does not have certain bits of data.

Industry Classification Levels In competition studies definition of the market is typically the biggest difficulty facing a researcher. There are many methods to discover the extent of the market, but a favoured one is use of industry classification. It is in these terms that Boone (2008) specifies the size of the market, recommending 4 or 5 digit level, so that the key assumption of one dimensional efficiency is valid. He argues that at lower levels, particularly at the 2 digit level, it could be that two firms have efficiency advantages in two different goods that both fit within the 2 digit category. In order to constrain output and efficiency considerations to one product (one dimensional efficiency) the market must be sufficiently small. ${ }^{12}$

[^38]Cost Function vs Entry Cost equation 5.32 states that the profit of the firm should include the cost function $C\left(q, n_{i}\right)$ but not the entry cost $\gamma_{i}$. This then requires the researcher to distribute the costs associated with the firm to either the entry cost or the cost function. Variable costs (such as materials, production workers, and energy bills) are attributed to the cost function, whilst fixed costs can be distributed between either the cost function or the entry cost. The important distinction in this case is that only the entry cost can be increasing with respect to efficiency (higher efficiency leads to higher cost), therefore any such fixed costs (investments in research and development or capital stock) must be included in the entry cost. Fixed costs that fall with increasing efficiency can be included in either depending on the particular characteristics of model that the researcher is aiming for.

Alternatives (Boone, 2008) also discusses ways that variables can be measured when different levels of data are available. When measuring efficiency; if data on output is readily found then average variable costs should be used, if no data on output can be found then revenue divided by a price index is an effective proxy for output which can then be used in other measures, or lastly with information on the size of the labour force, labour productivity can be used as a proxy for efficiency.

### 5.3.6 Potential Drawbacks

There are three core assumptions that underpin the relative profit difference model; efficiency is one dimensional, a firm's efficiency level can be observed, and firms compete on a level playing field (different terminology used to describe the symmetry assumption on equilibrium) (Boone, 2008). Within various applications these three assumptions may be difficult to make hold, or may require fairly strict assumptions. One dimensional efficiency can sometimes be a difficult assumption to make, particularly when there are restrictions on the availability of market size data. If markets are too large it is likely that firms can produce at least two good which fit in the same market thus negating the assumption of one dimensional efficiency; one firm could be more efficient at producing one product, whilst another more efficient at a
second product. In this situation an increase in competition intensity would lead to each firm focusing on the product that are respectively more efficient at. Overall reallocation of profits and output would then be very difficult to separate making the analysis less than robust.

Observable firm efficiency is another philosophical question upon which a whole discipline of economics is based. Proponents of SFA or DEA models would suggest that efficiency is observable, though others might counter that these are imprecise estimates. If the researcher is happy to settle for imperfect estimates of efficiency then it is safe to assume firm efficiency is observable, all that is left is to decide the methodology of choice for estimating the efficiency values.

The final assumption of firms competing on a level playing field is a necessary condition as "neither RPD [...] can deal with the asymmetric case" (Boone, 2008) (page 1248). This assumption is otherwise known as symmetry assumption and requires that all firms face the same entry and exit conditions as specified in equation 5.25.

### 5.3.7 Concluding Remarks

The Boone (2008) model of competition represents an innovation in competition analysis that can overcome many, if not all, of the issues presented by price-cost margin based measures such as the SCP paradigm and the NEIO methodologies. The greater robustness and ease of applicability to markets where even only a small sub-section of firms can be examined make it a highly attractive method which is beginning to see usage within academic literature (Schaeck and Cihak, 2010; Gourlay et al., 2006).

### 5.4 Competition Summary

Each of the models presented and discussed in this section are viable candidates for use in the examination of competition within any industry; the volume of empirical works conducted on a broad range of different industries lay testament to that fact. However, it is becoming ever clearer that price cost Margin based models are prone to significant drawbacks in studies
where data is less available or in more complex markets. Whilst a number of researchers still prefer Price - Cost margin based models, there is a blossoming interest by researchers in the Boone measure and in particular its empirical robustness and ease of application. Of utmost importance will be a thorough look at which of the three models will best enable the examination and analysis of competition within the higher education sector.

### 5.5 Methodology: The Boone Measure of Competition

### 5.6 Introduction

Measuring competition within an industry is a highly desirable, yet complex undertaking. It has a long history which has undergone several structural shifts and seen a number of iterations within two main schools of thought. The relative profit difference model (Boone, 2008) is forming a new school of thought which deem the measure superior as it does not rely on many assumptions, nor does it require the approximation of particular measures of performance that are found in older methods. Though theoretically stronger, the Boone measure proposed is just that, theoretical. There is no empirical application within the paper. In order to use this superior model it is therefore necessary to examine an empirical applications of the measure and evaluate how the approaches shown might benefit this particular piece of research. It appears that there have been few direct applications of the Boone measure, Schaeck and Cihak (2010) and Deygun et al. being two prime examples.

### 5.7 Deygun et al.

### 5.7.1 Introduction

In this paper the authors consider a translation of the theoretical model into an applicable set of computations that allow a researcher to generate a comparison of competition between different regimes. In a more distal context, the paper suggests, this is a very simple two-step process as implied by Boone (2008). The two steps are:

1. Confirm that profits are positively related to efficiency of the firms: $\pi^{\prime}(E)>0$
2. Compute $\frac{\left[\pi\left(E^{\prime}\right)-\pi(\min E)\right]}{[\pi(\max E)-\pi(\min E)]}$

The researcher is then left with the relatively simple task of comparing, grapically or analytically, whether the area is less in the first or second regime (which would give a negative or positive sign from an analytical perspective) and hence whether competition was more stringent in the former or latter regime. Though in an overall sense this seems a fairly trivial undertaking, the nature of empirical observations dictates that a researcher will be unable to find the true relationship between the relative profit difference $(\rho)$ and the normalised efficiency measure $(\eta)$.

### 5.7.2 Sample Procedure

Practically speaking, the first step remains relatively straight forward. The authors suggest that the efficiency measures to be used in the comparison are generated by a SFA, and confirmation of their positive relationship with profit be secured via a basic linear regression. The second step is, however, less straight forward and requires more careful consideration. Consider first the objective, to be able to computational distinguish between two competition regimes whether, temporal or geographical. This will require the calculation of area and hence requires a curve to integrate. There in-lies the first challenge of moving from theory to application with the Boone estimator. In an empirical investigation a researcher would have to create a scatter plot of the different pairs of relative profit difference and normalised efficiency values $(\eta, \rho)$.

With a number of sample points $(\eta, \rho)$ it would be relatively easy to calculate a simple ordinary least squares (OLS) regression and use the resulting coefficients to determine a bounding curve to integrate, however, the difficulty posed by an OLS regression is that it takes the average effect of all of the data and can be much cruder than other methods. The authors suggest a polynomial quantile (PQ) regression as a far more appropriate manner in which to generate the bounding line.

The use of a PQ regression over OLS is beneficial in a two key areas. The first is its mathematical properties make it easy to use with integrals; the integral of a PQ regression is a simple linear function of its coefficients (see equation 5.39)

$$
\begin{equation*}
\int_{0}^{1}\left[\sum_{m=1}^{m=M} \alpha_{m}\left(\eta_{i t}\right)^{m-1}\right] \mathrm{d} \eta=\left(\frac{\hat{\alpha}_{m}}{m}\right)=\boldsymbol{h}^{\prime} \hat{\boldsymbol{\alpha}} \tag{5.39}
\end{equation*}
$$

where $\hat{\alpha}$ is a vector of the estimates of the regression coefficients $\hat{\alpha}_{m}$ and $\mathbf{h}$ is a vector of multiplying factors $\left(1, \frac{1}{2}, \ldots, \frac{1}{M}\right)$.

Obviously this makes calculating integral areas much easier, but a question remains over how to distinguish between the two different regimes. The solution to this, as presented by the authors, is rather elegant. The introduction of a product between a dummy variable and a second set of coefficients allows for a secondary regression to be formed, creating a secondary boundary. This occurs as follows:

$$
\begin{equation*}
\sum_{m=1}^{m=M} \alpha_{m}\left(\eta_{i t}\right)^{m-1}+\sum_{m=1}^{m=M} \beta_{m}\left(\left(\eta_{i t}\right)^{m-1} \times D_{i t}\right) \tag{5.40}
\end{equation*}
$$

where, for a before regime (B) and an after regime (A);

$$
D_{i t}= \begin{cases}0: & i, t \in \mathrm{~B} \Rightarrow \alpha^{B}=\alpha,  \tag{5.41}\\ 1: & i, t \in \mathrm{~A} \Rightarrow \alpha^{A}=\beta+\alpha\end{cases}
$$

The $\hat{\beta}_{m}$ coefficients are then tested by a linear restriction, with the test statistic and criteria, based on Wald Statistic, as follows:

$$
\begin{align*}
W & =\left(\boldsymbol{h}^{\prime} \hat{\boldsymbol{\beta}}\right)^{\prime}\left[\left(\boldsymbol{h}(\operatorname{var}(\hat{\boldsymbol{\beta}})) \boldsymbol{h}^{\prime}\right)\right]^{-1}\left(\boldsymbol{h}^{\prime} \hat{\boldsymbol{\beta}}\right)  \tag{5.42}\\
\text { distributed as } \quad\left(\frac{1}{r}\right) W & \sim F(r, N T-K) \tag{5.43}
\end{align*}
$$

where, $r$ is the number of restrictions, $N T$ is the total number of observations, and $K$ is the degress of freedom.

If the null of $\mathbf{h}^{\prime} \beta=0$ is accepted then there is no significant difference in the competitive environment. Conversely, a rejection of the null allows for the conclusion that there is a significant difference and a cursory glance at numerical values or graphical plots will signal whether there is greater competition or less competition.

Despite these substantial benefits, there is a weakness inherent within the PQ regression; it can be influenced by outliers. It is important to note that as a least absolute deviation based regression as opposed to the least squared residuals approach of OLS, its susceptibility to outliers is lower even though it remains present.

The introduction of a parameter $q$ allows the researcher to consider the balance between including as many sample points as possible and excluding any undue effect of outliers. The PQ regression equation is modified to included a probability component:

$$
\begin{equation*}
\operatorname{Pr}\left(\rho_{i t} \leq \sum_{m=1}^{m=M} \alpha_{m}\left(\eta_{i t}\right)^{m-1}+\sum_{m=1}^{m=M} \beta_{m}\left(\left(\eta_{i t}\right)^{m-1} \mathrm{x} D_{i t}\right)\right)=q \tag{5.44}
\end{equation*}
$$

The authors chose a value of 0.75 for q , thus including $75 \%$ of the data, arguing it is an optimal balance between including values and omitting outliers for their particular configuration and data, though future works may necessitate a different combination of values. Altering the determining criteria for the upper boundary in this manner allows the researcher to include a majority of the data whilst negating any potential outlier effect thus improving the quality of the results.

### 5.8 Schaeck and Cihak 2010

The methodology presented in this paper is rather different from that of Deygun et al.. The authors focus on the theoretical argument that when competition is more fierce, firms with higher marginal costs will tend to have falling profits as their margins are squeezed. To that end they identify a modified version of the Boone indicator that "gauges the strength of the relationship between efficiency and performance" (page 4).

First an estimate the Boone indicator is made using the equation 5.45:

$$
\begin{equation*}
\pi_{i t}=\alpha_{i}+\sum_{i=1, \ldots, T} \beta_{t}\left(d_{t}\right) \ln \left(c_{i t}\right)+\sum_{i=1, \ldots, T-1} \gamma_{t}\left(d_{t}\right)+u_{i t} \tag{5.45}
\end{equation*}
$$

where $\pi_{i t}$ are the profits of bank $i, c_{i t}$ are average variable costs, $d_{t}$ is a time dummy, and $u_{i t}$ is the error term. ${ }^{13}$

This model is set up to be estimated via a two step Generalised Method of Moments (GMM) style estimator (where $\gamma_{t}$ represent firm characteristics used as instruments) over a more traditional instrumental variable estimator because of the concern of the authors that "performance and cost are jointly determined" (page 10).

After the GMM estimator is completed, the coefficients that are reported for the $\beta$ term are then used as values for the Boone indicator of competition. With these estimates the authors then go on to compare relationships between the competition indicator and variables such as efficiency (computed via a stochastic frontier analysis) and bank soundness. The relationships are determined by simple panel model regressions and the results suggest that the competition indicator is significant in the efficiency and soundness regressions. However, the authors struggle with endogeneity issues which would necessitate some type of instrumental approach.

### 5.9 Comparison and Evaluation

The described methods offer two completely different takes on the measure suggested by Boone (2008). The measures implemented by Schaeck and Cihak (2010) are admirable attempts at implementation, and could arguably be said to follow the theory and spirit of Boone (2008). The results they obtain are robust to different measures of the key variables which suggest credibility of their conclusions.

However, there seems to be little consideration or allowance made for the relative differences of both profit and efficiency that seem core to the proposition of Boone (2008) in particular

[^39]the manner in which competition change over time is determined. The measures that have been used are perhaps too simplistic and rely on many of the older methodologies previously considered, such as HHI concentration measures and linear structural equations.

Deygun et al. on the other hand seems far more true to the intentions of Boone (2008). It is particularly focused on the use of relative differences of both efficiency and profit as seems the focus of the Boone measure. The determination of changing competitive regimes is also identical to that of the theoretical paper. Moreover, the paper considers the more technical issues that may be faced such as inclusivity of sample points but exclusion of outliers.

Overall the estimator as implemented by Deygun et al. is a much closer representation of the theoretical measure postulated in Boone (2008), following the theoretical ideals and the empirical equations that are suggested by Boone. The methodology proposed also takes into account the mathematical difficulties that would be faced by a researcher in attempts at their own application. This makes the Deygun et al. measure more desirable and more useful not just for this study but in general.

### 5.10 Application

The Boone (2008) model rests of three key assumptions (Section 5.3.6, page 200); one dimensional efficiency, observable efficiency, and efficiency based on firms competing on a level playing field. All three of these assumptions are met by the model.

### 5.10.1 One Dimensional Efficiency

The final assumption with regard to one dimensional efficiency is slightly more difficult to reconcile. One dimensional efficiency is the assumption that a firm cannot shift from one product where it is uncompetitive to another where it is more efficient in order to continue competing in the market. Fortunately, it would be impractical for HEI (as common practice) to focus on either teaching or research; a focus on research will remove a large part of the reason for being a university, and significant funding streams to keep facilities open, a focus
on teaching would also close off very large sources of funding and make it difficult to survive financially. Additionally any observations with zero research income or zero undergraduate teaching were removed at the start of the procedure, isolating them from the sample.

### 5.10.2 Observable Efficiency

Efficiency is not "observed", however, estimation processes can be undertaken to infer efficiency scores which can be used in later estimation. Such as estimation was conducted using stochastic frontier analysis as in Chapter 3.8.

$$
\begin{align*}
\ln C_{i t}= & \alpha+\sum_{j=1}^{n} \beta_{j} \ln Q_{j}+\sum_{j=1}^{n} \gamma_{j} \ln W_{j}+\sum_{k=1}^{n} \sum_{j=1}^{n} \gamma_{j k} \ln W_{j} \ln W_{k}+\sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{j k} \ln Q_{j} \ln Q_{k} \\
& +\sum_{k=1}^{n} \sum_{j=1}^{n} \theta_{j k} \ln Q_{j} \ln W_{k}+\sum_{l=1}^{q} \phi_{l} Z_{l, i t}+u_{i t}+v_{i t}+\delta_{1} t+\delta_{2} t^{2} \\
u_{i t} \sim & N^{+}\left(\left[\delta_{0}+\sum_{h=1}^{p} \lambda_{h} Z_{h, i t}\right], \sigma^{2}\right) \tag{5.46}
\end{align*}
$$

where, $\ln C_{i t}$ is the natural $\log$ of costs (as defined in Table 4.1) of university $i$ at time $t, \alpha$ is an intercept, $\ln Q_{j}$ is the natural $\log$ of output $j, \ln W_{j}$ is the natural $\log$ of the price of output $j, Z_{l, i t}$ is a matrix of environmental variables $l$ affecting the frontier, $Z_{h, i t}$ is a matrix of environmental variables $h$ affecting the mean of the inefficiency distribution, $u_{i t}$ is the inefficiency term, $v_{i t}$ is the idiosyncratic error term, $t$ is a time variable, $\beta, \gamma, \theta, \phi, \delta, \lambda, \sigma$ are parameters of the estimation, and subscript $k$ also maps to the different outputs being a twin of subscript $j$ which allows for the formation of interaction terms where $j$ does not equal $k$ and square terms where it does.

### 5.10.3 Level Playing Field

The efficiency returned by the stochastic frontier model (Equation 5.46) takes into account the environmental effects on each HEI and factors in the uncontrollable differences that are present between them. The creation of the frontier is partially determined by, and hence
returns efficiency scores that are independent of, uncontrollable environmental factors. Firms can then be said to compete on a level playing field. The model used for this estimation is described in Equation 5.46.

### 5.11 Applying Deygun et al.

The estimation of Equation 5.46 provides a list of efficiency scores which should then be matched against an appropriate value of profit. HEI do not generate profit and so it is necessary to use a proxy value. For this research the most appropriate proxy for profit is the deficit or surplus on continuing operations before taxation of each institution, which for a novel application of this methodology to the higher education sector will be a more than satisfactory approximation of profit.

The proxy for profit is then regressed against the estimated efficiency of each institution to determine the relationship between the two variables which was both positive (as required for this methodology) and significant.

The observations were then ordered by efficiency score so as to allow for the calculation of relative profit differences and relative efficiency differences as in Boone (2008), and determination of any significant differences between two different regimes using a quadratic quantile regression with a 0.60 quantile value, different to that in Deygun et al. as it allows for a better to fit to the data of this research. Sensitivity analysis was conducted on the quantile value by conducting the estimation over varying quantiles. This is discussed in Section 5.13. Equations 5.40 and 5.41 show that variable $D$ is used as a dummy variable to denote the changing competition regime. The final component to be considered before conducting the estimation is what will represent these different regimes and how they will differentiate between different groups of institutions. As the aim of this research is to consider changing levels of competitiveness over time the distinguishing factor will be which year of data is used. In practice this involves reducing the dataset to include only two time periods (via a year marker). The later year is then given a value for $D$ of 1 , and the earlier year is given a value
for $D$ of 0 . This allows the estimation to distinguish between two competition regimes which are, more specifically, different time periods.

For completeness, and to detect both short and medium term trends, the process was repeated for 1 year intervals (2004/2005-2005/2006), 2 year intervals (2004/20052006/2007), 3 year intervals (2004/2005-2007/2008), and 4 year intervals (2004/20052008/2009) where applicable for all starting years. The results of these calculations are shown in Table 5.1 where the rows are the initial years and the columns the comparator years. It is worth noting at this stage that the calculations were based on a pooled sample of all institutions so as to generate a sense of the competitive environment at play in the higher education sector, as well as being broken into three subsamples; the Russell Group, pre-1992 institutions, and post-1992 institutions.

### 5.12 Results

|  | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $2004-2005$ |  | + | - | - | - |
| $2005-2006$ |  |  | + | - | - |
| $2006-2007$ |  |  |  | - | - |
| $2007-2008$ |  |  |  |  | - |
| $2008-2009$ |  |  |  |  |  |

Table 5.1 Annual Changes in Competition - Full Sample - q value 0.60

Entries in Table 5.1 show the difference between the integral of the base year and the comparison year, and hence, are indicative of the movement of competition between the two years; determined using equation 5.47.

$$
\begin{equation*}
\text { Competition change }=\sum_{m=1}^{m=M} \alpha_{m}\left(\eta_{i t}\right)^{m-1}-\sum_{m=1}^{m=M} \beta_{m}\left(\eta_{i t}\right)^{m-1} \tag{5.47}
\end{equation*}
$$

Care must be taken to note that the difference of the integrals and the movement of competition are in line (alternative constructions will give an inverse relationship). If the integral for the second year $\left(\sum_{m=1}^{m=M} \beta_{m}\left(\eta_{i t}\right)^{m-1}\right)$ is smaller than that of the first year
$\left(\sum_{m=1}^{m=M} \alpha_{m}\left(\eta_{i t}\right)^{m-1}\right)$ then competition is said to have intensified (see Figure 5.4$)$. equation 5.47 will in this case give a positive signed result for intensifying competition.

A minus sign for the result of equation 5.47 represents a weakening of competition as the first year integral is smaller than that of the second year, and a "NH" representing an acceptance of the null hypothesis and hence, no change.

This can be clarified by observing an example from this study in Figure 5.5 which depicts a weakening of competition between 2004-2005 and 2007-2008.


Figure 5.5 Competition Change 04-05 to 07-08 - Full Sample

The results suggest that the competitive environment actually weakened after the imposition of the tuition fee increase with the graph supporting the equation results (as depicted in Table 5.1. Figure 5.5 shows a greater area under the curve for 2007-2008 in light grey than in 2004-2005 in black and hence there is weaker competition. Though initially a little odd, this results seems to suggest that whilst the cost of higher education increased over the period there was also continued growth in student numbers (from 22.8 million to 23.1 million) and so perhaps there was simply greater demand for higher education places making it less competitive for the suppliers, more institutions were in a position to select rather than recruit.

Next consider more broadly the results of the pooled estimation. Increasing competition is demonstrated from 2004-2005 to 2005-2006 and from 2005-2006 to 2006-2007. It would appear that this increase in competition is in the build up to the increasing fees, which may align well to the general environment and response to the increase in fees. Many students were considering not attending university and so institutions were spending a great deal of money on ensuring students were well briefed on how the funding that was available. This would reduce surplus of the institutions and simulate increased competition (which as discussed previously would typically see a fall in profits).

All other results are suggest a fall in competition, which may seem to agree with the specific example between 2004-2005 and 2007-2008 as represented in Figure 5.5. Over the time period examined in the study there was an increase of 1.1 million students, ( 22.8 to 23.9 million) which represents an approximate $5 \%$ increase in student numbers and may therefore suggest an abundance of demand for the supply provided by HEI.

The pooled estimation assumes that the changing levels of competitiveness are common across the full sample. By drawing several sub-samples and repeating the estimation across these sub-samples it will be possible to consider whether there were particular parts of the sector that were more or less affected by the changing competition environment. Table 5.2 gives the results for the Russell Group sample, Table 5.3 gives the results of the Pre-1992 sample, and Table 5.4 gives the results of the Post-1992 sample.

|  | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $2004-2005$ |  | + | - | - | - |
| $2005-2006$ |  |  | - | - | - |
| $2006-2007$ |  |  |  | + | + |
| $2007-2008$ |  |  |  |  | - |
| $2008-2009$ |  |  |  |  |  |

Table 5.2 Annual Changes in Competition - Russell Group Sample - q value 0.60

These sub-sample tables provide several different perspectives on the level of competition over the period examined. The results suggests that within the pre-1992 group there was actually a reduction in competition across all time periods, whereas the post-1992 group saw mostly

|  | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $2004-2005$ |  | - | - | - | - |
| $2005-2006$ |  |  | - | - | - |
| $2006-2007$ |  |  |  | - | - |
| $2007-2008$ |  |  |  |  |  |
| $2008-2009$ |  |  |  |  |  |

Table 5.3 Annual Changes in Competition - Pre-1992 Group Sample - q value 0.60

|  | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| $2004-2005$ |  | - | + | + | + |
| $2005-2006$ |  |  | + | + | + |
| $2006-2007$ |  |  |  | - | - |
| $2007-2008$ |  |  |  |  | + |
| $2008-2009$ |  |  |  |  |  |

Table 5.4 Annual Changes in Competition - Post-1992 Group Sample - q value 0.60 increases in competition, and the Russell group saw some increases in competition when specifically comparing the year of fees introduction to others but mostly saw decreases in competition. These results describe tough competitive environment at the top and bottom of the "table" of institutions whilst presenting a relatively comfortable middle ground. With increasing numbers and increases fees these types of results are to be expected. Increasing numbers of students would suggest a greater supply and an easier time for all but the increasing fees in combination would deter students from applying to the less prestigious institutions (typical of the post-1992 group) and focus on the upper end of the table which gives more chance of a successful graduate job after completion. This would make it very comfortable for members of the pre-1992 group (Loughborough, Lancaster, Leicester) all solid, respected institutions with good graduate prospects.

At the top end, for those Russell Group institutions, the indication is that after the introduction of tuition fees competition became more fierce but only in relation to the year of the fees introduction. It is in this very specific context only that there was additional competition, in all other comparisons there was less competition including periods before and after the tuition fee increase. A possible explanation for this may go to the decrease in student numbers from 2006-2007 to 2007-2008 where numbers fell by 0.6 million;
competition may have increased as there were less students than places meaning all institutions were actively recruiting.

This competition would be perhaps more fierce within the Russell Group as they all attract a similar type of student in terms of entry grades and background, and if the fall in numbers of students (perhaps through early take up of places in 2006-2007 rather deferring to 2007 2008) was predominantly within that demographic the recruitment pool would be much smaller. It is also typical for institutions that aren't in the Russell Group but are operating on the fringe (Durham University, University of Exeter, Queen Mary University of London, and University of York all became Russell Group members in 2012 and would have been competitive in the space for many years previous) would also be targeting the same students as the Russell Group, further driving up competition.

The Post-1992 group, which typically make up the lower end of the performance tables, interestingly had an inverse competitive result to that of the Russell Group. The competition environment became less intense from 2004-2005 to 2005-2006, and then 2006-2007 to 2007-2008 and 2006-2007 to 2008-2009. The suggestion of this result is that the fall in students experienced from 2006-2007 to 2007-2008 was predominantly in the top end of students rather than the more specialist, vocationally focused students which are more common within the specialist, teaching (rather than research) focused institutions typically of the post-1992 period.

In all other comparisons there were increases in competition. Intuitively this aligns with the increasing costs of higher education (once students had recovered from the initial shock of the increase) causing students to think more carefully about the decision to take higher education and to ensure that it would leave them employable upon exit. These results, in conjunction with falling competitiveness in the pre-1992 group, suggests a general movement of the student body up the league tables; targeting more prestigious institutions. This would ring true when considering an increasing focus on the value of a degree in gaining employment rather than developing life experience.

It is interesting to consider the different groups in comparison with the pooled sample. It
would appear that the increasing competition from 2004-2005 to 2005-2006 in the Russell Group and the increase from 2005-2006 to 2006-2007 in the Post - 1992 group was the overriding effect across the sector, overruling the decreasing competition experience by the Pre - 1992 group. However, over the rest of the time periods the falling competition experience by the Russell Group and the Pre-1992 group was more than sufficient to compensate for the increased competition experienced by the Post - 1992 group. This is of particular interest as the Post - 1992 group is larger than both the Russell and Pre-1992 groups and so the expectation may be that it has a stronger effect on the overall results.

The Russell and Post - 1992 groups have seen competition increases over the period. The response to increased competition within the higher education sector would be different to that of any firm in an alternative sector which would be expected to cut prices so as to attract more consumers. This would then allow those more efficient firms to continue trading whilst less efficient firms had to fold as they could not continue to supply at the low price. The difference in the higher education sector, particularly at this time, is that the top available price of $£ 3000$ was seen not as a price ceiling but as the price. No HEI could set for lower tuition fees, doing so would devalue the perception of the quality of their degrees and lead to further losses of students.

Instead the competition would revolve around increasing advertising and recruitment expenditure. Though this seems different to reduction of price, it creates the same effect; the increasing recruitment spend can be spread across the student intake, essentially the cost of revenue generation, and so the net revenue from the student is the fees less the recruitment costs. This net revenue will be smaller if there is greater competition as there will be higher advertising spend to increase recruitment, just as if the HEI had reduced the price to increase recruitment. The result of this would be a lower surplus, which in the case of this research is tantamount to a lower profit.

### 5.13 Sensitivity Analysis

This is a novel application of the Deygun et al. methodology to the higher education sector. It has also used a different value for the quantile stage than the original authors. As such is it sensible to conduct some sensitivity analysis to determine whether the results discussed are vulnerable to changes in quantile. To conduct this analysis each estimation (pooled, pre-1992, russell, post-1992) was repeated for a range of quantiles, from 60th to 95 th quantiles in intervals of 5 (i.e. $60 \mathrm{th}, 65 \mathrm{th}, 70 \mathrm{th}, \ldots, 95 \mathrm{th}$ ). The results of these estimations are presented below. In each table a + represents the same as in the results chapter, that there has been an increase in competition as the integral from the second regime is smaller than in the first. A indicates the opposite and falling competition, whilst a NH represents an acceptance of the null hypothesis that there has been no change. Finally a n/a indicates that there was insufficient data for the model to compute a variance covariance matrix.

| Pooled Sample | Quantiles |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Academic Year Comparisons | 60 th | 65 th | 70 th | 75 th | 80 th | 85 th | 90 th | 95 th |
| $2004-2005$ to $2005-2006$ | + | - | - | - | + | - | - | - |
| $2005-2006$ to $2006-2007$ | + | + | + | + | + | + | - | - |
| $2006-2007$ to $2007-2008$ | - | - | - | - | - | - | - | + |
| $2007-2008$ to 2008-2009 | - | - | - | - | - | + | + | + |
| $2004-2005$ to $2006-2007$ | - | + | + | + | + | + | + | - |
| $2005-2006$ to $2007-2008$ | - | - | + | + | + | + | + | + |
| $2006-2007$ to $2008-2009$ | - | - | - | - | - | - | - | + |
| $2004-2005$ to $2007-2008$ | - | - | - | - | - | - | - | - |
| $2005-2006$ to $2008-2009$ | - | - | - | - | - | - | - | - |
| $2004-2005$ to $2008-2009$ | - | - | - | - | - | - | - | - |

Table 5.5 Changes in competition - Pooled Samples - Varying q values

The results of the pooled sample (Table 5.5) indicate that there is some stability in the comparisons which span longer time periods (each of 3 or 4 year comparisons are stable across each choice of quantile. In contrast there is more instability across the shorter time period comparisons, the one year time periods demonstrate fluctuating results across the various quantiles. This is likely related to the previously discovered breakdown of results across the sub-samples, the pooled sample appears to be affected predominately by different sub-samples
at different quantile levels. This result is to be expected as the different groups have clearly distinct average efficiencies and so will likely form clusters across the distribution of results.

Differing quantiles will therefore include or exclude particular groups more than others.

| Russell Group | Quantiles |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Academic Year Comparisons | 60 th | 65 th | 70 th | 75 th | 80 th | 85 th | 90 th | 95 th |
| $2004-2005$ to 2005-2006 | + | + | + | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to $2006-2007$ | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to 2007-2008 | + | + | + | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2007-2008$ to $2008-2009$ | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2006-2007 | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2007-2008 | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to 2008-2009 | + | + | + | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2007-2008 | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2008-2009 | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to $2008-2009$ | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |

Table 5.6 Changes in competition - Russell Group Samples - Varying q values

| Pre-1992 Group | Quantiles |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Academic Year Comparisons | 60 th | 65 th | 70 th | 75 th | 80 th | 85 th | 90 th | 95 th |
| $2004-2005$ to 2005-2006 | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to $2006-2007$ | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to $2007-2008$ | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2007-2008$ to 2008-2009 | - | + | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to $2006-2007$ | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2007-2008 | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to 2008-2009 | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2007-2008 | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2008-2009 | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to $2008-2009$ | - | - | - | - | - | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ | $\mathrm{n} / \mathrm{a}$ |

Table 5.7 Changes in competition - Pre-1992 Group Samples - Varying q values

Consider now the sub-samples. The Russell Group sub-sample (Table 5.6) shows a great deal more consistency. In fact it is completely consistent across all quantiles and all time periods. It also highlights that small samples (this subsample includes the smallest number, 17, of all subgroups) have difficulty computing a variance-covariance matrix for the quantile regression. The pre-1992 group (Table 5.7) also demonstrates considerable stability apart from one exception for the 65 th quantile, and some difficulty computing the variance-covariance matrix (even with a group size of 25).

| Post-1992 Group | Quantiles |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Academic Year Comparisons | 60 th | 65 th | 70 th | 75 th | 80 th | 85 th | 90 th | 95 th |
| $2004-2005$ to 2005-2006 | - | - | - | - | + | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2006-2007 | + | + | + | + | + | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to 2007-2008 | - | - | - | - | - | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2007-2008$ to 2008-2009 | + | - | - | - | - | - | + | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2006-2007 | + | + | + | + | + | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2007-2008 | + | + | + | + | + | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2006-2007$ to 2008-2009 | - | - | - | - | NH | NH | + | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2007-2008 | + | + | + | + | NH | NH | NH | $\mathrm{n} / \mathrm{a}$ |
| $2005-2006$ to 2008-2009 | + | + | + | + | + | + | + | $\mathrm{n} / \mathrm{a}$ |
| $2004-2005$ to 2008-2009 | + | - | - | + | + | + | + | $\mathrm{n} / \mathrm{a}$ |

Table 5.8 Changes in competition - Post-1992 Group Samples - Varying q values

The stability demonstrated by the Russell and Pre-1992 groups (Tables 5.6 and 5.7) gives support to the supposition that smaller, more homogeneous groups will experience similar competitive environments. They also demonstrate a resistance to changing values of quantile for the regressions. By contrast the Post-1992 group (Table 5.8) demonstrates greater sensitivity to changing quantiles, fluctuating from increasing to decreasing competitiveness to no change in competitiveness. Taken individually it would suggest that the model is sensitive to choices in quantile, taken in conjunction with the other sub-samples (Russell and Pre-1992) it instead suggests that the Post-1992 group is more heterogenous than the others; it is therefore more sensitive to quantile choice.

A final points to note from these results is the difficulty some of the models had in generating the variance covariance matrix. Even the largest group (Post-1992) had some difficulty at higher quantiles. It is therefore possible, and perhaps necessary, to note that a larger sample size (in the region of 50 entries) would be required to utilise the highest quantiles for the regression. Of course, should authors prefer a slightly less inclusive value which rejected more values as outliers, then smaller sample sizes can be used.

### 5.14 Conclusion

This empirical chapter has performed a novel application of the Boone (2008) model to the higher education sector using the operational procedure as derived in Deygun et al.. It contributes to a small, beginning body of literature on applying the Boone (2008) model and provides some useful observations on application and draws some important conclusions regarding sensitivity.

The results of the study are also of interest. Four samples are used to give different perspectives on the sector; Pooled, Pre-1992, Post-1992, and Russell Group. The Pooled sample, using all of the institutions, shows a generally declining level of competitiveness over the years of the study, particular during longer time horizons. This would seem to align with an increasing number of students engaging in higher education. It also shows an increase in competition in the run up to the implementation of the tuition fees, perhaps as institutions began to feel the delay in students applying or the perception that they would have to compete more fiercely for students that were still taking up higher education within the new fee regime.

The results of the pooled sample do, however, seem to elude to a more complex story and upon breaking down the results this becomes more obvious. When the estimations are repeated across the three smaller sub-samples (Russell, Pre-1992, Post-1992) a different story, in fact, three different stories are forthcoming. These results are all relative measures, comparing the competitiveness in the base year with that of the comparator, all results will be presented in this way. The Russell group primarily see an increase in competition in the two years following 2006-2007 (2006-2007 to 2007-2008, and 2006-2007 to 2008-2009) whilst otherwise seeing falls in competition, the Pre-1992 groups sees a general fall in competition across all comparators, whilst the Post-1992 group sees increases in competition across most comparators. It is crucial here to note the differences experience by the sub-groups, such as result should caution policymakers from enacting broad policy to stimulate competition. Such an action would asymmetrically affect the institutions and perhaps lead to results other than
those desired.

The sensitivity analysis conducted following the results of is equitable importance to the results themselves. It speaks to a necessity to accurately and correctly create sub-samples for any application as groups which are too heterogeneous will find themselves with varying results dependent on choice of quantile. By contrast well defined and homogeneous sub-samples will find consistent results whichever quantile is chosen, demonstrating a lack of sensitivity. The sensitivity analysis also reveals that sample size will be important in applications of this work, particularly where careful sub-sampling is necessary as samples which are too small will have difficulty forming the variance co-variance matrix.

This interesting application of a novel technique has given some illuminating insights into the state of the higher education sector throughout the period of the last fee changes. An exciting area for further work would be to extend this study using data up to and beyond the move $£ 9000$ fees with particular focus on when the data shows a shock from the increasing fees, and, additionally if the data supports the feeling of continually building competition that seems pervasive in the media from academic year 2009-2010 onwards.

## CHAPTER 6. Conclusions and Further Work

This thesis covers the very broad theme of performance in higher education. It begins with a historical perspective of the higher education sector, from some of the initial public statements and implementations of performance measurement by the Government (1980 reference), through a tumultuous few decades of increasing intake and decreasing funding, to the present day sector which is only faintly akin to that of the early 1980s.

A commonly used method for assessing performance within the higher education sector is efficiency and a number of previous studies have utilised it to assess sectors across the world (insert references here). A majority of these studies have utilised Data Envelopment Analysis (DEA) (insert references), with few choosing Stochastic Frontier Analysis (input references). Moreover, there has been light investigation of environmental factors which contribute to the level of efficiency achieved by institutions (Stevens, 2005; Johnes, 2014).

This empirical work of this thesis begins with analysis of higher education institutions within England and Wales, which whilst different in terms of funding styles are more similar than those in Scotland. This analysis is conducted through SFA, initially developed by (references), and takes an important step of including environmental variables in the determination of the frontier position and the conditional mean of the error distribution. This has the effect of allowing certain environmental variables to be deemed uncontrollable, such as location, and hence included in determining the beat practice frontier for that institution, creating a more level playing field with other peers. Similarly those variables which are controllable are included as a managerial choice and hence used to determine level of efficiency the institutions will return.

The results of this empirical chapter echo those of studies conducted on time periods preceding this one (Stevens, 2005; Johnes et al., 2008). There appears to be a high level of efficiency across the sector as an average. This high average is formed from a very high peak cluster (in the 90th percentile) which is predominantly Russell group members, with clusters of lower efficiency groups populated by speciliast institutions with limited scope of offering. Perhaps more important than the overall efficiency scores are the factors which are deemed significant in contribution. Location in both London and Wales had a significant effect on positioning the frontier (London was expensive pushing out the cost frontier, whilst Wales contracted it). A study of how location within a city affected cost efficiency such as by (Italian one) may prove fruitful establishing a preferred location for institutions.

It is also able to draw conclusions, aligning with expectations, that a balanced approach to staffing levels (academic and non-academic) is much preferred to heavy weighting in favour of one or the other. This avoids overburdening academic staff with administration duties, allowing for specialisation and division of labour. Interestingly the results also suggest that larger numbers of part time staff are beneficial to the cost efficiency of an institution, as long as there remains a balance between academic and non academic staff. This is an important result for managers as institutions much like any business, rely on part time staff to help deal with volatility.

Examination of the efficiency results over time, shows an approximate fall in efficiency of one percentage point per year. This also supports the work of Johnes et al. (2008) which studies the period preceding that used in this study. It can be subdivided by university grouping, into Russell, Pre-1992, and Post-1992. Doing so reveals that the Russell group shows a fairly stable level of efficiency in the 90s, whilst the Pre-1992 group showed a fall of approximately 1 percentage point, and the Post-1992 group fell by a much greater 5 percentage points.

Such a result is particularly useful for policymakers who may wish to use the results of this study to enact policy to sure up the sector and prevent failing institutions. It would enable them to be more targeted in their approach and avoid the possibility of widening the gap between top and bottom institutions by enacting sweeping, general changes. The caveat here
of course is that a the hybrid traeanslogarithmic function application such as used here creates efficiencies relative to current industry best practice rather than what could be achievable. This suggests that efficiencies reported may be generous and should therefore be viewed as such.

The work also presents an alternative research measure to those used in previous papers. By using a price index derived from research council figures as per Boone (2008) and applying it to measures of research income the study was able to provide a measure which took into account quality and quantity of research from institutions, as well as changing levels of general research output, and providedchanging levels of general research output, and provided a more intuitively consistent result (it was number of research outputs rather than a currency). Not that this research measure correlates closely to the RAE score (Johnes and Johnes, 2009).

The stochastic frontier analysis performed in the Chapter 3.8 looks at several variables not previously examined, in addition to those familiar to higher education sector efficiency analysis. The results reveal that the number of part-time staff are wholly bad for both the level and efficiency of cost incurred by a HEI, and that increasing proportions of academic staff also negatively affect the efficiency of an institution. These results should encourage HEI, a typical employer of a wide range of part time staff, to consider hiring practice far more carefully and prioritise full time employment over part time, as well as being mindful of the proportion of their total staffing body that is made up by academic staff. This thesis acknowledges that academic staff are required for the majority of revenue generation and is in no way suggesting that proportions of academic staff should be minimised; but in the harsh funding climate that the higher education sector finds itself in HEI must be acutely aware how their decisions may be incurring more costs than are necessary.

Of additional, and significant, importance is the positive results achieved by the measure of research output. Measuring research has posed a great challenge to academics over a number of years and has been used in very few studies. The results of this thesis provide an alternative measure of total output that is relatively straightforward to calculate and provides significant results, which will open up a number of avenues for future research into the
production process of HEI.
The first empirical chapter was successful in illuminating the efficiency of institutions across England and Wales. In doing so it highlighted institutions where there had been stark changes in efficiency following a merger (e.g. University of Cumbria). Given the troublesome environment in which institutions are now finding themselves it seems prudent to consider that some may begin to struggle and in that case the favoured response, both in the UK and abroad is to encourage, or force, a merger between the failing institution a stronger one. To that end an application of the Bogetoft and Wang (2005) model was applied to the sample of data available for this research.

Before the application of Bogetoft and Wang (2005) it was necessary to conduct a DEA estimation of the data to confirm it was not too biased (DEA can introduce bias during the estimation process). This confirmation came through a bootstrap analysis and allow for the merger analysis to proceed. The first contribution of this chapter was to support the results of other authors (Johnes, 2006) in determining a high efficiency for many of the institutions with a cluster of lower efficiencies for a small group of predominantly specialist colleges. Moreover, when the environmental variables were added to the estimation it once again confirmed the earlier SFA work conducted within this thesis showing a marked change in efficiency. Hence, these two different methods of analysis provide some test of the sensitivity of efficiency to different models and whilst not identical both models shows that the inclusion of environmental variables is an important facet of efficiency estimation. This should inform future studies and encourage them to consider the importance of including environmental variables in their estimations of efficiency. A caveat here is also that the list of environmental variables used is neither definitive nor exhaustive, so whilst future studies are encouraged to consider environmental variables this research does not try to be prescriptive in which variables are chosen.

With the efficiencies confirmed not overly biased the merger analysis continued and provided a raft of interesting results. The Bogetoft and Wang (2005) model provides an analysis of the potential gains from any particular merger rather than the actualised gains, and importantly
in this chapter of work the mergers are hypotheses rather than actual mergers. In all 62 mergers were estimated, and only restricted by geographical proximity. A 10 mile radius limit was placed on the merger candidates but, despite this, a range of mergers were formed, from two small specialist colleges to one large and a few medium and small institutions, giving a complete range to examine.

The scale and harmony factors provide evidence on the likely benefits to a merger; they represent the true gains from the merger and cannot be achieved without merging. The scale factor results indicate that there are no gains to be made through the increase in scale of any institutions. Initial thoughts are that this would indicate all participants were already at sufficient scale and therefore would not be on an increasing returns to scale portion of their long run average cost curve. However an important caveat here is that if there are no very large institutions, the mergers may create an institution which has a greater scale than the largest institution. This would then leave it no comparator for the model to use in assessing what would be a normal level of production of that scale and so would be unable to determine if the merger were successful. The harmony factor provides more scope for improvement with an average value of 0.976 . This suggests that there are approximately $2-3$ percentage points worth of growth to be captured through the combination and average of inputs and outputs across the institutions within the merger.

The learning factor is quite different, being much lower on average (approximately 0.501 ). This lower figure suggests that approximately 50 percentage points of efficiency could be captured through improvements in process, technology, and general moves towards best practice by the institutions involved in the merger. This is typical in the mergers with a large institution and several smaller ones; clearly the larger institution (in the case of Birmingham for examples) will have better practice and technology that Newman College of HE and so would be able to provide improvements in this regard. An important caveat here is that the these improvements can also be achieved through research collaborations, visiting lectureships, and knowledge transfer. This is an important point for policymakers should the situation prevail where it is deemed necessary to merge institutions to increase efficiency - it could well
be achieved through simpler means, which would also be much quicker to put into place. A further contribution of this work is in the analysis of changes in potential gains over time. The results show that whilst some mergers present their potential gains immediately and later taper off, others presenting minimal gains initially and later increase; some by up to 11 percentage points. This echoes results of other authors work (Gourlay et al., 2006; Mao et al., 2009) where time varying efficiencies for mergers were found and indeed took up to ten years to stablise. This would be an important point to note for policymakers as any performance measurement that was applied to a merger scenario would need to factor in the long time scales associated with realising the potential gains of a merger otherwise it may risk over- or understanding the performance of a merger and doing so unfairly.

Though there have been a number of positive outcomes from this research in terms of informing policymakers over mergers within the higher education sector there are some areas of future work that would be crucial before any actionable conclusions are drawn. Refreshing the time period under examination would prove interesting to researchers in confirming whether there is still scope for gains from mergers in the new, harsh environment that institutions find themselves. Should such an refreshed study also find scope of gains from mergers this would give further support to the notion that mergers would be an acceptable proposition for the higher education sector, assuming of course that a contraction in the number of institutions was a preferred outcome. The inclusion of a cost within the merger analysis would also be vital. This research has not factored in cost, the Bogetoft and Wang (2005) model assumes that any costs of the merger are factored in to the post merger unit and so are captured in that way. Given that the mergers within this work are hypothetical the costs of merger could not be counted by the model and hence there is an implicit assumption of costlessness. This is of course not the case in real mergers and extending this work to account for the costs of the merger would give policymakers sufficient information to decide whether a merger was desirable or whether in fact the preference would be to promote collaboration and knowledge sharing.

The work of the second empirical chapter suggest that mergers may be of benefit to the sector
in increasing the efficiency of individual institutions. Were a tranche of mergers to occur within the English and Welsh higher education sectors then there would be a contraction in the number of institutions and hence a lowering of competition within the sector. Typically competition is assumed to be of benefit in a market and is therefore a desirable scenario. This prompts questions over the current level of competitiveness within the sector; does the large number of institutions suggest it is competitive, and how has this changed as the funding environment has constricted. The third empirical chapter of this thesis sets out to answer these questions through application of the Boone (2008) model, as operationalised in Deygun et al..

The first result of this paper is a novel application of this model within the higher education sector. It has previously been applied only once by the original authors (Deygun et al.) wherein the Indian banking sector was used. This is therefore the first quantitative analysis of the competitive environment within the English and Welsh higher education sectors. The results of the study are also interesting. Four samples are used to give different perspectives on the sector; Pooled, Pre-1992, Post-1992, and Russell Group. The Pooled sample shows a generally declining level of competitiveness over the years of the study which seem to align with an increasing number of students engaging in higher education. However in actuality the pooled sample belies a more accurate picture of what is happening within smaller groups.

When broken down in to the three groups, it is clear that there are different levels of competitiveness for each sample. Whilst the pooled sample suggest that from 2004-2005 to 2005-2006 there was an increase in competitiveness this is in fact only true of the Russell group subsample, both of the others give a declining competitive environment i.e. it was getting weaker. There is clear evidence presented that different parts of the sector have responded differently to the changing environment, which is, in and of itself, an important result. Future applications of this methodology should consider the importance of subdividing pooled samples to prevent misleading results.

The results of the analysis are also important, suggesting that over time there have been increases in the levels of competition for the Russell group and the Post-1992 group. These
indicate trends in student demand moving away from the lower end of the table towards the more prestigious institutions, and the fight for top end students increasing. This is likely due to institutions on the fringe of the Russell group (such as York and Queen Mary which joined the group after the period of this study) competing for the same students. The Pre-1992 group however have benefited from the increased aspirations of students who would normally target lower table institutions and a general increase in student numbers to find a weakening in competition across all years. This finding, that the competition faced will be asymmetrical amongst different segments of the higher education sector will be important for policymakers wanting to stimulate competition within the sector. A broad, sweeping application of policy will affect different groups in different ways and may cause much greater levels of stress on particular type of institution without affecting other types. The recommendation is therefore to be specific in targeting policy aimed at increasing competition.

A further contribution of this paper is in analysis of the sensitivity of this model to choices of quantile for the regressions. The sensitivity analysis is conducted by re-running the estimation for all three sub-samples and the pooled sample across all years and changing the quantiles from the 60 th percentile to the 95 th percentile in steps of 5 . The pooled and post-1992 samples demonstrate fluctuating results which change depending on the quantile used; sometimes there will be increasing competition, other times there will be decreasing, and others still will accept the null hypothesis of no change. The Russell and Pre-1992 groups (with a one year exception) maintain consistent results across a range of different quantiles (some do not allow for a variance covariance matrix to be formed). This contrast suggests that the more homogeneous groups will present consistent responses to quantile choice, whilst more heterogeneous groups will vary. It is important to be aware of this for future research applying this model where the choice of sub-sample to be estimated will affect the level of sensitivity to quantile choice, but if sub-samples are chosen correctly the choice will not matter. A small caveat here exists around sample size.

All three of our sub-samples had difficulty forming a variance covariance matrix as the quantile increased. It is therefore recommended that a sample size of approximately 50 is
used to ensure that the variance covariance matrix can be formed at the higher quantile levels. Of course if the research preference is for a lower quantile, excluding more outliers then smaller sample sizes will be viable.

A caveat to this study is present in the choice of profit variable. The surplus on continuing operations before taxation has been used as a representative proxy for profit in this application; extensions should consider other variables which may be more suitable but were unavailable for this research. Additionally these results are affected by the particular manner of estimating efficiency, repeated applications would need to determine similar levels of efficiency to have comparable results.

## APPENDIX A. List of Institutions

Table A.1: All institutions included in efficiency study

| Name of Institution | Name of Institution | Name of Institution |
| :---: | :---: | :---: |
| Courtauld Institute of Art | University of Gloucestershire | The University of Warwick |
| Royal Northern College of Music | Aberystwyth University | The University of Cambridge |
| Leeds College of Music | Royal Holloway and Bedford | The University of |
|  | New Colleg | Newcastle-upon-Tyne |
| Royal College of Music | The University of Lincoln | The University of Wolverhampton |
| Wimbledon School of Art | The University of Bolton | The University of Salford |
| Royal Academy of Music | York St John University | The University of East Anglia |
| Trinity Laban | The University of Lancaster | Sheffield Hallam University |
| The Liverpool Institute for | York St John College | The University of Surrey |
| Performing Arts <br> Royal Agricultural College |  |  |
|  | Roehampton University | Imperial College of Science, <br> Technology and Medicine |
| Norwich School of Art and Design | The University of Essex | Birmingham City University |
| Continued on the next page |  |  |

TableA. 1 - continued from the previous page

| Name of Institution | Name of Institution | Name of Institution |
| :---: | :---: | :---: |
| Heythrop College | The Nottingham Trent University | The Manchester Metropolitan University |
| Rose Bruford College | Birkbeck Colleg | The University of Bristol |
| Trinity Laban Conservatoire of Music and Dance | The University of Sussex | Liverpool John Moores University |
| Conservatoire for Dance and <br> Drama | Aston University | London South Bank University |
| Ravensbourne College of Design and Communication | The University of Worcester | University of Central England in Birmingham |
| Cumbria Institute of the Arts | University of Worcester | University of Hertfordshire |
| Norwich University College of the Arts | The University of Reading | The University of Brighton |
| The Arts Institute at <br> Bournemouth | The University of Westminster | Thames Valley University |
| Harper Adams University College | University of Wales Institute, Cardiff | City University |
| University College Falmouth | Homerton College | Anglia Ruskin University |
| Kent Institute of Art and Design | London Metropolitan University | The University of Northumbria at Newcastle |
| The Arts University College at Bournemouth | The University of Exeter | The University of Liverpool |
|  |  | Continued on the next page |

TableA. 1 - continued from the previous page

| Name of Institution | Name of Institution | Name of Institution |
| :---: | :---: | :---: |
| The Surrey Institute of Art and Design, University College <br> The School of Oriental and African Studies <br> The University College for the Creative Arts at Canterbury, Epsom, Farnham, Maidstone, Rochester <br> The University College for the Creative Arts <br> University for the Creative Arts <br> Trinity College, Carmarthen <br> The University of Wales, <br> Lampeter <br> Royal Welsh College of Music and Drama <br> Bishop Grosseteste College <br> Bishop Grosseteste University College Lincoln <br> The University of Buckingham <br> Writtle College | The University of Northampton Brunel University The University of Sunderland <br> Buckinghamshire Chilterns University College University of Cumbria <br> Buckinghamshire New University <br> Loughborough University <br> The University of Bath <br> The University of Kent <br> St George's Hospital Medical School University of Derby | The University of Sheffield <br> Liverpool John Moores University <br> The University of Teesside <br> University of the West of England, Bristol University College London <br> The University of Southampton <br> The University of Birmingham <br> The University of Central Lancashire <br> The University of Plymouth <br> The University of Leeds <br> Cardiff University <br> King's College London |
|  |  | Continued on the next page |

TableA. 1 - continued from the previous page

| Name of Institution | Name of Institution | Name of Institution |
| :---: | :---: | :---: |
| Central School of Speech and Drama <br> Trinity University College <br> Institute of Education <br> Birmingham College of <br> Food, Tourism and Creative <br> Studies <br> The University of Wales, <br> Newport <br> Swansea Institute of Higher <br> Education <br> London School of Eco- <br> nomics and Political <br> Science <br> University of the Arts, Lon- <br> don <br> Swansea Metropolitan University <br> Newman College of HE <br> Newman College of Higher <br> Education <br> University College Birmingham | St Martin's College <br> The University of Keele <br> University of Wales, Bangor <br> The University of East London <br> Bangor University <br> Swansea University <br> University of Durham <br> Bournemouth University <br> Staffordshire University <br> Queen Mary and Westfield <br> College <br> The University of <br> Portsmouth <br> The University of Hudders- <br> field | ```The University of Notting- ham The University of Manch- ester Liverpool Hope University St Mary's University Col- lege, Twickenham``` The North-East Wales Insti- tute of Higher Education The School of Pharmacy <br> The Royal Veterinary College <br> University of Wales, <br> Aberystwyth <br> Coventry University <br> De Montfort University <br> The City University <br> University of Chester |
|  |  | Continued on the next page |

TableA. 1 - continued from the previous page

| Name of Institution | Name of Institution | Name of Institution |
| :---: | :---: | :---: |
| Bath Spa University | Canterbury Christ Church University | The University of Bradford |
| Southampton Solent University | The University of Leicester | The University of Oxford |
| Newman University College | University of Luton | Middlesex University |
| Trinity and All Saints College | Kingston University | The University of Greenwich |
| College of St Mark and St John | Leeds Metropolitan University | Edge Hill University |
| The University of Winchester | University of Glamorgan | The University of Hull |
| Leeds Trinity and All Saints | University of Wales, Swansea | University of Chichester |
| Leeds Trinity University College | University of Bedfordshire | Glyndwr University |
| University College Plymouth St Mark and St John | The University of York | Goldsmiths College |
| The University of Chichester | Edge Hill College of Higher <br> Education | St Mary's College |

APPENDIX B. Results
Table B.1: Efficiency Scores

| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Institution 1 | 0.4896 | 0.4927 | 0.4329 | 0.4237 | 0.3714 | 0.4420 | 0.1182 |
| Institution 2 | 0.7546 | 0.7529 | 0.7118 | 0.6421 | 0.6874 | 0.7098 | 0.0672 |
| Institution 3 | 0.1488 | 0.1810 | 0.1982 | 0.2097 | 0.2043 | 0.1884 | -0.0555 |
| Institution 4 | 0.6979 | 0.6796 | 0.5938 | 0.6493 | 0.6748 | 0.6591 | 0.0231 |
| Institution 5 | 0.6979 | 0.6925 | 0.6935 | 0.6572 | 0.6533 | 0.6789 | 0.0446 |
| Institution 6 | 0.5440 | 0.4504 | 0.4612 | 0.4778 | 0.4785 | 0.4824 | 0.0655 |
| Institution 7 | 0.4407 | 0.4617 | 0.4470 | 0.4268 | 0.4235 | 0.4399 | 0.0172 |
| Institution 8 | 0.6687 | 0.6814 | 0.6249 | 0.5729 | 0.5332 | 0.6162 | 0.1355 |
| Institution 9 | 0.8204 | 0.7568 | 0.5202 | 0.5897 | 0.6448 | 0.6664 | 0.1756 |
| Institution 10 | 0.9377 | 0.6755 | 0.6954 | 0.5552 | 0.5423 | 0.6812 | 0.3955 |
| Institution 11 | 0.1114 |  |  |  |  | 0.1114 | 0.0000 |
| Institution 12 | 0.7888 |  |  |  |  | 0.7888 | 0.0000 |
| Institution 13 | 0.5946 | 0.5913 | 0.6286 | 0.6303 | 0.6623 | 0.6214 | -0.0678 |
| Institution 14 | 0.5520 | 0.5442 | 0.5581 | 0.5727 | 0.5452 | 0.5544 | 0.0068 |
| Institution 15 | 0.9579 | 0.9611 | 0.9763 | 0.9209 | 0.9276 | 0.9488 | 0.0302 |
| Institution 16 | 0.4945 | 0.4879 | 0.6065 | 0.5425 | 0.4257 | 0.5114 | 0.0689 |

TableB． 1 －continued from the previous page

|  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| モ8L0 $0^{-}$ | EELG0 | L8EG0 | L979．0 | 87t90 | 9979．0 | 7097＊ 0 |  |
| 98780－ | 7872．0 | $0898{ }^{\circ}$ | 7798＊0 | ¢798＊0 | ¢689＊0 | Etico |  |
| ¢89 ${ }^{\circ} 0^{-}$ | $2879^{\circ} 0$ |  | LEL2．0 | ๖¢\＆9．0 | L6L9．0 | OGLCO | I¢ uọqnı！？sui |
| $0000 \cdot 0$ | $8609{ }^{\circ}$ |  |  |  |  | 8609.0 | 08 uo！̣ņ！${ }^{\text {asui }}$ |
| $92800^{-}$ | 69760 | 99960 | 7896.0 | L9960 | L026．0 | 6898.0 |  |
| $679 \mathrm{I}^{\circ} 0$ | TLICO | L697＊ 0 | 9687＊ 0 | 8LS9．0 | 97L9＊0 | 07\％9＊0 |  |
| モぁL0．0 | 9999．0 | \＃LIC．0 | 8\＆L90 | ¢GLg 0 | ¢789．0 | 8L99．0 |  |
| 97LZ＊0－ | $8269^{\circ} 0$ | $6918 \cdot 0$ | モ998．0 | z0¢9＊0 | 98L9 0 | 7809＊0 | 97 uoṭņ！̧̣sui |
| LZEL 0 | モ069＊0 | ¢989＊0 | も¢¢9．0 | ¢069＊0 | 96020 | 7892．0 |  |
| LZE0＊0 | 60960 | 79860 | 9886.0 | もL960 | 91960 | $6296{ }^{\circ} 0$ |  |
| $670{ }^{\circ} 0$ | \＆L08．0 | 7892．0 | 68920 | LE62．0 | LI980 | LE98．0 |  |
| ¢907\％ 0 | モ678．0 | 2972．0 | 9982．0 | L208＊ 0 | L768．0 | 0786．0 |  |
| L960＊0－ | 9267\％ | ¢98．\％ 0 | 8908：0 | ¢998．0 | 067\％\％ | 968\％＊0 |  |
| 662I 0 | 20920 | 6 L\％9 0 | 8LTL＊0 | モ018．0 | 8LI8．0 | $8 \mathrm{~L} 78^{\circ} 0$ |  |
| tost 0 | 0才CT＊ 0 | $6768^{\circ} 0$ | 897\％ 0 | 89もt\％ 0 | 2097＊ 0 | モ\＆tcio |  |
| 2670＊0－ | 9727\％ | 6967＊0 | $9987 \% 0$ | 2L97\％ 0 | 789\％0 | 7997＊ 0 | 8L uoṭņ！${ }^{\text {asui }}$ |
| $9 \pm 20{ }^{\circ}$ | 989900 | $6709{ }^{\circ}$ | LIt9 0 | \＆LL9 0 | L86900 | 7LL9 0 | LI uọ̣ņ！̣̂sui |
| Крп7S ЈəлО ә．ءчечО \％ |  | 6007－800z | 8007－2007 | 2007－900z | 900\％－ç0 | ¢00\％－モ00z |  |

TableB． 1 －continued from the previous page

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| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ¢910．0 | L998＊0 | 99980 | 6¢98．0 | 0298．0 | 6［98．0 | 6I88．0 | 0¢ uo！̣qn＋！̣sui |
| $960{ }^{\circ} 0$ | LILL：0 | LSTLO 0 | LSGLO | モ622．0 | 8082．0 | L¢78．0 |  |
| gqL0 0 | LSL60 | $0898{ }^{\circ}$ | ¢ \％\％6．0 | ¢LZ6．0 | \＆\＆76．0 | 9¢f6．0 | $8 \pm$ uọqņ！qsui |
| L897：0－ | 0978．0 | L0L6．0 | モ¢96．0 | £ஏ 88.0 | 08T2．0 | 0702：0 | L® uọpnq！qsui |
| 2070 $0^{-}$ | 960 $L^{\circ} 0$ | 69820 | ¢982．0 | モ029\％ 0 | 7689＊0 | 7912．0 | $9 \pm$ uọpņ！qsui |
| ธ900 $0^{-}$ | $7868{ }^{\circ} 0$ | 8828．0 | ¢988．0 | ¢LE6．0 | 0786.0 | ¢728．0 | ¢ぇ uọqņ！qsui |
| モ¢L0．0 | ¢ヵt60 | $0968{ }^{\circ} 0$ | モ686．0 | L976．0 | 9706.0 | モ606．0 | 轨 uọqņ！qsui |
| ¢900 $0^{-}$ | \％LZ9．0 | \％LIS 0 | LLIC0 | 0699．0 | LLEC 0 | 60tco | ¢\％uọqņ！qsui |
| ¢¢60＊0 | も8L゙っ0 | 97ざ゚ 0 | L987＊ 0 | 7¢67＊ 0 | ๖¢67＊ 0 | $6209^{\circ} 0$ | 7\％uọqņ！qsui |
| 0L80＊0 | 97960 | 0086.0 | 87960 | 8L96．0 | 0296．0 | 0L96．0 |  |
| LSIL＇0 | $6706{ }^{\circ}$ | $8788{ }^{\circ} 0$ | L268．0 | L668．0 | $9286{ }^{\circ}$ | 08才6．0 |  |
| \％LLE ${ }^{-}$ | 7¢78 ${ }^{\circ} 0$ | $69 ¢ 8{ }^{\circ} 0$ | 7¢08．0 | L268＊0 | ELL6．0 | L699＊0 |  |
| $68700^{\circ}$ | 98L2．0 | 0202\％ | 69L9＇0 | 8882．0 | モ072\％ 0 | $69 ¢ 200$ | 88 uo！̣ņ！̣sui |
| 86It 0 | $8998{ }^{\circ}$ | 726200 | LE980 | モ698．0 | 0206．0 | 02I6．0 | L\＆uọqņ！qsui |
| 7610\％${ }^{-}$ | ¢¢68＊ 0 | $28 \mathrm{~L} 6^{\circ} 0$ | 8806.0 | $0068{ }^{\circ}$ | 9698．0 | ¢668．0 |  |
| $2980{ }^{\circ} 0$ | L889＊0 | 0889 ${ }^{\circ}$ | $9099{ }^{\circ}$ | LIE9 0 | も¢¢9．0 | LTL9 0 | ¢\＆uọpņ̧̣sui |
| $9690{ }^{\circ} 0$ | 88970 | gLEF＊ 0 | 997た 0 | 0997＊ 0 | 0¢97＊ 0 | LLO9．0 | モ¢ uọpņ̧̧̣sui |
| Крп7S เəлО ә．ภиечО \％ |  | 6007－8007 | 8007－2007 | 2007－9007 | 9007－9007 | 900\％－モ00\％ |  |

TableB. 1 - continued from the previous page

| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Institution 51 | 0.5954 | 0.5499 | 0.4964 | 0.4246 | 0.4827 | 0.5098 | 0.1127 |
| Institution 52 | 0.8929 | 0.8334 | 0.8078 | 0.8231 | 0.8032 | 0.8321 | 0.0897 |
| Institution 53 | 0.8151 | 0.8295 | 0.8399 | 0.8284 | 0.7858 | 0.8197 | 0.0293 |
| Institution 54 | 0.8874 | 0.8336 | 0.8980 | 0.8571 | 0.8488 | 0.8650 | 0.0386 |
| Institution 55 | 0.8920 | 0.8709 | 0.8829 | 0.8893 | 0.8971 | 0.8864 | -0.0051 |
| Institution 56 | 0.8255 | 0.7566 | 0.7376 | 0.7527 | 0.7004 | 0.7545 | 0.1251 |
| Institution 57 | 0.9163 | 0.9217 | 0.8962 | 0.8979 | 0.8102 | 0.8885 | 0.1060 |
| Institution 58 | 0.7947 | 0.8641 | 0.8367 | 0.7865 | 0.7538 | 0.8072 | 0.0409 |
| Institution 59 | 0.4713 | 0.4676 | 0.4666 | 0.4255 | 0.5032 | 0.4668 | -0.0319 |
| Institution 60 | 0.8166 | 0.8278 | 0.8386 | 0.8610 | 0.7972 | 0.8283 | 0.0194 |
| Institution 61 | 0.7226 | 0.6665 | 0.6236 | 0.6729 | 0.6020 | 0.6575 | 0.1207 |
| Institution 62 | 0.7184 | 0.7133 | 0.6729 | 0.6661 | 0.5897 | 0.6721 | 0.1286 |
| Institution 63 | 0.7815 | 0.8085 | 0.7669 | 0.6539 | 0.5904 | 0.7202 | 0.1911 |
| Institution 64 | 0.8601 | 0.7950 | 0.8129 | 0.7528 | 0.7609 | 0.7964 | 0.0992 |
| Institution 65 | 0.5512 | 0.5360 | 0.5549 | 0.5999 | 0.6234 | 0.5731 | -0.0722 |
| Institution 66 | 0.5043 | 0.4960 | 0.5859 | 0.5995 | 0.5943 | 0.5560 | -0.0900 |
| Institution 67 | 0.8112 | 0.9131 |  |  |  | 0.8621 | -0.1018 |
|  |  |  |  |  | Continued on the next page |  |  |

TableB． 1 －continued from the previous page

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| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Z¢70＇0－ | $6776{ }^{\circ} 0$ | L¢960 | LLI6 0 | LZ980 | $9686{ }^{\circ}$ | 0LZ6．0 | モ8 uo！̣qnษ！̣sui |
| $9780{ }^{\circ}$ | 6898．0 | L¢\＆8．0 | g $298{ }^{\circ} 0$ | 99980 | $87 \pm 8.0$ | $2898{ }^{\circ} 0$ |  |
| $680{ }^{\circ} 0^{-}$ | gLE9 0 | 8929\％ 0 | $0899{ }^{\circ}$ | 7ヵ¢900 | 69 L900 | 6729．0 |  |
| $90 \pm 0 \cdot 0$－ | 78L6．0 | $9 \mathrm{LG6} 0$ | $9676^{\circ} 0$ | モ028．0 | 96060 | 0LL6．0 |  |
| $9200{ }^{\circ}$ | モ9¢9．0 | 8099＊0 | モも¢9＊0 | п899\％ 0 | $6699{ }^{\circ}$ | 7899\％ | 08 uo！̣nษ！${ }^{\text {asui }}$ |
| $92700^{-}$ | L0\＆6．0 | モ076．0 | 98960 | 8i \％60 | $7 \boxed{76} 8^{\circ}$ | 82L6．0 |  |
| ¢690＊0 | 8706.0 | $8088^{\circ} 0$ | 8LI6．0 | モ628＊0 | 8 L 06.0 | LOt6．0 | 82 uo！̣nษ！${ }^{\text {asui }}$ |
| 9970．0 | ¢ $8888^{\circ}$ | 86980 | ¢068＊0 | ¢888＊0 | $6998{ }^{\circ} 0$ | ¢906．0 | $\angle L$ uoṭnq！qsui |
| 2010．0－ | 0998．0 | \＆6980 | ES980 | $6798{ }^{\circ}$ | 9978．0 | $2878{ }^{\circ} 0$ |  |
| $689 \mathrm{I}^{\circ} 0$ | 69L9＇0 | $9709{ }^{\circ}$ | $6289{ }^{\circ} 0$ | モ689＊0 | $67 ¢ 9 \times 0$ | 99920 |  |
| 7810＊0－ | 291た．0 | モL68：0 | モ6970 | てLE®＊ 0 | 891ヵ＊ 0 | 7628：0 |  |
| ¢890．0 | ¢ち79\％ 0 | LI89．0 | モ209\％ 0 | 9099＊0 | 67ヶ9＊0 | 7079．0 |  |
| 78L7＊0－ | LF62．0 | 6 Lt 6.0 | $9678^{\circ} 0$ | 0982\％ | 78¢ $2^{\circ} 0$ | L899\％ 0 |  |
| 7870 $0^{-}$ | 7798．0 | 0968．0 | ¢¢68＊ 0 | 2062\％0 | \＆8L8＊0 | 8L980 |  |
| \％7п0＊0－ | 02Iだ0 | 9しだて 0 | ¢LE®＊ 0 | 79じ0 | 9968＊0 | 7668：0 |  |
| LLS0 0 | \＆¢0L\％ | L289＊0 | 9689＊0 | 9669＊0 | ETLL＊0 | ģtio | 69 บо！̣nษ！̣sui |
| gsto $0^{-}$ | 86 I 6.0 | モ¢ $¢ 60$ | LLも6．0 | 0ヵI6．0 | $2868^{\circ} 0$ | $6668^{\circ} 0$ | 89 บо！̣nษ！ุ̣suI |
|  |  | 6007－8007 | 8007－2007 | 2007－9007 | 900\％－c00z | 900\％－๒00\％ |  |

TableB. 1 - continued from the previous page

| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Institution 85 | 0.9212 | 0.9275 | 0.9378 | 0.9558 | 0.9435 | 0.9372 | -0.0223 |
| Institution 86 | 0.9001 | 0.8463 | 0.8388 | 0.8767 | 0.8305 | 0.8585 | 0.0695 |
| Institution 87 | 0.7098 | 0.7172 | 0.7108 | 0.7073 | 0.6405 | 0.6971 | 0.0693 |
| Institution 88 | 0.7337 | 0.7985 | 0.8939 | 0.9225 | 0.9472 | 0.8592 | -0.2135 |
| Institution 89 | 0.9249 | 0.9245 | 0.9481 | 0.9408 | 0.9499 | 0.9376 | -0.0250 |
| Institution 90 | 0.7289 | 0.7646 | 0.8088 | 0.8951 | 0.9140 | 0.8223 | -0.1852 |
| Institution 91 | 0.8555 | 0.8623 | 0.8859 | 0.8868 | 0.8810 | 0.8743 | -0.0255 |
| Institution 92 | 0.8929 | 0.8589 | 0.9126 | 0.9194 | 0.8978 | 0.8963 | -0.0049 |
| Institution 93 | 0.9384 | 0.9272 | 0.9352 | 0.9404 | 0.9282 | 0.9339 | 0.0102 |
| Institution 94 | 0.7175 | 0.4508 | 0.4688 | 0.5644 | 0.5238 | 0.5450 | 0.1937 |
| Institution 95 | 0.4971 | 0.4501 | 0.4805 | 0.5015 | 0.5312 | 0.4921 | -0.0341 |
| Institution 96 | 0.9610 | 0.9656 | 0.9525 | 0.9442 | 0.9453 | 0.9537 | 0.0157 |
| Institution 97 | 0.3978 | 0.3763 | 0.4171 | 0.4085 | 0.3683 | 0.3936 | 0.0295 |
| Institution 98 | 0.8195 | 0.8217 | 0.8696 | 0.8654 | 0.8434 | 0.8439 | -0.0239 |
| Institution 99 | 0.8164 | 0.8198 | 0.8369 | 0.8411 | 0.8318 | 0.8292 | -0.0154 |
| Institution 100 | 0.8046 | 0.8138 | 0.8508 | 0.8133 | 0.8674 | 0.8300 | -0.0628 |
| Institution 101 | 0.9597 | 0.9582 | 0.9595 | 0.9581 | 0.9538 | 0.9579 | 0.0059 |
|  |  |  |  |  | Continued on the next page |  |  |

TableB. 1 - continued from the previous page

| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Institution 102 | 0.9422 | 0.9162 | 0.9077 | 0.9486 | 0.9200 | 0.9270 | 0.0222 |
| Institution 103 | 0.8841 | 0.8863 | 0.9379 | 0.9248 | 0.9272 | 0.9121 | -0.0431 |
| Institution 104 | 0.9233 | 0.9362 | 0.9411 | 0.9091 | 0.9130 | 0.9246 | 0.0103 |
| Institution 105 | 0.2461 | 0.2658 | 0.2694 | 0.2892 | 0.2395 | 0.2620 | 0.0066 |
| Institution 106 | 0.9313 | 0.9056 | 0.9458 | 0.9196 | 0.9118 | 0.9228 | 0.0195 |
| Institution 107 | 0.8910 | 0.8639 | 0.9048 | 0.8900 | 0.9083 | 0.8916 | -0.0174 |
| Institution 108 | 0.9486 | 0.9469 | 0.9522 | 0.9437 | 0.9422 | 0.9467 | 0.0063 |
| Institution 109 | 0.9166 | 0.8960 | 0.9121 | 0.9294 | 0.9201 | 0.9149 | -0.0035 |
| Institution 110 | 0.9362 | 0.9230 | 0.9227 | 0.9272 | 0.9253 | 0.9269 | 0.0109 |
| Institution 111 | 0.9138 | 0.9048 | 0.9201 | 0.9160 | 0.9124 | 0.9134 | 0.0014 |
| Institution 112 | 0.9272 | 0.9207 | 0.8160 | 0.8228 | 0.7983 | 0.8570 | 0.1289 |
| Institution 113 | 0.9442 | 0.9295 | 0.9324 | 0.9194 | 0.9248 | 0.9301 | 0.0194 |
| Institution 114 | 0.9048 | 0.8679 | 0.9211 | 0.9257 | 0.9263 | 0.9091 | -0.0215 |
| Institution 115 | 0.7699 | 0.7756 | 0.8482 | 0.8536 | 0.8529 | 0.8201 | -0.0830 |
| Institution 116 | 0.9289 | 0.8947 | 0.8794 | 0.8917 | 0.9029 | 0.8995 | 0.0260 |
| Institution 117 | 0.7670 | 0.6787 | 0.7251 | 0.7590 | 0.7275 | 0.7315 | 0.0395 |
| Institution 118 | 0.9024 | 0.8836 | 0.8888 | 0.9010 | 0.8846 | 0.8921 | 0.0178 |
|  |  |  |  |  | Continued on the next page |  |  |

TableB. 1 - continued from the previous page

| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Institution 119 | 0.3239 | 0.2649 | 0.3016 | 0.2858 | 0.3041 | 0.2961 | 0.0198 |
| Institution 120 | 0.9293 | 0.9217 | 0.8666 | 0.8944 | 0.8978 | 0.9020 | 0.0315 |
| Institution 121 | 0.9435 | 0.9059 | 0.8988 | 0.8440 | 0.8718 | 0.8928 | 0.0717 |
| Institution 122 | 0.9292 | 0.8940 | 0.9140 | 0.9389 | 0.9158 | 0.9184 | 0.0134 |
| Institution 123 | 0.7673 | 0.6831 | 0.6205 | 0.8434 | 0.8239 | 0.7476 | -0.0565 |
| Institution 124 | 0.7724 | 0.7342 | 0.9097 |  |  | 0.8054 | -0.1373 |
| Institution 125 | 0.9512 | 0.9407 | 0.8906 | 0.7897 | 0.7307 | 0.8606 | 0.2205 |
| Institution 126 | 0.8636 | 0.8208 | 0.7802 | 0.7225 | 0.7466 | 0.7868 | 0.1170 |
| Institution 127 | 0.6492 | 0.6823 | 0.6389 |  |  | 0.6568 | 0.0104 |
| Institution 128 | 0.4834 | 0.4628 | 0.4694 | 0.4489 | 0.4529 | 0.4635 | 0.0305 |
| Institution 129 | 0.6487 | 0.7158 | 0.6462 | 0.5989 | 0.6362 | 0.6492 | 0.0125 |
| Institution 130 | 0.8821 | 0.6835 | 0.8505 | 0.6947 | 0.5148 | 0.7251 | 0.3673 |
| Institution 131 | 0.5007 | 0.4910 | 0.4337 | 0.4356 | 0.4169 | 0.4556 | 0.0838 |
| Institution 132 | 0.4209 | 0.3538 | 0.3137 | 0.2700 | 0.3025 | 0.3322 | 0.1184 |
| Institution 133 | 0.7452 | 0.4726 | 0.4460 | 0.4393 | 0.4399 | 0.5086 | 0.3053 |
| Institution 134 |  | 0.4638 | 0.4457 | 0.4796 | 0.6180 | 0.5018 | -0.1542 |
| Institution 135 | 0.9411 | 0.9011 | 0.9340 | 0.9334 | 0.9242 | 0.9268 | 0.0169 |

TableB. 1 - continued from the previous page

| TableB.1 - continued from the previous page |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Name of Institution | $2004-2005$ | $2005-2006$ | $2006-2007$ | $2007-2008$ | $2008-2009$ | Average Efficiency | \% Change Over Study |
| Institution 136 |  |  | 0.1819 | 0.1612 | 0.1581 | 0.1671 | 0.0238 |
| Institution 137 |  | 0.8568 | 0.7960 | 0.8219 | 0.7769 | 0.8129 | 0.0799 |
| Institution 138 |  | 0.7715 | 0.8780 | 0.8133 | 0.7661 | 0.8072 | 0.0054 |
| Institution 139 |  |  | 0.3228 | 0.3639 | 0.3249 | 0.3372 | -0.0021 |

Table B.2: Merger Units

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 1 | Bishop <br> Grosseteste <br> College | The University of Lincoln |  |  |  |  |
| Merger 2 | Canterbury <br> Christ Church <br> University | The University of Kent |  |  |  |  |
| Merger 3 | York St John College | The University of York |  |  |  |  |
| Merger 4 | College of St <br> Mark and St <br> John | The University of Plymouth |  |  |  |  |
| Merger 5 | The University <br> of <br> Wolverhampton | Harper Adams <br> University <br> College | Staffordshire <br> University |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 6 <br> Merger 7 <br> Merger 8 <br> Merger 9 <br> Merger 10 | The University of Birmingham <br> University of Central England in Birmingham <br> The University of Birmingham <br> Liverpool Hope University <br> Royal Northern College of Music | University of Central England in Birmingham <br> Aston <br> University <br> Newman <br> College of HE <br> Liverpool John <br> Moores <br> University <br> The University of Manchester | Aston <br> University <br> Birmingham <br> College of Food, <br> Tourism and Creative Studies <br> The University of Liverpool | Newman <br> College of HE <br> The Liverpool Institute for Performing Arts | Birmingham <br> College of Food, <br> Tourism and <br> Creative Studies |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 16 | Leeds <br> Metropolitan <br> University | Leeds College of Music | The University of Leeds | Trinity and All Saints College |  |  |
| Merger 17 | Leeds <br> Metropolitan <br> University | The University of Leeds |  |  |  |  |
| Merger 18 | Leeds <br> Metropolitan <br> University | Leeds College of Music | Trinity and All Saints College |  |  |  |
| Merger 19 | The University of Cambridge | Anglia Ruskin University |  |  |  |  |
| Merger 20 | The University of Bath | Bath Spa <br> University |  |  |  |  |
| Merger 21 | The University of Brighton | The University of Sussex |  |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 22 | The University <br> of Central <br> Lancashire | The University of Lancaster |  |  |  |  |
| Merger 23 | Coventry <br> University | The University of Warwick |  |  |  |  |
| Merger 24 | University of Luton | University of Hertfordshire |  |  |  |  |
| Merger 25 | The University of Bradford | The University of Huddersfield |  |  |  |  |
| Merger 26 | The University of Leicester | De Montfort University |  |  |  |  |
| Merger 27 | The University of Newcastle-upon-Tyne | The University of Northumbria at Newcastle |  |  |  |  |
| Merger 28 | The University of Nottingham | The Nottingham <br> Trent University |  |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 29 | The University of Oxford | Oxford Brookes University |  |  |  |  |
| Merger 30 | The University of Sheffield | Sheffield Hallam <br> University |  |  |  |  |
| Merger 31 | Staffordshire <br> University | The University of Keele |  |  |  |  |
| Merger 32 | University of the West of England, Bristol | The University of Bristol |  |  |  |  |
| Merger 33 | The University of Wales, Newport | University of Wales Institute, Cardiff | University of Wales, Swansea | University of <br> Glamorgan | Swansea <br> Institute of <br> Higher <br> Education | Royal Welsh College of Music and Drama |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| TableB. 2 - continued from the previous page |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| Merger 34 <br> Merger 35 <br> Merger 36 <br> Merger 37 | University of Chester <br> University of Wales, Swansea The University of Wales, Lampeter <br> The University of East Anglia | The North-East <br> Wales Institute of Higher <br> Education <br> Swansea <br> Institute of <br> Higher <br> Education <br> Swansea <br> Institute of <br> Higher <br> Education <br> Norwich School of Art and Design | University of Wales, Bangor |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 38 | Anglia Ruskin University | The University of Essex |  |  |  |  |
| Merger 39 | The University of Exeter | College of St <br> Mark and St John | The University of Plymouth |  |  |  |
| Merger 40 | The University of York | The University of Hull |  |  |  |  |
| Merger 41 | The University <br> of Wales, <br> Lampeter | University of <br> Wales, <br> Aberystwyth |  |  |  |  |
| Merger 42 | Writtle College | Anglia Ruskin University |  |  |  |  |
| Merger 43 | University of Gloucestershire | Royal <br> Agricultural <br> College |  |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| TableB. 2 - continued from the previous page |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| Merger 44 <br> Merger 45 <br> Merger 46 <br> Merger 47 | The Arts <br> Institute at <br> Bournemouth <br> Harper Adams <br> University <br> College <br> University of Central England in Birmingham <br> Aston <br> University | Bournemouth <br> University <br> Staffordshire <br> University <br> Birmingham <br> College of Food, <br> Tourism and <br> Creative Studies <br> Newman <br> College of HE | Birmingham College of Food, <br> Tourism and Creative Studies |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 48 | Newman College of HE | Birmingham |  |  |  |  |
|  |  | College of Food, |  |  |  |  |
|  |  | Tourism and |  |  |  |  |
|  |  | Creative Studies |  |  |  |  |
| Merger 49 | Liverpool Hope <br> University | The Liverpool |  |  |  |  |
|  |  | Institute for |  |  |  |  |
|  |  | Performing Arts |  |  |  |  |
| Merger 50 | The University | Royal Northern |  |  |  |  |
|  | of Salford | College of Music |  |  |  |  |
| Merger 51 | Leeds College of | Trinity and All |  |  |  |  |
|  | Music | Saints College |  |  |  |  |
| Merger 52 | The University of Wales, |  |  |  | Royal Welsh |  |
|  |  | University of | University of | Institute of |  |  |
|  |  | Wales, Swansea | Glamorgan | Higher | College of Music |  |
|  | Newport |  |  | Education | and Drama |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 53 <br> Merger 54 <br> Merger 55 <br> Merger 56 <br> Merger 57 | The University of Wales, Newport <br> The University of Wales, Newport <br> College of St <br> Mark and St <br> John <br> University of the <br> Arts, London <br> Ravensbourne <br> College of <br> Design and <br> Communication | University of Glamorgan <br> University of Glamorgan <br> The University of Plymouth <br> Courtauld Institute of Art <br> Trinity Laban | Swansea <br> Institute of <br> Higher <br> Education <br> Royal Welsh <br> College of Music <br> and Drama | Royal Welsh College of Music and Drama |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 2 - continued from the previous page

| Merger Number | University 1 | University 2 | University 3 | University 4 | University 5 | University 6 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 58 | Royal Academy of Music | St Martin's College |  |  |  |  |
| Merger 59 | Trinity Laban | Goldsmiths College |  |  |  |  |
| Merger 60 | University of the Arts, London | Institute of Education | Conservatoire for Dance and Drama | Courtauld <br> Institute of Art |  |  |
| Merger 61 | Institute of <br> Education | Conservatoire for Dance and Drama |  |  |  |  |
| Merger 62 | Imperial College of Science, Technology and Medicine | Heythrop <br> College |  |  |  |  |

Table B.3: Merger Efficiency Scores

| Merger <br> Number | Time ID | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 1 | $2004-2005$ | 0.3791 | 0.9905 | 0.3828 | 0.9905 | 1.0000 |
| Merger 1 | $2005-2006$ | 0.3611 | 0.9906 | 0.3645 | 0.9906 | 1.0000 |
| Merger 1 | $2006-2007$ | 0.3572 | 0.9819 | 0.3638 | 0.9819 | 1.0000 |
| Merger 1 | $2007-2008$ | 0.3226 | 0.9870 | 0.3269 | 0.9870 | 1.0000 |
| Merger 1 | $2008-2009$ | 0.3204 | 0.9772 | 0.3278 | 0.9772 | 1.0000 |
| Merger 2 | $2004-2005$ | 0.4864 | 0.9833 | 0.4947 | 0.9833 | 1.0000 |
| Merger 2 | $2005-2006$ | 0.4843 | 0.9873 | 0.4905 | 0.9873 | 1.0000 |
| Merger 2 | $2006-2007$ | 0.4399 | 0.9815 | 0.4481 | 0.9815 | 1.0000 |
| Merger 2 | $2007-2008$ | 0.4253 | 0.9925 | 0.4285 | 0.9925 | 1.0000 |
| Merger 2 | $2008-2009$ | 0.4348 | 0.9852 | 0.4413 | 0.9852 | 1.0000 |
| Merger 3 | $2004-2005$ | 0.6109 | 0.9809 | 0.6229 | 0.9809 | 1.0000 |
| Merger 3 | $2005-2006$ | 0.6692 | 0.9738 | 0.6872 | 0.9738 | 1.0000 |
| Merger 3 | $2006-2007$ | 0.5989 | 0.9728 | 0.6156 | 0.9728 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 3 | 2007-2008 | 0.6299 | 0.9746 | 0.6464 | 0.9746 | 1.0000 |
| Merger 3 | 2008-2009 | 0.6591 | 0.9854 | 0.6689 | 0.9854 | 1.0000 |
| Merger 4 | 2004-2005 | 0.6832 | 0.9943 | 0.6871 | 0.9943 | 1.0000 |
| Merger 4 | 2005-2006 | 0.6861 | 0.9914 | 0.6921 | 0.9914 | 1.0000 |
| Merger 4 | 2006-2007 | 0.6665 | 0.9906 | 0.6728 | 0.9906 | 1.0000 |
| Merger 4 | 2007-2008 | 0.6306 | 0.9887 | 0.6378 | 0.9887 | 1.0000 |
| Merger 4 | 2008-2009 | 0.6588 | 0.9891 | 0.6661 | 0.9891 | 1.0000 |
| Merger 5 | 2004-2005 | 0.4983 | 0.9893 | 0.5037 | 0.9893 | 1.0000 |
| Merger 5 | 2005-2006 | 0.5069 | 0.9845 | 0.5149 | 0.9845 | 1.0000 |
| Merger 5 | 2006-2007 | 0.4560 | 0.9827 | 0.4641 | 0.9827 | 1.0000 |
| Merger 5 | 2007-2008 | 0.4533 | 0.9732 | 0.4657 | 0.9732 | 1.0000 |
| Merger 5 | 2008-2009 | 0.4527 | 0.9845 | 0.4598 | 0.9845 | 1.0000 |
| Merger 6 | 2004-2005 | 0.5006 | 0.9817 | 0.5099 | 0.9817 | 1.0000 |
| Merger 6 | 2005-2006 | 0.5357 | 0.9826 | 0.5452 | 0.9826 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 6 | 2006-2007 | 0.5061 | 0.9888 | 0.5118 | 0.9888 | 1.0000 |
| Merger 6 | 2007-2008 | 0.5057 | 0.9875 | 0.5121 | 0.9875 | 1.0000 |
| Merger 6 | 2008-2009 | 0.5574 | 0.9932 | 0.5612 | 0.9932 | 1.0000 |
| Merger 7 | 2004-2005 | 0.3594 | 0.9585 | 0.3750 | 0.9585 | 1.0000 |
| Merger 7 | 2005-2006 | 0.3801 | 0.9645 | 0.3941 | 0.9645 | 1.0000 |
| Merger 7 | 2006-2007 | 0.3674 | 0.9815 | 0.3743 | 0.9815 | 1.0000 |
| Merger 7 | 2007-2008 | 0.3541 | 0.9751 | 0.3632 | 0.9751 | 1.0000 |
| Merger 7 | 2008-2009 | 0.3876 | 0.9851 | 0.3934 | 0.9851 | 1.0000 |
| Merger 8 | 2004-2005 | 0.6326 | 0.9962 | 0.6350 | 0.9962 | 1.0000 |
| Merger 8 | 2005-2006 | 0.6770 | 0.9945 | 0.6808 | 0.9945 | 1.0000 |
| Merger 8 | 2006-2007 | 0.6412 | 0.9972 | 0.6430 | 0.9972 | 1.0000 |
| Merger 8 | 2007-2008 | 0.6533 | 0.9975 | 0.6550 | 0.9975 | 1.0000 |
| Merger 8 | 2008-2009 | 0.7187 | 0.9974 | 0.7205 | 0.9974 | 1.0000 |
| Merger 9 | 2004-2005 | 0.6046 | 0.9338 | 0.6475 | 0.9338 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 9 | 2005-2006 | 0.6809 | 0.9361 | 0.7274 | 0.9361 | 1.0000 |
| Merger 9 | 2006-2007 | 0.6302 | 0.9692 | 0.6503 | 0.9692 | 1.0000 |
| Merger 9 | 2007-2008 | 0.6512 | 0.9617 | 0.6771 | 0.9617 | 1.0000 |
| Merger 9 | 2008-2009 | 0.6717 | 0.9796 | 0.6857 | 0.9796 | 1.0000 |
| Merger 10 | 2004-2005 | 0.6230 | 1.0000 | 0.6230 | 1.0000 | 1.0000 |
| Merger 10 | 2005-2006 | 0.7209 | 1.0000 | 0.7209 | 1.0000 | 1.0000 |
| Merger 10 | 2006-2007 | 0.6640 | 0.9997 | 0.6642 | 0.9997 | 1.0000 |
| Merger 10 | 2007-2008 | 0.6533 | 1.0000 | 0.6533 | 1.0000 | 1.0000 |
| Merger 10 | 2008-2009 | 0.7104 | 1.0000 | 0.7104 | 1.0000 | 1.0000 |
| Merger 11 | 2004-2005 | 0.4946 | 0.9525 | 0.5192 | 0.9525 | 1.0000 |
| Merger 11 | 2005-2006 | 0.5602 | 0.9910 | 0.5653 | 0.9910 | 1.0000 |
| Merger 11 | 2006-2007 | 0.5480 | 0.9974 | 0.5495 | 0.9974 | 1.0000 |
| Merger 11 | 2007-2008 | 0.5464 | 0.9967 | 0.5482 | 0.9967 | 1.0000 |
| Merger 11 | 2008-2009 | 0.5764 | 0.9963 | 0.5786 | 0.9963 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 12 | 2004-2005 | 0.5407 | 0.9609 | 0.5627 | 0.9609 | 1.0000 |
| Merger 12 | 2005-2006 | 0.6265 | 0.9905 | 0.6326 | 0.9905 | 1.0000 |
| Merger 12 | 2006-2007 | 0.5942 | 0.9972 | 0.5958 | 0.9972 | 1.0000 |
| Merger 12 | 2007-2008 | 0.5792 | 0.9964 | 0.5813 | 0.9964 | 1.0000 |
| Merger 12 | 2008-2009 | 0.6196 | 0.9960 | 0.6220 | 0.9960 | 1.0000 |
| Merger 13 | 2004-2005 | 0.6127 | 0.9860 | 0.6214 | 0.9860 | 1.0000 |
| Merger 13 | 2005-2006 | 0.6624 | 0.9854 | 0.6723 | 0.9854 | 1.0000 |
| Merger 13 | 2006-2007 | 0.5368 | 0.9933 | 0.5404 | 0.9933 | 1.0000 |
| Merger 13 | 2007-2008 | 0.5563 | 0.9923 | 0.5606 | 0.9923 | 1.0000 |
| Merger 13 | 2008-2009 | 0.5638 | 0.9932 | 0.5676 | 0.9932 | 1.0000 |
| Merger 14 | 2004-2005 | 0.5132 | 0.9616 | 0.5337 | 0.9616 | 1.0000 |
| Merger 14 | 2005-2006 | 0.5384 | 0.9675 | 0.5565 | 0.9675 | 1.0000 |
| Merger 14 | 2006-2007 | 0.4837 | 0.9842 | 0.4915 | 0.9842 | 1.0000 |
| Merger 14 | 2007-2008 | 0.4811 | 0.9875 | 0.4872 | 0.9875 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 14 | 2008-2009 | 0.4855 | 0.9878 | 0.4915 | 0.9878 | 1.0000 |
| Merger 15 | 2004-2005 | 0.3665 | 0.9944 | 0.3686 | 0.9944 | 1.0000 |
| Merger 15 | 2005-2006 | 0.3499 | 0.9957 | 0.3514 | 0.9957 | 1.0000 |
| Merger 15 | 2006-2007 | 0.3855 | 0.9959 | 0.3871 | 0.9959 | 1.0000 |
| Merger 15 | 2007-2008 | 0.3395 | 0.9966 | 0.3406 | 0.9966 | 1.0000 |
| Merger 15 | 2008-2009 | 0.3448 | 0.9923 | 0.3475 | 0.9923 | 1.0000 |
| Merger 16 | 2004-2005 | 0.5484 | 0.9654 | 0.5681 | 0.9654 | 1.0000 |
| Merger 16 | 2005-2006 | 0.5610 | 0.9564 | 0.5866 | 0.9564 | 1.0000 |
| Merger 16 | 2006-2007 | 0.5293 | 0.9660 | 0.5480 | 0.9660 | 1.0000 |
| Merger 16 | 2007-2008 | 0.5298 | 0.9754 | 0.5431 | 0.9754 | 1.0000 |
| Merger 16 | 2008-2009 | 0.5787 | 0.9733 | 0.5946 | 0.9733 | 1.0000 |
| Merger 17 | 2004-2005 | 0.5558 | 0.9665 | 0.5751 | 0.9665 | 1.0000 |
| Merger 17 | 2005-2006 | 0.5852 | 0.9570 | 0.6115 | 0.9570 | 1.0000 |
| Merger 17 | 2006-2007 | 0.5544 | 0.9669 | 0.5734 | 0.9669 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 17 | 2007-2008 | 0.5526 | 0.9770 | 0.5656 | 0.9770 | 1.0000 |
| Merger 17 | 2008-2009 | 0.6028 | 0.9744 | 0.6187 | 0.9744 | 1.0000 |
| Merger 18 | 2004-2005 | 0.3530 | 0.9936 | 0.3553 | 0.9936 | 1.0000 |
| Merger 18 | 2005-2006 | 0.3581 | 0.9934 | 0.3605 | 0.9934 | 1.0000 |
| Merger 18 | 2006-2007 | 0.3367 | 0.9953 | 0.3383 | 0.9953 | 1.0000 |
| Merger 18 | 2007-2008 | 0.3129 | 0.9948 | 0.3145 | 0.9948 | 1.0000 |
| Merger 18 | 2008-2009 | 0.3549 | 0.9975 | 0.3558 | 0.9975 | 1.0000 |
| Merger 19 | 2004-2005 | 0.6975 | 0.9867 | 0.7069 | 0.9867 | 1.0000 |
| Merger 19 | 2005-2006 | 0.7609 | 0.9756 | 0.7799 | 0.9756 | 1.0000 |
| Merger 19 | 2006-2007 | 0.6485 | 0.9752 | 0.6649 | 0.9752 | 1.0000 |
| Merger 19 | 2007-2008 | 0.6943 | 0.9784 | 0.7096 | 0.9784 | 1.0000 |
| Merger 19 | 2008-2009 | 0.7232 | 0.9749 | 0.7418 | 0.9749 | 1.0000 |
| Merger 20 | 2004-2005 | 0.4576 | 0.9760 | 0.4689 | 0.9760 | 1.0000 |
| Merger 20 | 2005-2006 | 0.4700 | 0.9750 | 0.4821 | 0.9750 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 20 | 2006-2007 | 0.4180 | 0.9616 | 0.4347 | 0.9616 | 1.0000 |
| Merger 20 | 2007-2008 | 0.4393 | 0.9378 | 0.4685 | 0.9378 | 1.0000 |
| Merger 20 | 2008-2009 | 0.4363 | 0.9360 | 0.4662 | 0.9360 | 1.0000 |
| Merger 21 | 2004-2005 | 0.3527 | 0.9261 | 0.3808 | 0.9261 | 1.0000 |
| Merger 21 | 2005-2006 | 0.4110 | 0.9347 | 0.4397 | 0.9347 | 1.0000 |
| Merger 21 | 2006-2007 | 0.3911 | 0.9560 | 0.4091 | 0.9560 | 1.0000 |
| Merger 21 | 2007-2008 | 0.3798 | 0.9431 | 0.4028 | 0.9431 | 1.0000 |
| Merger 21 | 2008-2009 | 0.3860 | 0.9554 | 0.4040 | 0.9554 | 1.0000 |
| Merger 22 | 2004-2005 | 0.5160 | 0.9980 | 0.5170 | 0.9980 | 1.0000 |
| Merger 22 | 2005-2006 | 0.5060 | 0.9820 | 0.5153 | 0.9820 | 1.0000 |
| Merger 22 | 2006-2007 | 0.5044 | 0.9905 | 0.5092 | 0.9905 | 1.0000 |
| Merger 22 | 2007-2008 | 0.4684 | 0.9815 | 0.4772 | 0.9815 | 1.0000 |
| Merger 22 | 2008-2009 | 0.4639 | 0.9862 | 0.4703 | 0.9862 | 1.0000 |
| Merger 23 | 2004-2005 | 0.5889 | 0.9892 | 0.5953 | 0.9892 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 23 | $2005-2006$ | 0.6436 | 0.9903 | 0.6499 | 0.9903 | 1.0000 |
| Merger 23 | $2006-2007$ | 0.6124 | 0.9937 | 0.6163 | 0.9937 | 1.0000 |
| Merger 23 | $2007-2008$ | 0.5743 | 0.9973 | 0.5759 | 0.9973 | 1.0000 |
| Merger 23 | $2008-2009$ | 0.6047 | 0.9977 | 0.6061 | 0.9977 | 1.0000 |
| Merger 24 | $2004-2005$ | 0.5238 | 0.9960 | 0.5259 | 0.9960 | 1.0000 |
| Merger 24 | $2005-2006$ | 0.4849 | 0.9961 | 0.4868 | 0.9961 | 1.0000 |
| Merger 24 | $2006-2007$ | 0.4323 | 0.9937 | 0.4351 | 0.9937 | 1.0000 |
| Merger 24 | $2007-2008$ | 0.4068 | 0.9843 | 0.4133 | 0.9843 | 1.0000 |
| Merger 24 | $2008-2009$ | 0.4768 | 0.9862 | 0.4835 | 0.9862 | 1.0000 |
| Merger 25 | $2004-2005$ | 0.4456 | 1.0000 | 0.4456 | 1.0000 | 1.0000 |
| Merger 25 | $2005-2006$ | 0.4423 | 1.0000 | 0.4423 | 1.0000 | 1.0000 |
| Merger 25 | $2006-2007$ | 0.4473 | 0.9926 | 0.4507 | 0.9926 | 1.0000 |
| Merger 25 | $2007-2008$ | 0.4697 | 0.9839 | 0.4774 | 0.9839 | 1.0000 |
| Merger 25 | $2008-2009$ | 0.4635 | 0.9769 | 0.4744 | 0.9769 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 26 | $2004-2005$ | 0.5460 | 0.9307 | 0.5867 | 0.9307 | 1.0000 |
| Merger 26 | $2005-2006$ | 0.5785 | 0.9640 | 0.6001 | 0.9640 | 1.0000 |
| Merger 26 | $2006-2007$ | 0.4927 | 0.9681 | 0.5089 | 0.9681 | 1.0000 |
| Merger 26 | $2007-2008$ | 0.4928 | 0.9691 | 0.5086 | 0.9691 | 1.0000 |
| Merger 26 | $2008-2009$ | 0.5076 | 0.9680 | 0.5244 | 0.9680 | 1.0000 |
| Merger 27 | $2004-2005$ | 0.6088 | 0.8527 | 0.7139 | 0.8527 | 1.0000 |
| Merger 27 | $2005-2006$ | 0.5840 | 0.7851 | 0.7439 | 0.7851 | 1.0000 |
| Merger 27 | $2006-2007$ | 0.5349 | 0.7839 | 0.6823 | 0.7839 | 1.0000 |
| Merger 27 | $2007-2008$ | 0.5767 | 0.8367 | 0.6892 | 0.8367 | 1.0000 |
| Merger 27 | $2008-2009$ | 0.5932 | 0.8745 | 0.6784 | 0.8745 | 1.0000 |
| Merger 28 | $2004-2005$ | 0.5104 | 1.0000 | 0.5104 | 1.0000 | 1.0000 |
| Merger 28 | $2005-2006$ | 0.5348 | 0.9960 | 0.5369 | 0.9960 | 1.0000 |
| Merger 28 | $2006-2007$ | 0.5022 | 0.9954 | 0.5045 | 0.9954 | 1.0000 |
| Merger 28 | $2007-2008$ | 0.4984 | 0.9947 | 0.5010 | 0.9947 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 28 | 2008-2009 | 0.5275 | 0.9901 | 0.5328 | 0.9901 | 1.0000 |
| Merger 29 | 2004-2005 | 0.6401 | 0.9840 | 0.6505 | 0.9840 | 1.0000 |
| Merger 29 | 2005-2006 | 0.7352 | 0.9861 | 0.7456 | 0.9861 | 1.0000 |
| Merger 29 | 2006-2007 | 0.6722 | 0.9879 | 0.6805 | 0.9879 | 1.0000 |
| Merger 29 | 2007-2008 | 0.7289 | 0.9784 | 0.7450 | 0.9784 | 1.0000 |
| Merger 29 | 2008-2009 | 0.7726 | 0.9739 | 0.7933 | 0.9739 | 1.0000 |
| Merger 30 | 2004-2005 | 0.5859 | 0.9918 | 0.5907 | 0.9918 | 1.0000 |
| Merger 30 | 2005-2006 | 0.5560 | 0.9853 | 0.5643 | 0.9853 | 1.0000 |
| Merger 30 | 2006-2007 | 0.5353 | 0.9841 | 0.5440 | 0.9841 | 1.0000 |
| Merger 30 | 2007-2008 | 0.5458 | 0.9892 | 0.5518 | 0.9892 | 1.0000 |
| Merger 30 | 2008-2009 | 0.5625 | 0.9889 | 0.5688 | 0.9889 | 1.0000 |
| Merger 31 | 2004-2005 | 0.5600 | 0.9889 | 0.5663 | 0.9889 | 1.0000 |
| Merger 31 | 2005-2006 | 0.5222 | 0.9836 | 0.5310 | 0.9836 | 1.0000 |
| Merger 31 | 2006-2007 | 0.4710 | 0.9756 | 0.4828 | 0.9756 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 31 | 2007-2008 | 0.4561 | 0.9732 | 0.4687 | 0.9732 | 1.0000 |
| Merger 31 | 2008-2009 | 0.4719 | 0.9756 | 0.4837 | 0.9756 | 1.0000 |
| Merger 32 | 2004-2005 | 0.5155 | 0.9473 | 0.5441 | 0.9473 | 1.0000 |
| Merger 32 | 2005-2006 | 0.5682 | 0.9676 | 0.5872 | 0.9676 | 1.0000 |
| Merger 32 | 2006-2007 | 0.5195 | 0.9686 | 0.5364 | 0.9686 | 1.0000 |
| Merger 32 | 2007-2008 | 0.5431 | 0.9744 | 0.5574 | 0.9744 | 1.0000 |
| Merger 32 | 2008-2009 | 0.5952 | 0.9957 | 0.5978 | 0.9957 | 1.0000 |
| Merger 33 | 2004-2005 | 0.4725 | 0.8991 | 0.5256 | 0.8991 | 1.0000 |
| Merger 33 | 2005-2006 | 0.4956 | 0.9574 | 0.5177 | 0.9574 | 1.0000 |
| Merger 33 | 2006-2007 | 0.4957 | 0.9660 | 0.5132 | 0.9660 | 1.0000 |
| Merger 33 | 2007-2008 | 0.4419 | 0.9192 | 0.4807 | 0.9192 | 1.0000 |
| Merger 33 | 2008-2009 | 0.4212 | 0.9075 | 0.4642 | 0.9075 | 1.0000 |
| Merger 34 | 2004-2005 | 0.6241 | 0.9609 | 0.6496 | 0.9609 | 1.0000 |
| Merger 34 | 2005-2006 | 0.6900 | 0.9435 | 0.7313 | 0.9435 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 34 | $2006-2007$ | 0.6594 | 0.9498 | 0.6942 | 0.9498 | 1.0000 |
| Merger 34 | $2007-2008$ | 0.6111 | 0.9321 | 0.6556 | 0.9321 | 1.0000 |
| Merger 34 | $2008-2009$ | 0.6121 | 0.9542 | 0.6415 | 0.9542 | 1.0000 |
| Merger 35 | $2004-2005$ | 0.5440 | 0.9392 | 0.5792 | 0.9392 | 1.0000 |
| Merger 35 | $2005-2006$ | 0.6386 | 0.9900 | 0.6451 | 0.9900 | 1.0000 |
| Merger 35 | $2006-2007$ | 0.6216 | 0.9912 | 0.6272 | 0.9912 | 1.0000 |
| Merger 35 | $2007-2008$ | 0.5500 | 0.9260 | 0.5940 | 0.9260 | 1.0000 |
| Merger 35 | $2008-2009$ | 0.5251 | 0.8820 | 0.5953 | 0.8820 | 1.0000 |
| Merger 36 | $2004-2005$ | 0.3067 | 1.0000 | 0.3067 | 1.0000 | 1.0000 |
| Merger 36 | $2005-2006$ | 0.3169 | 1.0000 | 0.3169 | 1.0000 | 1.0000 |
| Merger 36 | $2006-2007$ | 0.5279 | 1.0000 | 0.5279 | 1.0000 | 1.0000 |
| Merger 36 | $2007-2008$ | 0.4801 | 0.9927 | 0.4836 | 0.9927 | 1.0000 |
| Merger 36 | $2008-2009$ | 0.4528 | 1.0000 | 0.4528 | 1.0000 | 1.0000 |
| Merger 37 | $2004-2005$ | 0.5328 | 0.9956 | 0.5351 | 0.9956 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 37 | $2005-2006$ | 0.4791 | 0.9977 | 0.4802 | 0.9977 | 1.0000 |
| Merger 37 | $2006-2007$ | 0.5395 | 0.9940 | 0.5428 | 0.9940 | 1.0000 |
| Merger 37 | $2007-2008$ | 0.4182 | 0.9956 | 0.4201 | 0.9956 | 1.0000 |
| Merger 37 | $2008-2009$ | 0.3356 | 0.9982 | 0.3362 | 0.9982 | 1.0000 |
| Merger 38 | $2004-2005$ | 0.5479 | 0.9704 | 0.5647 | 0.9704 | 1.0000 |
| Merger 38 | $2005-2006$ | 0.5365 | 0.9584 | 0.5598 | 0.9584 | 1.0000 |
| Merger 38 | $2006-2007$ | 0.4440 | 0.9439 | 0.4704 | 0.9439 | 1.0000 |
| Merger 38 | $2007-2008$ | 0.4291 | 0.9646 | 0.4449 | 0.9646 | 1.0000 |
| Merger 38 | $2008-2009$ | 0.4705 | 0.9577 | 0.4912 | 0.9577 | 1.0000 |
| Merger 39 | $2004-2005$ | 0.5553 | 0.9806 | 0.5663 | 0.9806 | 1.0000 |
| Merger 39 | $2005-2006$ | 0.5917 | 0.9861 | 0.6001 | 0.9861 | 1.0000 |
| Merger 39 | $2006-2007$ | 0.5950 | 0.9942 | 0.5985 | 0.9942 | 1.0000 |
| Merger 39 | $2007-2008$ | 0.5919 | 0.9932 | 0.5960 | 0.9932 | 1.0000 |
| Merger 39 | $2008-2009$ | 0.6535 | 0.9939 | 0.6575 | 0.9939 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 40 | 2004-2005 | 0.6186 | 0.9801 | 0.6312 | 0.9801 | 1.0000 |
| Merger 40 | 2005-2006 | 0.6555 | 0.9879 | 0.6635 | 0.9879 | 1.0000 |
| Merger 40 | 2006-2007 | 0.6035 | 0.9965 | 0.6057 | 0.9965 | 1.0000 |
| Merger 40 | 2007-2008 | 0.6311 | 1.0000 | 0.6311 | 1.0000 | 1.0000 |
| Merger 40 | 2008-2009 | 0.6710 | 1.0000 | 0.6710 | 1.0000 | 1.0000 |
| Merger 41 | 2004-2005 | 0.3941 | 1.0000 | 0.3941 | 1.0000 | 1.0000 |
| Merger 41 | 2005-2006 | 0.3749 | 1.0000 | 0.3749 | 1.0000 | 1.0000 |
| Merger 41 | 2006-2007 | 0.4737 | 1.0000 | 0.4737 | 1.0000 | 1.0000 |
| Merger 41 | 2007-2008 | 0.4407 | 1.0000 | 0.4407 | 1.0000 | 1.0000 |
| Merger 41 | 2008-2009 | 0.4664 | 0.9922 | 0.4701 | 0.9922 | 1.0000 |
| Merger 42 | 2004-2005 | 0.6012 | 0.9977 | 0.6026 | 0.9977 | 1.0000 |
| Merger 42 | 2005-2006 | 0.5868 | 0.9981 | 0.5879 | 0.9981 | 1.0000 |
| Merger 42 | 2006-2007 | 0.4657 | 0.9905 | 0.4701 | 0.9905 | 1.0000 |
| Merger 42 | 2007-2008 | 0.4227 | 0.9949 | 0.4249 | 0.9949 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 42 | 2008-2009 | 0.4547 | 0.9866 | 0.4609 | 0.9866 | 1.0000 |
| Merger 43 | 2004-2005 | 0.4341 | 0.9871 | 0.4398 | 0.9871 | 1.0000 |
| Merger 43 | 2005-2006 | 0.2869 | 0.9899 | 0.2899 | 0.9899 | 1.0000 |
| Merger 43 | 2006-2007 | 0.2822 | 0.9870 | 0.2859 | 0.9870 | 1.0000 |
| Merger 43 | 2007-2008 | 0.2990 | 0.9832 | 0.3041 | 0.9832 | 1.0000 |
| Merger 43 | 2008-2009 | 0.2975 | 0.9827 | 0.3027 | 0.9827 | 1.0000 |
| Merger 44 | 2004-2005 | 0.4644 | 0.9909 | 0.4686 | 0.9909 | 1.0000 |
| Merger 44 | 2005-2006 | 0.5039 | 0.9940 | 0.5070 | 0.9940 | 1.0000 |
| Merger 44 | 2006-2007 | 0.5149 | 0.9896 | 0.5203 | 0.9896 | 1.0000 |
| Merger 44 | 2007-2008 | 0.5276 | 0.9872 | 0.5345 | 0.9872 | 1.0000 |
| Merger 44 | 2008-2009 | 0.5752 | 0.9886 | 0.5818 | 0.9886 | 1.0000 |
| Merger 45 | 2004-2005 | 0.4652 | 0.9832 | 0.4731 | 0.9832 | 1.0000 |
| Merger 45 | 2005-2006 | 0.4796 | 0.9647 | 0.4971 | 0.9647 | 1.0000 |
| Merger 45 | 2006-2007 | 0.4475 | 0.9664 | 0.4631 | 0.9664 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 45 | 2007-2008 | 0.4799 | 0.9446 | 0.5080 | 0.9446 | 1.0000 |
| Merger 45 | 2008-2009 | 0.5109 | 0.9790 | 0.5218 | 0.9790 | 1.0000 |
| Merger 46 | 2004-2005 | 0.3370 | 0.9701 | 0.3473 | 0.9701 | 1.0000 |
| Merger 46 | 2005-2006 | 0.3306 | 0.9734 | 0.3397 | 0.9734 | 1.0000 |
| Merger 46 | 2006-2007 | 0.3296 | 0.9820 | 0.3356 | 0.9820 | 1.0000 |
| Merger 46 | 2007-2008 | 0.3197 | 0.9631 | 0.3320 | 0.9631 | 1.0000 |
| Merger 46 | 2008-2009 | 0.3509 | 0.9832 | 0.3569 | 0.9832 | 1.0000 |
| Merger 47 | 2004-2005 | 0.4307 | 0.9687 | 0.4446 | 0.9687 | 1.0000 |
| Merger 47 | 2005-2006 | 0.5286 | 0.9777 | 0.5407 | 0.9777 | 1.0000 |
| Merger 47 | 2006-2007 | 0.4364 | 0.9742 | 0.4479 | 0.9742 | 1.0000 |
| Merger 47 | 2007-2008 | 0.3972 | 0.9696 | 0.4097 | 0.9696 | 1.0000 |
| Merger 47 | 2008-2009 | 0.4289 | 0.9742 | 0.4403 | 0.9742 | 1.0000 |
| Merger 48 | 2004-2005 | 0.3980 | 0.9874 | 0.4031 | 0.9874 | 1.0000 |
| Merger 48 | 2005-2006 | 0.4114 | 0.9771 | 0.4210 | 0.9771 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 48 | 2006-2007 | 0.3591 | 0.9825 | 0.3655 | 0.9825 | 1.0000 |
| Merger 48 | 2007-2008 | 0.3284 | 0.9787 | 0.3355 | 0.9787 | 1.0000 |
| Merger 48 | 2008-2009 | 0.3369 | 0.9679 | 0.3481 | 0.9679 | 1.0000 |
| Merger 49 | 2004-2005 | 0.5432 | 1.0000 | 0.5432 | 1.0000 | 1.0000 |
| Merger 49 | 2005-2006 | 0.5722 | 1.0000 | 0.5722 | 1.0000 | 1.0000 |
| Merger 49 | 2006-2007 | 0.5712 | 1.0000 | 0.5712 | 1.0000 | 1.0000 |
| Merger 49 | 2007-2008 | 0.4590 | 0.8730 | 0.5257 | 0.8730 | 1.0000 |
| Merger 49 | 2008-2009 | 0.4774 | 0.8907 | 0.5360 | 0.8907 | 1.0000 |
| Merger 50 | 2004-2005 | 0.3513 | 0.9992 | 0.3516 | 0.9992 | 1.0000 |
| Merger 50 | 2005-2006 | 0.3329 | 0.9990 | 0.3333 | 0.9990 | 1.0000 |
| Merger 50 | 2006-2007 | 0.3559 | 0.9986 | 0.3564 | 0.9986 | 1.0000 |
| Merger 50 | 2007-2008 | 0.3903 | 0.9987 | 0.3908 | 0.9987 | 1.0000 |
| Merger 50 | 2008-2009 | 0.3835 | 0.9987 | 0.3840 | 0.9987 | 1.0000 |
| Merger 51 | 2004-2005 | 0.3663 | 1.0000 | 0.3663 | 1.0000 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 51 | $2005-2006$ | 0.2292 | 0.9919 | 0.2311 | 0.9919 | 1.0000 |
| Merger 51 | $2006-2007$ | 0.2170 | 0.9838 | 0.2206 | 0.9838 | 1.0000 |
| Merger 51 | $2007-2008$ | 0.2364 | 0.9858 | 0.2398 | 0.9858 | 1.0000 |
| Merger 51 | $2008-2009$ | 0.2559 | 0.9889 | 0.2588 | 0.9889 | 1.0000 |
| Merger 52 | $2004-2005$ | 0.4554 | 0.9173 | 0.4965 | 0.9173 | 1.0000 |
| Merger 52 | $2005-2006$ | 0.4959 | 0.9702 | 0.5111 | 0.9702 | 1.0000 |
| Merger 52 | $2006-2007$ | 0.4661 | 0.9623 | 0.4843 | 0.9623 | 1.0000 |
| Merger 52 | $2007-2008$ | 0.4483 | 0.9088 | 0.4933 | 0.9088 | 1.0000 |
| Merger 52 | $2008-2009$ | 0.4195 | 0.8944 | 0.4690 | 0.8944 | 1.0000 |
| Merger 53 | $2004-2005$ | 0.2900 | 0.9869 | 0.2938 | 0.9869 | 1.0000 |
| Merger 53 | $2005-2006$ | 0.3963 | 0.9706 | 0.4083 | 0.9706 | 1.0000 |
| Merger 53 | $2006-2007$ | 0.3724 | 0.9559 | 0.3895 | 0.9559 | 1.0000 |
| Merger 53 | $2007-2008$ | 0.3787 | 0.9724 | 0.3895 | 0.9724 | 1.0000 |
| Merger 53 | $2008-2009$ | 0.3423 | 0.9557 | 0.3581 | 0.9557 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 54 | $2004-2005$ | 0.2810 | 0.9794 | 0.2869 | 0.9794 | 1.0000 |
| Merger 54 | $2005-2006$ | 0.4218 | 0.9875 | 0.4272 | 0.9875 | 1.0000 |
| Merger 54 | $2006-2007$ | 0.3921 | 0.9685 | 0.4049 | 0.9685 | 1.0000 |
| Merger 54 | $2007-2008$ | 0.3994 | 0.9868 | 0.4047 | 0.9868 | 1.0000 |
| Merger 54 | $2008-2009$ | 0.3575 | 0.9801 | 0.3648 | 0.9801 | 1.0000 |
| Merger 55 | $2004-2005$ | 0.6832 | 0.9943 | 0.6871 | 0.9943 | 1.0000 |
| Merger 55 | $2005-2006$ | 0.6861 | 0.9914 | 0.6921 | 0.9914 | 1.0000 |
| Merger 55 | $2006-2007$ | 0.6665 | 0.9906 | 0.6728 | 0.9906 | 1.0000 |
| Merger 55 | $2007-2008$ | 0.6306 | 0.9887 | 0.6378 | 0.9887 | 1.0000 |
| Merger 55 | $2008-2009$ | 0.6588 | 0.9891 | 0.6661 | 0.9891 | 1.0000 |
| Merger 56 | $2004-2005$ | 0.1333 | 1.0000 | 0.1333 | 1.0000 | 1.0000 |
| Merger 56 | $2005-2006$ | 0.2868 | 1.0000 | 0.2868 | 1.0000 | 1.0000 |
| Merger 56 | $2006-2007$ | 0.1801 | 0.9431 | 0.1909 | 0.9431 | 1.0000 |
| Merger 56 | $2007-2008$ | 0.1591 | 0.9580 | 0.1661 | 0.9580 | 1.0000 |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 56 | 2008-2009 | 0.1347 | 1.0000 | 0.1347 | 1.0000 | 1.0000 |
| Merger 57 | 2004-2005 | 0.0963 | 0.8539 | 0.1127 | 0.8539 | 1.0000 |
| Merger 57 | 2005-2006 | 0.0681 | 0.9627 | 0.0707 | 0.9627 | 1.0000 |
| Merger 57 | 2006-2007 | 0.0651 | 0.9662 | 0.0674 | 0.9662 | 1.0000 |
| Merger 57 | 2007-2008 | 0.0598 | 0.9599 | 0.0623 | 0.9599 | 1.0000 |
| Merger 57 | 2008-2009 | 0.0653 | 0.9642 | 0.0678 | 0.9642 | 1.0000 |
| Merger 58 | 2004-2005 | 0.4295 | 0.9972 | 0.4307 | 0.9972 | 1.0000 |
| Merger 58 | 2005-2006 | 0.4518 | 0.9954 | 0.4539 | 0.9954 | 1.0000 |
| Merger 58 | 2006-2007 | 0.3731 | 0.9890 | 0.3772 | 0.9890 | 1.0000 |
| Merger 58 | 2007-2008 | 0.2656 | 0.9845 | 0.2698 | 0.9845 | 1.0000 |
| Merger 58 | 2008-2009 | 0.3223 | 0.9911 | 0.3252 | 0.9911 | 1.0000 |
| Merger 59 | 2004-2005 | 0.2680 | 0.9670 | 0.2771 | 0.9670 | 1.0000 |
| Merger 59 | 2005-2006 | 0.2312 | 0.9966 | 0.2320 | 0.9966 | 1.0000 |
| Merger 59 | 2006-2007 | 0.2344 | 0.9969 | 0.2351 | 0.9969 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

| Merger <br> Number | Year | Overall <br> Efficiency | Corrected <br> Efficiency | Learning | Harmony | Scale |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Merger 59 | 2007-2008 | 0.2261 | 0.9990 | 0.2264 | 0.9990 | 1.0000 |
| Merger 59 | 2008-2009 | 0.2238 | 0.9988 | 0.2241 | 0.9988 | 1.0000 |
| Merger 60 | 2004-2005 | 0.1333 | 1.0000 | 0.1333 | 1.0000 | 1.0000 |
| Merger 60 | 2005-2006 | 0.2868 | 1.0000 | 0.2868 | 1.0000 | 1.0000 |
| Merger 60 | 2006-2007 | 0.2938 | 0.7748 | 0.3791 | 0.7748 | 1.0000 |
| Merger 60 | 2007-2008 | 0.2835 | 0.9725 | 0.2915 | 0.9725 | 1.0000 |
| Merger 60 | 2008-2009 | 0.2695 | 0.9835 | 0.2741 | 0.9835 | 1.0000 |
| Merger 61 | 2004-2005 | 0.0000 | 0.0000 | NA | 0.0000 | NA |
| Merger 61 | 2005-2006 | 0.0000 | 0.0000 | NA | 0.0000 | NA |
| Merger 61 | 2006-2007 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Merger 61 | 2007-2008 | 0.8059 | 1.0000 | 0.8059 | 1.0000 | 1.0000 |
| Merger 61 | 2008-2009 | 0.9349 | 1.0000 | 0.9349 | 1.0000 | 1.0000 |
| Merger 62 | 2004-2005 | 0.8936 | 1.0000 | 0.8936 | 1.0000 | 1.0000 |
| Merger 62 | 2005-2006 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 3 - continued from the previous page

|  | 8 <br> 8 <br> - | 8 <br> 8 | 8 <br> 8 |
| :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & 8 \\ & \stackrel{8}{8} \\ & \hline \end{aligned}$ | $\begin{aligned} & \stackrel{20}{8} \\ & \stackrel{\circ}{\circ} \end{aligned}$ | 8 8 -8 - |
| B 蔦 -1 | $\begin{gathered} \stackrel{i}{0} \\ \stackrel{0}{0} \\ \dot{0} \end{gathered}$ | $\begin{aligned} & 8 \\ & \stackrel{8}{8} \\ & \hline \end{aligned}$ | L2 N No O |
|  | $\begin{aligned} & 8 \\ & \stackrel{8}{8} \\ & \hline \end{aligned}$ | $\begin{aligned} & \stackrel{20}{\otimes} \\ & \stackrel{O}{0} \end{aligned}$ | $\begin{aligned} & 8 \\ & 8 \\ & \hline \end{aligned}$ |
|  | $\begin{aligned} & \stackrel{i 0}{0} \\ & \stackrel{0}{0} \end{aligned}$ | $\begin{aligned} & \stackrel{20}{8} \\ & \stackrel{0}{0} \end{aligned}$ | L N ¢ |
| * |  | O N N N N |  |
|  | $\begin{aligned} & \text { No } \\ & \text { H. } \\ & \text { ©00 } \\ & \text { © } \end{aligned}$ |  |  |

Table B.4: Bootstrapping Results

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% | ence Interval |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Central School of Speech and Drama | 2005-2006 | 1.0000 | 0.9695 | 0.0305 | 0.8214 | 0.9994 |
| Leeds College of Music | 2008-2009 | 1.0000 | 0.9680 | 0.0320 | 0.8106 | 0.9994 |
| Central School of Speech and Drama | 2006-2007 | 1.0000 | 0.9704 | 0.0296 | 0.8303 | 0.9994 |
| The University of Buckingham | 2006-2007 | 1.0000 | 0.9681 | 0.0319 | 0.8086 | 0.9995 |
| Royal Agricultural College | 2006-2007 | 1.0000 | 0.9691 | 0.0309 | 0.8051 | 0.9996 |
| $\begin{aligned} & \text { Trinity College, Car- } \\ & \text { marthen } \end{aligned}$ | 2005-2006 | 1.0000 | 0.9708 | 0.0292 | 0.8330 | 0.9994 |
| Bishop Grosseteste University College Lincoln | 2007-2008 | 1.0000 | 0.9711 | 0.0289 | 0.8266 | 0.9993 |
| The University of Buckingham | 2008-2009 | 1.0000 | 0.9701 | 0.0299 | 0.8265 | 0.9994 |
| Royal Northern College of Music | 2006-2007 | 1.0000 | 0.9703 | 0.0297 | 0.8313 | 0.9994 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Trinity College, Car- | 2006-2007 | 1.0000 | 0.9673 | 0.0327 | 0.8111 | 0.9995 |
| marthen |  |  |  |  |  |  |
| Bishop Grosseteste Univer- | 2008-2009 | 1.0000 | 0.9701 | 0.0299 | 0.8305 | 0.9994 |
| sity College Lincoln |  |  |  |  |  |  |
| Trinity College, Car- | 2007-2008 | 1.0000 | 0.9711 | 0.0289 | 0.8330 | 0.9995 |
| marthen |  |  |  |  |  |  |
| Royal Northern College of | 2007-2008 | 1.0000 | 0.9683 | 0.0317 | 0.8056 | 0.9994 |
| Music |  |  |  |  |  |  |
| Newman College of Higher | 2006-2007 | 1.0000 | 0.9696 | 0.0304 | 0.8247 | 0.9993 |
| Education |  |  |  |  |  |  |
| University College Fal- | 2004-2005 | 1.0000 | 0.9689 | 0.0311 | 0.8223 | 0.9995 |
| mouth |  |  |  |  |  |  |
| Trinity and All Saints Col- | 2005-2006 | 1.0000 | 0.9699 | 0.0301 | 0.8162 | 0.9994 |
| lege |  |  |  |  |  |  |
| The University of Wales, | 2007-2008 | 1.0000 | 0.9674 | 0.0326 | 0.8279 | 0.9994 |
| Lampeter |  |  |  |  |  |  |
| Trinity Laban | 2006-2007 | 1.0000 | 0.9699 | 0.0301 | 0.8259 | 0.9992 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Trinity University College | 2008-2009 | 1.0000 | 0.9737 | 0.0263 | 0.8762 | 0.9993 |
| The University of Wales, | 2008-2009 | 1.0000 | 0.9686 | 0.0314 | 0.8142 | 0.9992 |
| Lampeter |  |  |  |  |  |  |
| Royal Northern College of | 2008-2009 | 1.0000 | 0.9705 | 0.0295 | 0.8296 | 0.9994 |
| Music |  |  |  |  |  |  |
| Leeds Trinity and All Saints | 2006-2007 | 0.9886 | 0.9766 | 0.0120 | 0.9493 | 0.9881 |
| University College Fal- | 2005-2006 | 1.0000 | 0.9690 | 0.0310 | 0.8246 | 0.9994 |
| mouth |  |  |  |  |  |  |
| Newman University College | 2007-2008 | 1.0000 | 0.9697 | 0.0303 | 0.8317 | 0.9994 |
| The Arts Institute at | 2006-2007 | 1.0000 | 0.9681 | 0.0319 | 0.8234 | 0.9995 |
| Bournemouth |  |  |  |  |  |  |
| Royal College of Music | 2008-2009 | 1.0000 | 0.9712 | 0.0288 | 0.8264 | 0.9995 |
| Trinity Laban | 2007-2008 | 1.0000 | 0.9695 | 0.0305 | 0.8277 | 0.9994 |
| College of St Mark and St | 2004-2005 | 1.0000 | 0.9790 | 0.0210 | 0.9252 | 0.9994 |
| John |  |  |  |  |  |  |
| Leeds Trinity and All Saints | 2007-2008 | 0.9692 | 0.9581 | 0.0111 | 0.9399 | 0.9686 |
|  |  |  |  |  | Continued | he next page |

TableB. 4 - continued from the previous page

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University of Chichester | 2004-2005 | 0.9708 | 0.9578 | 0.0130 | 0.9281 | 0.9702 |
| Swansea Institute of Higher | 2005-2006 | 1.0000 | 0.9774 | 0.0226 | 0.9143 | 0.9994 |
| Education |  |  |  |  |  |  |
| The University of Chich- | 2005-2006 | 1.0000 | 0.9799 | 0.0201 | 0.9345 | 0.9996 |
| ester |  |  |  |  |  |  |
| Swansea Institute of Higher | 2006-2007 | 0.9642 | 0.9540 | 0.0102 | 0.9298 | 0.9634 |
| Education |  |  |  |  |  |  |
| The University of Winch- | 2004-2005 | 1.0000 | 0.9720 | 0.0280 | 0.8383 | 0.9994 |
| ester |  |  |  |  |  |  |
| York St John College | 2004-2005 | 1.0000 | 0.9683 | 0.0317 | 0.8265 | 0.9994 |
| York St John University | 2005-2006 | 1.0000 | 0.9830 | 0.0170 | 0.9486 | 0.9995 |
| The University of Winch- | 2005-2006 | 0.8330 | 0.8225 | 0.0106 | 0.8009 | 0.8325 |
| ester |  |  |  |  |  |  |
| The University of Chich- | 2006-2007 | 0.7061 | 0.6970 | 0.0091 | 0.6805 | 0.7056 |
| ester |  |  |  |  |  |  |
| Swansea Metropolitan Uni- | 2007-2008 | 0.8918 | 0.8821 | 0.0097 | 0.8687 | 0.8912 |
| versity |  |  |  |  |  |  |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University of Worcester <br> St Mary's University College, Twickenham | 2004-2005 | 1.0000 | 0.9789 | 0.0211 | 0.9289 | 0.9994 |
|  | 2008-2009 | 1.0000 | 0.9669 | 0.0331 | $0.7984$ | 0.9993 |
|  |  |  |  |  |  |  |
| The University of Winch- | 2006-2007 | 0.6809 | 0.6729 | 0.0080 | 0.6592 | 0.6803 |
| ester |  |  |  |  |  |  |
| Birmingham College of | 2006-2007 | 1.0000 | 0.9688 | 0.0312 | 0.8239 | 0.9994 |
| Food, Tourism and Creative |  |  |  |  |  |  |
| Studies |  |  |  |  |  |  |
| Swansea Metropolitan Uni- | 2008-2009 | 0.8431 | 0.8337 | 0.0094 | 0.8182 | 0.8425 |
| versity |  |  |  |  |  |  |
| York St John University | 2006-2007 | 1.0000 | 0.9824 | 0.0176 | 0.9395 | 0.9995 |
| The University of Chich- | 2007-2008 | 1.0000 | 0.9670 | 0.0330 | 0.8110 | 0.9994 |
| ester |  |  |  |  |  |  |
| University of Worcester | 2005-2006 | 1.0000 | 0.9662 | 0.0338 | 0.8060 | 0.9992 |
| University College Birming- | 2007-2008 | 1.0000 | 0.9700 | 0.0300 | 0.8318 | 0.9994 |
| ham |  |  |  |  |  |  |
| Continued on the next page |  |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Wales, | 2004-2005 | 1.0000 | 0.9690 | 0.0310 | 0.8138 | 0.9994 |
| Newport |  |  |  |  |  |  |
| The University of Winch- | 2007-2008 | 0.7185 | 0.7100 | 0.0085 | 0.6939 | 0.7179 |
| ester |  |  |  |  |  |  |
| York St John University | 2007-2008 | 1.0000 | 0.9870 | 0.0130 | 0.9554 | 0.9993 |
| The University of Chich- | 2008-2009 | 1.0000 | 0.9703 | 0.0297 | 0.8261 | 0.9995 |
| ester |  |  |  |  |  |  |
| The University of Wales, | 2005-2006 | 1.0000 | 0.9796 | 0.0204 | 0.9326 | 0.9995 |
| Newport |  |  |  |  |  |  |
| The University of Worcester | 2006-2007 | 0.9576 | 0.9462 | 0.0114 | 0.9259 | 0.9570 |
| University College Birming- | 2008-2009 | 1.0000 | 0.9691 | 0.0309 | 0.8269 | 0.9994 |
| ham |  |  |  |  |  |  |
| Bath Spa University | 2006-2007 | 1.0000 | 0.9669 | 0.0331 | 0.8030 | 0.9993 |
| The University of Wales, | 2006-2007 | 1.0000 | 0.9842 | 0.0158 | 0.9563 | 0.9994 |
| Newport |  |  |  |  |  |  |
| The University of Winch- | 2008-2009 | 0.7536 | 0.7443 | 0.0093 | 0.7255 | 0.7531 |
| ester |  |  |  |  |  |  |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| York St John University | $2008-2009$ | 1.0000 | 0.9703 | 0.0297 | 0.8228 | 0.9994 |
| Liverpool Hope University | $2004-2005$ | 1.0000 | 0.9677 | 0.0323 | 0.8170 | 0.9995 |
| The University of Wales, | $2007-2008$ | 1.0000 | 0.9705 | 0.0295 | 0.8381 | 0.9995 |
| Newport |  |  |  |  |  |  |
| The School of Oriental and | $2004-2005$ | 1.0000 | 0.9697 | 0.0303 | 0.8263 | 0.9994 |
| African Studies |  |  |  |  |  |  |
| The University of Worcester | $2007-2008$ | 1.0000 | 0.9697 | 0.0303 | 0.8237 | 0.9992 |
| Liverpool Hope University | $2005-2006$ | 1.0000 | 0.9809 | 0.0191 | 0.9433 | 0.9993 |
| The University of Bolton | $2006-2007$ | 1.0000 | 0.9688 | 0.0312 | 0.8251 | 0.9993 |
| The University of Bolton | $2007-2008$ | 1.0000 | 0.9737 | 0.0263 | 0.8641 | 0.9994 |
| The School of Oriental and | $2005-2006$ | 0.9482 | 0.9363 | 0.0119 | 0.9110 | 0.9476 |
| African Studies |  |  |  |  |  |  |
| Liverpool Hope University | $2007-2008$ | 1.0000 | 0.9695 | 0.0305 | 0.8255 | 0.9993 |
| The University of Wales, | $2008-2009$ | 0.9492 | 0.9386 | 0.0106 | 0.9215 | 0.9486 |
| Newport |  |  |  |  |  |  |
| The University of Bolton | $2008-2009$ | 0.9320 | 0.9198 |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The School of Oriental and | 2006-2007 | 0.9844 | 0.9720 | 0.0125 | 0.9404 | 0.9838 |
| African Studies |  |  |  |  |  |  |
| Roehampton University | 2005-2006 | 1.0000 | 0.9675 | 0.0325 | 0.8025 | 0.9994 |
| The University of Worcester | 2008-2009 | 1.0000 | 0.9706 | 0.0294 | 0.8271 | 0.9993 |
| University of Gloucester- | 2004-2005 | 1.0000 | 0.9683 | 0.0317 | 0.8148 | 0.9993 |
| shire |  |  |  |  |  |  |
| Edge Hill University | 2005-2006 | 1.0000 | 0.9704 | 0.0296 | 0.8365 | 0.9994 |
| University of Gloucester- | 2005-2006 | 0.8875 | 0.8760 | 0.0115 | 0.8490 | 0.8870 |
| shire |  |  |  |  |  |  |
| Goldsmiths College | 2004-2005 | 1.0000 | 0.9702 | 0.0298 | 0.8183 | 0.9994 |
| The School of Oriental and | 2007-2008 | 1.0000 | 0.9697 | 0.0303 | 0.8264 | 0.9993 |
| African Studies |  |  |  |  |  |  |
| University of Wales Insti- | 2004-2005 | 0.8654 | 0.8558 | 0.0096 | 0.8405 | 0.8649 |
| tute, Cardiff |  |  |  |  |  |  |
| Buckinghamshire New Uni- | 2006-2007 | 1.0000 | 0.9687 | 0.0313 | 0.8149 | 0.9995 |
| versity |  |  |  |  |  |  |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of | 2005-2006 | 1.0000 | 0.9715 | 0.0285 | 0.8342 | 0.9995 |
| Northampton |  |  |  |  |  |  |
| Buckinghamshire New Uni- | 2007-2008 | 1.0000 | 0.9697 | 0.0303 | 0.8219 | 0.9992 |
| versity |  |  |  |  |  |  |
| University of Gloucester- | 2006-2007 | 0.8243 | 0.8151 | 0.0091 | 0.8024 | 0.8237 |
| shire |  |  |  |  |  |  |
| St Martin's College | 2006-2007 | 1.0000 | 0.9666 | 0.0334 | 0.8063 | 0.9993 |
| Goldsmiths College | 2005-2006 | 1.0000 | 0.9696 | 0.0304 | 0.8099 | 0.9994 |
| Roehampton University | 2007-2008 | 1.0000 | 0.9686 | 0.0314 | 0.8179 | 0.9994 |
| The School of Oriental and | 2008-2009 | 1.0000 | 0.9715 | 0.0285 | 0.8275 | 0.9994 |
| African Studies |  |  |  |  |  |  |
| University of Wales Insti- | 2005-2006 | 0.8057 | 0.7977 | 0.0080 | 0.7875 | 0.8052 |
| tute, Cardiff |  |  |  |  |  |  |
| Buckinghamshire New Uni- | 2008-2009 | 1.0000 | 0.9684 | 0.0316 | 0.8199 | 0.9993 |
| versity |  |  |  |  |  |  |
| The University of | 2006-2007 | 1.0000 | 0.9710 | 0.0290 | 0.8292 | 0.9994 |
| Northampton |  |  |  |  |  |  |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Lincoln | 2006-2007 | 1.0000 | 0.9680 | 0.0320 | 0.8153 | 0.9994 |
| Institute of Education | 2007-2008 | 1.0000 | 0.9726 | 0.0274 | 0.8485 | 0.9993 |
| Bournemouth University | 2004-2005 | 1.0000 | 0.9696 | 0.0304 | 0.8287 | 0.9994 |
| St George's Hospital Medical School | 2006-2007 | 1.0000 | 0.9697 | 0.0303 | 0.8254 | 0.9994 |
| Canterbury Christ Church | 2005-2006 | 1.0000 | 0.9685 | 0.0315 | 0.8270 | 0.9994 |
| University |  |  |  |  |  |  |
| Goldsmiths College | 2008-2009 | 1.0000 | 0.9700 | 0.0300 | 0.8272 | 0.9993 |
| Aston University | 2004-2005 | 0.8756 | 0.8652 | 0.0103 | 0.8480 | 0.8750 |
| University of Wales, | 2004-2005 | 1.0000 | 0.9727 | 0.0273 | 0.8746 | 0.9994 |
| Aberystwyth |  |  |  |  |  |  |
| The University of | 2008-2009 | 1.0000 | 0.9781 | 0.0219 | 0.9251 | 0.9993 |
| Northampton |  |  |  |  |  |  |
| Birkbeck College | 2008-2009 | 1.0000 | 0.9676 | 0.0324 | 0.8066 | 0.9993 |
| University of Wales, | 2005-2006 | 0.9578 | 0.9468 | 0.0110 | 0.9158 | 0.9572 |
| Aberystwyth |  |  |  |  |  |  |
| Aston University | 2005-2006 | 1.0000 | 0.9702 | 0.0298 | 0.8342 | 0.9993 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University of Wales Insti- | 2008-2009 | 1.0000 | 0.9704 | 0.0296 | 0.8489 | 0.9993 |
| tute, Cardiff |  |  |  |  |  |  |
| Royal Holloway and Bedford | 2004-2005 | 1.0000 | 0.9722 | 0.0278 | 0.8346 | 0.9994 |
| New College |  |  |  |  |  |  |
| Canterbury Christ Church | 2006-2007 | 0.9864 | 0.9749 | 0.0115 | 0.9534 | 0.9857 |
| University |  |  |  |  |  |  |
| The University of Hudders- | 2004-2005 | 0.8532 | 0.8430 | 0.0102 | 0.8239 | 0.8527 |
| field |  |  |  |  |  |  |
| The University of Keele | 2004-2005 | 1.0000 | 0.9702 | 0.0298 | 0.8127 | 0.9994 |
| Bournemouth University | 2005-2006 | 1.0000 | 0.9706 | 0.0294 | 0.8190 | 0.9994 |
| Staffordshire University | 2004-2005 | 1.0000 | 0.9745 | 0.0255 | 0.8437 | 0.9993 |
| St George's Hospital Medi- | 2007-2008 | 1.0000 | 0.9697 | 0.0303 | 0.8287 | 0.9996 |
| cal School |  |  |  |  |  |  |
| University of Derby | 2005-2006 | 1.0000 | 0.9689 | 0.0311 | 0.8249 | 0.9994 |
| Aberystwyth University | 2006-2007 | 1.0000 | 0.9867 | 0.0133 | 0.9568 | 0.9993 |
| University of Wales, Bangor | 2004-2005 | 1.0000 | 0.9683 | 0.0317 | 0.8205 | 0.9995 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Royal Holloway and Bedford | 2005-2006 | 1.0000 | 0.9706 | 0.0294 | 0.8313 | 0.9994 |
| New College |  |  |  |  |  |  |
| Aston University | 2006-2007 | 0.9489 | 0.9372 | 0.0117 | 0.9132 | 0.9484 |
| The University of Essex | 2004-2005 | 1.0000 | 0.9726 | 0.0274 | 0.8708 | 0.9994 |
| The University of Bradford | 2004-2005 | 1.0000 | 0.9699 | 0.0301 | 0.8347 | 0.9994 |
| The University of Keele | 2005-2006 | 0.9012 | 0.8900 | 0.0112 | 0.8724 | 0.9007 |
| Canterbury Christ Church | 2007-2008 | 1.0000 | 0.9707 | 0.0293 | 0.8255 | 0.9995 |
| University |  |  |  |  |  |  |
| The University of Essex | 2005-2006 | 1.0000 | 0.9681 | 0.0319 | 0.8258 | 0.9994 |
| The University of Sunder- | 2004-2005 | 0.9950 | 0.9835 | 0.0115 | 0.9474 | 0.9944 |
| land |  |  |  |  |  |  |
| The University of East Lon- | 2004-2005 | 0.9313 | 0.9194 | 0.0118 | 0.8865 | 0.9307 |
| don |  |  |  |  |  |  |
| Bournemouth University | 2006-2007 | 1.0000 | 0.9792 | 0.0208 | 0.9272 | 0.9993 |
| University of Derby | 2006-2007 | 1.0000 | 0.9688 | 0.0312 | 0.8192 | 0.9994 |
| Staffordshire University | 2005-2006 | 1.0000 | 0.9678 | 0.0322 | 0.8227 | 0.9994 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Hudders- | $2005-2006$ | 1.0000 | 0.9878 | 0.0122 | 0.9612 | 0.9993 |
| field |  |  |  |  |  |  |
| University of Wales, Bangor | $2005-2006$ | 1.0000 | 0.9681 | 0.0319 | 0.8125 | 0.9995 |
| University of Glamorgan | $2005-2006$ | 1.0000 | 0.9685 | 0.0315 | 0.8242 | 0.9993 |
| The University of Keele | $2006-2007$ | 0.9584 | 0.9492 | 0.0093 | 0.9375 | 0.9580 |
| The University of Sunder- | $2005-2006$ | 1.0000 | 0.9756 | 0.0244 | 0.8990 | 0.9995 |
| land |  |  |  |  |  |  |
| Aston University | $2007-2008$ | 0.9854 | 0.9738 | 0.0117 | 0.9526 | 0.9848 |
| Aberystwyth University | $2007-2008$ | 1.0000 | 0.9695 | 0.0305 | 0.8302 | 0.9994 |
| The University of Bradford | $2005-2006$ | 1.0000 | 0.9841 | 0.0159 | 0.9532 | 0.9993 |
| The University of Kent | $2004-2005$ | 1.0000 | 0.9843 | 0.0157 | 0.9603 | 0.9993 |
| The University of East Lon- | $2005-2006$ | 1.0000 | 0.9798 | 0.0202 | 0.9313 | 0.9995 |
| don |  |  |  |  |  |  |
| Staffordshire University | $2006-2007$ | 0.8790 | 0.8687 | 0.0102 | 0.8483 | 0.8784 |
| Bangor University | $2006-2007$ | 1.0000 | 0.9691 | 0.0309 | 0.8180 | 0.9994 |
| University of Derby | $2007-2008$ | 1.0000 | 0.9705 | 0.0295 | 0.8255 | 0.9993 |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Royal Holloway and Bedford | $2006-2007$ | 1.0000 | 0.9687 | 0.0313 | 0.8069 | 0.9992 |
| New College |  |  |  |  |  |  |
| The University of Teesside | $2006-2007$ | 1.0000 | 0.9702 | 0.0298 | 0.8310 | 0.9994 |
| Canterbury Christ Church | $2008-2009$ | 1.0000 | 0.9699 | 0.0301 | 0.8288 | 0.9993 |
| University |  |  |  |  |  |  |
| The University of Keele | $2007-2008$ | 1.0000 | 0.9874 | 0.0126 | 0.9727 | 0.9994 |
| The University of Sunder- | $2006-2007$ | 1.0000 | 0.9813 | 0.0187 | 0.9428 | 0.9994 |
| land |  |  |  |  |  |  |
| The University of Hudders- | $2006-2007$ | 1.0000 | 0.9707 | 0.0293 | 0.8287 | 0.9995 |
| field |  |  | 0.9840 | 0.0160 | 0.9536 | 0.9995 |
| Coventry University | $2004-2005$ | 1.0000 | 0.9706 | 0.0294 | 0.8292 | 0.9994 |
| Bangor University | $2007-2008$ | 1.0000 | 0.9703 | 0.0297 | 0.8284 | 0.9994 |
| Bournemouth University | $2007-2008$ | 1.0000 | 0.9500 | 0.0113 | 0.9240 | 0.9607 |
| The University of Sunder- | $2007-2008$ | 0.9613 |  |  |  |  |
| land |  |  | 0.9692 | 0.0308 | 0.8280 | 0.9994 |
| The University of Bradford | $2006-2007$ | 1.0000 | 1.0000 | 0.9693 | 0.8264 | 0.9993 |
| Aston University | $2008-2009$ |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Staffordshire University | $2007-2008$ | 0.8876 | 0.8780 | 0.0096 | 0.8640 | 0.8870 |
| London South Bank Univer- | $2004-2005$ | 1.0000 | 0.9701 | 0.0299 | 0.8290 | 0.9994 |
| sity |  |  |  |  |  |  |
| The University of East Lon- | $2006-2007$ | 1.0000 | 0.9838 | 0.0162 | 0.9567 | 0.9994 |
| don |  |  |  |  |  |  |
| The University of Essex | $2006-2007$ | 1.0000 | 0.9881 | 0.0119 | 0.9639 | 0.9993 |
| Brunel University | $2004-2005$ | 0.7086 | 0.7001 | 0.0085 | 0.6863 | 0.7082 |
| The University of Essex | $2007-2008$ | 1.0000 | 0.9698 | 0.0302 | 0.8284 | 0.9994 |
| University of Derby | $2008-2009$ | 1.0000 | 0.9805 | 0.0195 | 0.9390 | 0.9994 |
| The University of Keele | $2008-2009$ | 1.0000 | 0.9765 | 0.0235 | 0.9124 | 0.9994 |
| The University of Hudders- | $2007-2008$ | 1.0000 | 0.9698 | 0.0302 | 0.8255 | 0.9994 |
| field |  |  |  |  |  |  |
| Anglia Ruskin University | $2006-2007$ | 1.0000 | 0.9674 | 0.0326 | 0.8178 | 0.9994 |
| Coventry University | $2005-2006$ | 1.0000 | 0.9700 | 0.0300 | 0.8276 | 0.9995 |
| Staffordshire University | $2008-2009$ | 0.9301 | 0.9191 | 0.0110 | 0.8972 | 0.9295 |
| The University of Kent | $2005-2006$ | 0.9991 | 0.9875 | 0.0115 | 0.9710 | 0.9981 |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Sunder- | $2008-2009$ | 1.0000 | 0.9696 | 0.0304 | 0.8242 | 0.9993 |
| land |  |  |  |  |  |  |
| The University of Hull | $2005-2006$ | 1.0000 | 0.9708 | 0.0292 | 0.8301 | 0.9995 |
| Aberystwyth University | $2008-2009$ | 1.0000 | 0.9700 | 0.0300 | 0.8242 | 0.9993 |
| The University of Sussex | $2004-2005$ | 1.0000 | 0.9691 | 0.0309 | 0.8210 | 0.9995 |
| Bangor University | $2008-2009$ | 1.0000 | 0.9702 | 0.0298 | 0.8285 | 0.9994 |
| The University of Sussex | $2005-2006$ | 1.0000 | 0.9698 | 0.0302 | 0.8253 | 0.9994 |
| Thames Valley University | $2007-2008$ | 1.0000 | 0.9707 | 0.0293 | 0.8313 | 0.9995 |
| The University $\quad$ of | $2004-2005$ | 1.0000 | 0.9739 | 0.0261 | 0.8781 | 0.9995 |
| Portsmouth |  |  |  |  |  |  |
| The University of Hudders- | $2008-2009$ | 1.0000 | 0.9716 | 0.0284 | 0.8339 | 0.9994 |
| field |  |  |  |  |  |  |
| Oxford Brookes University | $2004-2005$ | 0.8049 | 0.7966 | 0.0084 | 0.7859 | 0.8044 |
| The University of Wolver- | $2004-2005$ | 1.0000 | 0.9694 | 0.0306 | 0.8261 | 0.9994 |
| hampton |  |  |  |  |  |  |
| The University of Brighton | $2005-2006$ | 1.0000 | 0.9689 | 0.0311 | 0.8071 | 0.9995 |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| London South Bank Univer- | $2006-2007$ | 1.0000 | 0.9688 | 0.0312 | 0.8059 | 0.9995 |
| sity |  |  |  |  |  |  |
| The University of East Lon- | $2007-2008$ | 1.0000 | 0.9699 | 0.0301 | 0.8262 | 0.9995 |
| don |  |  |  |  |  |  |
| Kingston University | $2004-2005$ | 1.0000 | 0.9699 | 0.0301 | 0.8288 | 0.9996 |
| The University of Lancaster | $2004-2005$ | 1.0000 | 0.9700 | 0.0300 | 0.8271 | 0.9994 |
| University of Central Eng- | $2004-2005$ | 1.0000 | 0.9683 | 0.0317 | 0.8099 | 0.9993 |
| land in Birmingham |  |  |  |  |  |  |
| The University of East An- | $2004-2005$ | 1.0000 | 0.9838 | 0.0162 | 0.9552 | 0.9993 |
| glia |  |  | 0.7885 | 0.0086 | 0.7780 | 0.7965 |
| Oxford Brookes University | $2005-2006$ | 0.7970 | 0.9703 | 0.0297 | 0.8252 | 0.9993 |
| The University of Essex | $2008-2009$ | 1.0000 | 0.9703 | 0.0297 | 0.8224 | 0.9993 |
| De Montfort University | $2004-2005$ | 1.0000 | 0.9444 | 0.0112 | 0.9200 | 0.9550 |
| De Montfort University | $2006-2007$ | 0.9557 | 0.9700 | 0.0300 | 0.8241 | 0.9993 |
| Coventry University | $2006-2007$ | 1.0000 | 0.9285 | 0.0103 | 0.9114 | 0.9382 |
| The University of Bath | $2004-2005$ | 0.9388 | 1.0000 | 0.9793 | 0.0207 | 0.9275 |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Sussex | $2006-2007$ | 0.9310 | 0.9204 | 0.0106 | 0.8978 | 0.9304 |
| London School of Eco- | $2004-2005$ | 0.9253 | 0.9159 | 0.0094 | 0.8983 | 0.9248 |
| nomics and Political |  |  |  |  |  |  |
| Science |  |  |  |  |  |  |
| City University |  |  | 0.9693 | 0.8137 | 0.9995 |  |
| Liverpool John Moores Uni- | $2004-2005$ | 1.0000 | 0.9688 | 0.0312 | 0.8258 | 0.9993 |
| versity |  |  |  |  |  |  |
| Brunel University | $2005-2006$ | 0.7185 | 0.7100 | 0.0085 | 0.6953 | 0.7181 |
| The University of Brighton | $2006-2007$ | 1.0000 | 0.9690 | 0.8286 | 0.9995 |  |
| Oxford Brookes University | $2006-2007$ | 0.7998 | 0.7911 | 0.0087 | 0.7785 | 0.7992 |
| The University $\quad$ of | $2005-2006$ | 0.8864 | 0.8765 | 0.0100 | 0.8597 | 0.8859 |
| Portsmouth |  |  |  |  |  |  |
| The University of Lancaster | $2005-2006$ | 0.8629 | 0.8525 | 0.0104 | 0.8311 | 0.8624 |
| The University of Green- | $2005-2006$ | 1.0000 | 0.9746 | 0.0254 | 0.8965 | 0.9994 |
| wich |  |  |  |  |  |  |
| The University of Exeter | $2004-2005$ | 1.0000 | 0.9834 | 0.0166 | 0.9528 | 0.9994 |
| The University of Bath | $2005-2006$ | 0.9924 | 0.9822 | 0.9643 | 0.9918 |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% | ence Interval |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| University of Hertfordshire | 2004-2005 | 1.0000 | 0.9749 | 0.0251 | 0.8956 | 0.9994 |
| City University | 2005-2006 | 1.0000 | 0.9705 | 0.0295 | 0.8302 | 0.9995 |
| De Montfort University | 2007-2008 | 0.9442 | 0.9326 | 0.0117 | 0.9099 | 0.9438 |
| London School of Economics and Political | 2005-2006 | 1.0000 | 0.9690 | 0.0310 | 0.8212 | 0.9994 |
| Science |  |  |  |  |  |  |
| London South Bank University | 2008-2009 | 1.0000 | 0.9697 | 0.0303 | 0.8125 | 0.9993 |
| The University of Exeter | 2005-2006 | 0.9447 | 0.9344 | 0.0102 | 0.9106 | 0.9441 |
| The University of | 2006-2007 | 1.0000 | 0.9708 | 0.0292 | 0.8281 | 0.9994 |
| Portsmouth |  |  |  |  |  |  |
| The University of East Anglia | 2005-2006 | 0.9068 | 0.8971 | 0.0097 | 0.8741 | 0.9064 |
| Middlesex University | 2006-2007 | 1.0000 | 0.9788 | 0.0212 | 0.9272 | 0.9993 |
| University of Glamorgan | 2008-2009 | 1.0000 | 0.9695 | 0.0305 | 0.8211 | 0.9993 |
| The University of Brighton | 2007-2008 | 1.0000 | 0.9696 | 0.0304 | 0.8251 | 0.9994 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Green- | 2006-2007 | 1.0000 | 0.9783 | 0.0217 | 0.9210 | 0.9993 |
| wich |  |  |  |  |  |  |
| The University of Kent | 2007-2008 | 1.0000 | 0.9717 | 0.0283 | 0.8382 | 0.9995 |
| The University of Sussex | 2007-2008 | 1.0000 | 0.9666 | 0.0334 | 0.8072 | 0.9993 |
| Brunel University | 2006-2007 | 0.7520 | 0.7430 | 0.0090 | 0.7311 | 0.7515 |
| The University of Salford | 2004-2005 | 0.9411 | 0.9300 | 0.0111 | 0.9093 | 0.9405 |
| Oxford Brookes University | 2007-2008 | 0.7945 | 0.7865 | 0.0081 | 0.7771 | 0.7941 |
| Birmingham City Univer- | 2006-2007 | 1.0000 | 0.9683 | 0.0317 | 0.8206 | 0.9994 |
| sity |  |  |  |  |  |  |
| De Montfort University | 2008-2009 | 0.8948 | 0.8851 | 0.0097 | 0.8726 | 0.8942 |
| Kingston University | 2006-2007 | 1.0000 | 0.9714 | 0.0286 | 0.8363 | 0.9992 |
| The University of Wolver- | 2006-2007 | 0.9461 | 0.9359 | 0.0102 | 0.9112 | 0.9455 |
| hampton |  |  |  |  |  |  |
| The University of | 2007-2008 | 0.9493 | 0.9378 | 0.0115 | 0.9163 | 0.9486 |
| Portsmouth |  |  |  |  |  |  |
| Coventry University | 2007-2008 | 1.0000 | 0.9678 | 0.0322 | 0.8158 | 0.9994 |
| The University of Lancaster | 2006-2007 | 1.0000 | 0.9703 | 0.0297 | 0.8258 | 0.9995 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Brunel University | $2007-2008$ | 0.9111 | 0.9008 | 0.0103 | 0.8821 | 0.9106 |
| The University of Westmin- | $2007-2008$ | 1.0000 | 0.9684 | 0.0316 | 0.8099 | 0.9994 |
| ster |  |  |  |  |  |  |
| Middlesex University | $2007-2008$ | 1.0000 | 0.9671 | 0.0329 | 0.8023 | 0.9993 |
| The University of Bath | $2006-2007$ | 0.9770 | 0.9661 | 0.0109 | 0.9452 | 0.9764 |
| London School of Eco- | $2006-2007$ | 0.9661 | 0.9542 | 0.0119 | 0.9239 | 0.9655 |
| nomics and Political |  |  |  |  |  |  |
| Science |  |  |  |  |  |  |
| The City University | $2006-2007$ | 1.0000 | 0.9713 | 0.0287 | 0.8416 | 0.9994 |
| Birmingham City Univer- | $2007-2008$ | 1.0000 | 0.9672 | 0.8199 | 0.9994 |  |
| sity |  |  |  |  |  |  |
| The University of Reading | $2004-2005$ | 1.0000 | 0.9692 | 0.0308 | 0.8065 | 0.9995 |
| The University of Salford | $2005-2006$ | 1.0000 | 0.9681 | 0.0319 | 0.8060 | 0.9993 |
| Loughborough University | $2004-2005$ | 1.0000 | 0.9684 | 0.0316 | 0.8257 | 0.9992 |
| The University of Brighton | $2008-2009$ | 1.0000 | 0.9686 | 0.0314 | 0.8126 | 0.9994 |
| University of the West of | $2005-2006$ | 1.0000 | 0.9689 | 0.0311 | 0.8194 | 0.9994 |
| England, Bristol |  |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Oxford Brookes University | 2008-2009 | 0.7505 | 0.7438 | 0.0067 | 0.7360 | 0.7500 |
| The University of Kent | 2008-2009 | 1.0000 | 0.9695 | 0.0305 | 0.8251 | 0.9994 |
| Coventry University | 2008-2009 | 1.0000 | 0.9683 | 0.0317 | 0.8156 | 0.9994 |
| The University of York | 2004-2005 | 1.0000 | 0.9686 | 0.0314 | 0.8212 | 0.9993 |
| Brunel University | 2008-2009 | 1.0000 | 0.9810 | 0.0190 | 0.9378 | 0.9994 |
| The University of Reading | 2005-2006 | 1.0000 | 0.9714 | 0.0286 | 0.8303 | 0.9994 |
| The City University | 2007-2008 | 0.9710 | 0.9597 | 0.0113 | 0.9263 | 0.9705 |
| The University of Wolver- | 2007-2008 | 1.0000 | 0.9704 | 0.0296 | 0.8204 | 0.9995 |
| hampton |  |  |  |  |  |  |
| The Nottingham Trent Uni- | 2006-2007 | 1.0000 | 0.9704 | 0.0296 | 0.8307 | 0.9994 |
| versity |  |  |  |  |  |  |
| The University of Northum- | 2006-2007 | 1.0000 | 0.9681 | 0.0319 | 0.8211 | 0.9994 |
| bria at Newcastle |  |  |  |  |  |  |
| The University of Exeter | 2006-2007 | 1.0000 | 0.9683 | 0.0317 | 0.8048 | 0.9995 |
| The University of East An- | 2006-2007 | 1.0000 | 0.9730 | 0.0270 | 0.8666 | 0.9992 |
| glia |  |  |  |  |  |  |
| The University of Salford | 2006-2007 | 1.0000 | 0.9674 | 0.0326 | 0.8166 | 0.9993 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Kingston University | 2007-2008 | 1.0000 | 0.9709 | 0.0291 | 0.8257 | 0.9993 |
| The University of Lancaster | 2007-2008 | 0.8858 | 0.8742 | 0.0116 | 0.8438 | 0.8854 |
| Liverpool John Moores Uni- | 2007-2008 | 1.0000 | 0.9671 | 0.0329 | 0.8076 | 0.9994 |
| versity |  |  |  |  |  |  |
| University of Hertfordshire | 2005-2006 | 1.0000 | 0.9803 | 0.0197 | 0.9371 | 0.9994 |
| The University of | 2008-2009 | 1.0000 | 0.9678 | 0.0322 | 0.8132 | 0.9994 |
| Portsmouth |  |  |  |  |  |  |
| The University of Bath | 2007-2008 | 0.9866 | 0.9732 | 0.0134 | 0.8880 | 1.0008 |
| The University of Sussex | 2008-2009 | 1.0000 | 0.9695 | 0.0305 | 0.8237 | 0.9994 |
| Loughborough University | 2005-2006 | 1.0000 | 0.9820 | 0.0180 | 0.9437 | 0.9993 |
| The University of East An- | 2007-2008 | 1.0000 | 0.9703 | 0.0297 | 0.8289 | 0.9994 |
| glia |  |  |  |  |  |  |
| London School of Eco- | 2007-2008 | 1.0000 | 0.9668 | 0.0332 | 0.8075 | 0.9994 |
| nomics and Political |  |  |  |  |  |  |
| Science |  |  |  |  |  |  |
| London Metropolitan Uni- | 2007-2008 | 1.0000 | 0.9709 | 0.0291 | 0.8289 | 0.9994 |
| versity |  |  |  |  |  |  |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Westminster | 2008-2009 | 1.0000 | 0.9684 | 0.0316 | 0.8219 | 0.9993 |
| The University of Surrey | 2004-2005 | 1.0000 | 0.9749 | 0.0251 | 0.8967 | 0.9995 |
| The University of Lancaster | 2008-2009 | 1.0000 | 0.9723 | 0.0277 | 0.8308 | 1.0150 |
| The University of Wolver- | 2008-2009 | 1.0000 | 0.9686 | 0.0314 | 0.8244 | 0.9994 |
| hampton |  |  |  |  |  |  |
| The Nottingham Trent Uni- | 2007-2008 | 1.0000 | 0.9689 | 0.0311 | 0.8207 | 0.9993 |
| versity |  |  |  |  |  |  |
| The University of Reading | 2006-2007 | 0.9341 | 0.9230 | 0.0112 | 0.9008 | 0.9335 |
| The University of York | 2005-2006 | 1.0000 | 0.9699 | 0.0301 | 0.8243 | 0.9993 |
| The University of Bath | 2008-2009 | 1.0000 | 0.9701 | 0.0299 | 0.8300 | 0.9994 |
| Liverpool John Moores Uni- | 2008-2009 | 1.0000 | 0.9695 | 0.0305 | 0.8196 | 0.9993 |
| versity |  |  |  |  |  |  |
| Loughborough University | 2006-2007 | 1.0000 | 0.9702 | 0.0298 | 0.8305 | 0.9995 |
| University of the West of | 2006-2007 | 1.0000 | 0.9685 | 0.0315 | 0.8097 | 0.9993 |
| England, Bristol |  |  |  |  |  |  |
| The University of Surrey | 2005-2006 | 1.0000 | 0.9682 | 0.0318 | 0.8293 | 0.9993 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Sheffield Hallam University | $2006-2007$ | 1.0000 | 0.9696 | 0.0304 | 0.8256 | 0.9994 |
| The University of Salford | $2007-2008$ | 1.0000 | 0.9697 | 0.0303 | 0.8246 | 0.9994 |
| Queen Mary and Westfield | $2004-2005$ | 1.0000 | 0.9702 | 0.0298 | 0.8300 | 0.9994 |
| College |  |  |  |  |  |  |
| The University of Northum- | $2007-2008$ | 1.0000 | 0.9686 | 0.0314 | 0.8242 | 0.9993 |
| bria at Newcastle |  |  |  |  |  |  |
| The University of Exeter | $2007-2008$ | 1.0000 | 0.9682 | 0.0318 | 0.8109 | 0.9993 |
| The City University | $2008-2009$ | 1.0000 | 0.9679 | 0.0321 | 0.8109 | 0.9993 |
| University of Hertfordshire | $2006-2007$ | 1.0000 | 0.9678 | 0.0322 | 0.8145 | 0.9993 |
| The University of East An- | $2008-2009$ | 1.0000 | 0.9686 | 0.0314 | 0.8135 | 0.9994 |
| glia |  |  |  |  |  |  |
| The University of Salford | $2008-2009$ | 0.9326 | 0.9219 | 0.0107 | 0.9049 | 0.9320 |
| The University of Surrey | $2006-2007$ | 0.9212 | 0.9094 | 0.0118 | 0.8865 | 0.9206 |
| The University of York | $2006-2007$ | 1.0000 | 0.9687 | 0.0313 | 0.8062 | 0.9994 |
| The University of Leicester | $2006-2007$ | 1.0000 | 0.9743 | 0.0257 | 0.8909 | 0.9993 |
| The University of Reading | $2007-2008$ | 0.8762 | 0.8664 | 0.0098 | 0.8520 | 0.8756 |
| Sheffield Hallam University | $2007-2008$ | 1.0000 | 0.9678 | 0.0322 | 0.8128 | 0.9995 |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Surrey | $2007-2008$ | 1.0000 | 0.9686 | 0.0298 | 0.8199 | 0.9994 |
| Loughborough University | $2007-2008$ | 1.0000 | 0.9697 | 0.0303 | 0.8275 | 0.9995 |
| Queen Mary and Westfield | $2005-2006$ | 0.9603 | 0.9485 | 0.0118 | 0.9260 | 0.9597 |
| College |  |  |  |  |  |  |
| The University of Central | $2008-2009$ | 1.0000 | 0.9702 | 0.0298 | 0.8317 | 0.9994 |
| Lancashire |  |  |  |  |  |  |
| The University of Surrey | $2008-2009$ | 1.0000 | 0.9702 | 0.0314 | 0.8206 | 0.9993 |
| University of Hertfordshire | $2007-2008$ | 0.9412 | 0.9300 | 0.0112 | 0.9027 | 0.9406 |
| The University of Leicester | $2007-2008$ | 1.0000 | 0.9811 | 0.0189 | 0.9324 | 0.9995 |
| The University of York | $2007-2008$ | 1.0000 | 0.9711 | 0.0289 | 0.8238 | 0.9993 |
| University of the West of | $2008-2009$ | 1.0000 | 0.9706 | 0.0294 | 0.8282 | 0.9994 |
| England, Bristol |  |  |  |  |  |  |
| University of Hertfordshire | $2008-2009$ | 1.0000 | 0.9684 | 0.0316 | 0.8238 | 0.9994 |
| Queen Mary and Westfield | $2006-2007$ | 1.0000 | 0.9770 | 0.0230 | 0.9106 | 0.9993 |
| College |  |  |  |  |  |  |
| The University of York | $2008-2009$ | 1.0000 | 0.9702 | 0.0298 | 0.8301 | 0.9992 |
| The University of Reading | $2008-2009$ | 0.9589 | 0.9488 | 0.9345 | 0.9585 |  |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% Confidence Interval |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Leicester | 2008-2009 | 1.0000 | 0.9725 | 0.0275 | 0.8690 | 0.9993 |
| Queen Mary and Westfield | 2007-2008 | 1.0000 | 0.9716 | 0.0284 | 0.8360 | 0.9993 |
| College |  |  |  |  |  |  |
| The University of Bristol | 2004-2005 | 0.9951 | 0.9837 | 0.0114 | 0.9619 | 0.9946 |
| The University of Bristol | 2005-2006 | 1.0000 | 0.9697 | 0.0303 | 0.8082 | 0.9994 |
| The University of | 2004-2005 | 1.0000 | 0.9687 | 0.0313 | 0.8232 | 0.9995 |
| Southampton |  |  |  |  |  |  |
| The University of Liverpool | 2006-2007 | 1.0000 | 0.9697 | 0.0303 | 0.8216 | 0.9994 |
| Cardiff University | 2004-2005 | 1.0000 | 0.9676 | 0.0324 | 0.8166 | 0.9994 |
| The University of | 2005-2006 | 1.0000 | 0.9689 | 0.0311 | 0.8194 | 0.9994 |
| Southampton |  |  |  |  |  |  |
| The University of Bristol | 2006-2007 | 1.0000 | 0.9685 | 0.0315 | 0.8225 | 0.9994 |
| The University of Birming- | 2004-2005 | 1.0000 | 0.9700 | 0.0300 | 0.8263 | 0.9994 |
| ham |  |  |  |  |  |  |
| The University of | 2006-2007 | 1.0000 | 0.9718 | 0.0282 | 0.8237 | 0.9993 |
| Southampton |  |  |  |  |  |  |
| Cardiff University | 2005-2006 | 1.0000 | 0.9689 | 0.0311 | 0.8132 | 0.9995 |
|  |  |  |  |  | Continue | he next page |

TableB. 4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | 97.5\% | ence Interval |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| The University of Birmingham | 2005-2006 | 1.0000 | 0.9714 | 0.0286 | 0.8271 | 0.9994 |
| The University of Bristol | 2007-2008 | 1.0000 | 0.9703 | 0.0297 | 0.8317 | 0.9994 |
| The University of Warwick | 2007-2008 | 1.0000 | 0.9679 | 0.0321 | 0.8201 | 0.9994 |
| Cardiff University | 2006-2007 | 1.0000 | 0.9691 | 0.0309 | 0.8086 | 0.9994 |
| The University of | 2007-2008 | 1.0000 | 0.9712 | 0.0288 | 0.8315 | 0.9995 |
| Southampton |  |  |  |  |  |  |
| The University of Birmingham | 2006-2007 | 1.0000 | 0.9692 | 0.0308 | 0.8233 | 0.9995 |
| The University of Liverpool | 2008-2009 | 1.0000 | 0.9675 | 0.0325 | 0.8156 | 0.9992 |
| The University of Bristol | 2008-2009 | 1.0000 | 0.9701 | 0.0299 | 0.8327 | 0.9993 |
| Cardiff University | 2007-2008 | 1.0000 | 0.9681 | 0.0319 | 0.8164 | 0.9993 |
| The University of | 2008-2009 | 1.0000 | 0.9692 | 0.0308 | 0.8277 | 0.9994 |
| Southampton |  |  |  |  |  |  |
| The University of Birmingham | 2007-2008 | 1.0000 | 0.9695 | 0.0305 | 0.8230 | 0.9994 |
| Cardiff University | 2008-2009 | 1.0000 | 0.9688 | 0.0312 | 0.8014 | 0.9994 |
| Continued on the next page |  |  |  |  |  |  |

TableB. 4 - continued from the previous page
TableB.4 - continued from the previous page

| Name of Institution | Year | Efficiency | Bias Corrected Efficiency | Bias | $97.5 \%$ Confidence Interval |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| King's College London | $2006-2007$ | 1.0000 | 0.9696 | 0.0304 | 0.8301 | 0.9994 |
| The University of Sheffield | $2008-2009$ | 1.0000 | 0.9699 | 0.0301 | 0.8266 | 0.9994 |
| University College London | $2006-2007$ | 1.0000 | 0.9698 | 0.0302 | 0.8292 | 0.9994 |
| University College London | $2007-2008$ | 1.0000 | 0.9688 | 0.0312 | 0.8241 | 0.9993 |
| The University of Oxford | $2006-2007$ | 1.0000 | 0.9678 | 0.0322 | 0.8128 | 0.9992 |
| The University of Cam- | $2006-2007$ | 1.0000 | 0.9691 | 0.0309 | 0.8298 | 0.9991 |
| bridge |  |  |  |  |  |  |

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[^0]:    ${ }^{1}$ An endowment fund is a pot of money created by charitable donations which can be used to generate income

[^1]:    ${ }^{1}$ Some cost based models are specified slightly differently as $c(w, q) \exp (u) \exp (v)$ so that taking logs of the equation will return the composite error term $\varepsilon_{i}=v_{i}+u_{i}$.

[^2]:    ${ }^{2}$ Note use of $-u_{i}$ as opposed to $+u_{i t}$ distinguishes a maximisation problem such as production from a minimisation problem such as cost.

[^3]:    ${ }^{3}$ Here the subscript $f$ is used in place of the typical $i$.

[^4]:    ${ }^{4}$ Abbott and Doucouliagos (2003) used a disaggregated staffing input and a proxy for capital stock but the intention remains the same.
    ${ }^{5}$ Authors using simple staff counts include but are not limited to: Madden et al. (1997); Agasisti and Dal Bianco (2006); Bonaccorsi et al. (2006).
    ${ }^{6}$ Authors using full time equivalent measures include but are not limited to: Abbott and Doucouliagos (2003); Athanassapoulos and Shale (1997); Avkiran (2001).
    ${ }^{7}$ Website address: http://www.iu.qs.com/2009/08/30/why-do-we-use-fte/.

[^5]:    ${ }^{8}$ One might consider some of the original buildings at Oxbridge, such as the Bodleian Library, as examples relevant to this particular research.
    ${ }^{9}$ Contract separation is becoming more common as of the academic year 2013-2014.

[^6]:    ${ }^{10}$ Accounting depreciation, or depreciation, is, briefly, the purchase price of the capital divided by its expected life span. Each year that sum is put aside to be used to replace the piece of capital at the end of its predicted life span.

[^7]:    ${ }^{11}$ Though it is noted that these are all implied cost considerations (extra staff time will cost extra).

[^8]:    ${ }^{12}$ This figure excludes atypical staff who are defined as: those members of staff whose contracts are those with working arrangements that are not permanent, involve complex employment relationships and/or involve work away from the supervision of the normal work provider, Staff Package 08/09 Definitions - http://www.hesa.ac.uk/index.php?option=com_datatables\&task=show_file\&defs=1\&Itemid=121\&catdex= 2\&dfile=staffdefs0809.htm.
    ${ }^{13}$ The HESA data utilised for the survey sums total fixed assets from intangible assets, tangible assets, and investments.
    ${ }^{14}$ Effects caused by the FT/PT mix of staff will be captured via a proportional variable (proportion of part time staff) which shall also be included within the model.

[^9]:    ${ }^{15}$ These map to STEM and non-STEM subjects used in this study.

[^10]:    ${ }^{16}$ Transcendental Logarithmic Function.

[^11]:    ${ }^{17}$ HESA Publications can be found here-www.hesa.ac.uk/component/option, com_pubs/Itemid, 122/.

[^12]:    ${ }^{18}$ GDP Deflator is available here - http://www.hm-treasury.gov.uk/data_gdp_fig.htm.
    ${ }^{19}$ Arts and Humanities Research Council - http://www.ahrc.ac.uk/Pages/Home.aspx.
    ${ }^{20}$ Biotechnology and Biological Sciences Research Council - http://www.bbsrc.ac.uk/home/home.aspx.
    ${ }^{21}$ Engineering and Physical Sciences Research Council - http://www.epsrc.ac.uk/Pages/default.aspx.
    ${ }^{22}$ Economic and Social Research Council - http://www.esrc.ac.uk.
    ${ }^{23}$ Medical Research Council - http://www.mrc.ac.uk/index.htm.
    ${ }^{24}$ Natural Environment Research Council - http://www.nerc.ac.uk/index.asp.
    ${ }^{25}$ Science and Technology Facilities Council - http://www.stfc.ac.uk/home.aspx.

[^13]:    ${ }^{26}$ Full membership list available at www.ukadia.ac.uk/members/.

[^14]:    ${ }^{27}$ Wales was not covered in their study.

[^15]:    ${ }^{1}$ Both papers use data envelopment analysis (DEA) which focuses on decision making units (DMUs) as a delineation between cross sectional elements.

[^16]:    ${ }^{2}$ There may be issues with the practical application of this assumption when there are decreasing returns to scale. Mergers may end up beyond the frontier and appear infeasible as shown in Figure 4.1.

[^17]:    ${ }^{3}$ Bogetoft and Wang (2005) assume it makes organizational sense to conduct this merger, and more specifically use geographical proximity to determine suitable candidates for merger.

[^18]:    ${ }^{4} E^{* J}$ is made of a multiplicative combination of harmony and scale effects, i.e. harmony x scale.

[^19]:    ${ }^{5}$ Bogetoft and Wang (2005) use $T^{J}$ as the name for this variables however to avoid confusion with the Production Possibility Set this has been changed.
    ${ }^{6}$ Similar sizes and average outputs are assumed to avoid capturing any scale effects that occur with asymmetric market shares.
    ${ }^{7}$ Merged units appear on the the 45 degree line because it is assumed the units are of similar size and hence average production will be an even distribution of the input/output mixes.

[^20]:    ${ }^{8}$ In one example, a firm operates an aerial cableway, whilst in the other three one of the firms currently operates in a different country.

[^21]:    ${ }^{9}$ Though the Kolmogorov-Smirnov test utilised in Gourlay et al. (2006) is a more powerful test (being parametric), a simpler alternative would be a Banker (1996) test. The Banker (1996) test (non-parametric) identifies significant differences between two distributions, utilising a standard significance test and a null hypothesis that they are equal. Should the test be rejected, then the distributions are deemed significantly different and it then falls to prior assumptions to determine which model is then selected.

[^22]:    ${ }^{10}$ The operating environment is represented in empirical work by a series of environmental variables.

[^23]:    ${ }^{11}$ This must be done one environmental variable at a time.

[^24]:    ${ }^{12}$ Abbott and Doucouliagos (2003) used a disaggregated staffing input and a proxy for capital stock but the intention remains the same.
    ${ }^{13}$ Authors using simple staff counts include but are not limited to: Madden et al. (1997); Agasisti and Dal Bianco (2006); Bonaccorsi et al. (2006).
    ${ }^{14}$ Authors using full time equivalent measures include but are not limited to: Abbott and Doucouliagos (2003); Athanassapoulos and Shale (1997); Avkiran (2001).
    ${ }^{15}$ Website address: http://www.iu.qs.com/2009/08/30/why-do-we-use-fte/.

[^25]:    ${ }^{16}$ One might consider some of the original buildings at Oxbridge, such as the Bodleian Library, as examples relevant to this particular research.
    ${ }^{17}$ Contract separation is becoming more common as of the academic year 2013-2014.

[^26]:    ${ }^{18}$ This figure excludes atypical staff who are defined as: those members of staff whose contracts are those with working arrangements that are not permanent, involve complex employment relationships and/or involve work away from the supervision of the normal work provider, Staff Package 08/09 Definitions - http://www.hesa.ac.uk/index.php?option=com_datatables\&task=show_file\&defs=1\&Itemid=121\&catdex= 2\&dfile=staffdefs0809.htm.
    ${ }^{19}$ The HESA data utilised for the survey sums total fixed assets from intangible assets, tangible assets, and investments.

[^27]:    ${ }^{20}$ As shown in Table B. 2 (Page 245), where there are more than 3 universities several combinations are created.

[^28]:    ${ }^{21}$ HESA Publications can be found here - www.hesa.ac.uk/component/option, com_pubs/Itemid, 122/.
    ${ }^{22}$ GDP Deflator is available here - http://www.hm-treasury.gov.uk/data_gdp_fig.htm.

[^29]:    ${ }^{1}$ Burgess (1988) refers to contestable markets rather than competitive markets (page 179).
    ${ }^{2}$ Carlton and Perloff (1994) refer to a sunk cost as "a fixed cost that is not recoverable" (page 51), though this is typically generalised to costs which cannot be recouped upon exit of the market via selling of plant or leaseholds.

[^30]:    ${ }^{3}$ For more information please see https://www.google.com/selfdrivingcar/.
    ${ }^{4}$ For more information please see https://www.newscientist.com/article/ dn28003-facebook-unveils-drone-for-beaming-internet-access-from-the-sky/.

[^31]:    ${ }^{5}$ Please see http://www.topuniversities.com/university-rankings/world-university-rankings/2015\# sorting=rank+region=+country=+faculty=+stars=false+search= for full rankings

[^32]:    ${ }^{6}$ The conjectural variation term arises from oligopoly theory and the work of Bowley (1924) who suggested that any assumptions made by a firm can be more appropriately named a conjecture. The variation part is how much firm $i$ believes firm $j$ will change its production by firm $i$ changes its production. So the conjectural variation is simply the assumed value of $\frac{d q_{j}}{d q_{i}}$.

[^33]:    ${ }^{7}$ Normal profit is considered to be a return above costs for taking a risk in participating in the market.

[^34]:    ${ }^{8}$ Church and Ware (2000); Carlton and Perloff (1994) cover much the same ground in reference to the pitfalls the SCP model and the discussion which follows is inspired heavily by both works. I shall avoid over-referencing by making reference only where specific points are made rather than the overall thrust of the issues.

[^35]:    ${ }^{9}$ Please see footnote 3

[^36]:    ${ }^{10}$ Should the market be characterised by constant marginal costs then $\tau_{1}=0$ and $\delta_{1}$ can be used to place a value on the $\lambda$ term.

[^37]:    ${ }^{11}$ The third condition must hold strictly for one pairing and tells us simply that one firm, with superior efficiency, must produce at a lower marginal cost than at least one other firm in the market.

[^38]:    ${ }^{12}$ One dimensional efficiency is also a requirement for price cost margins to be used in estimating competition.

[^39]:    ${ }^{13}$ Often $\pi_{i t}$ is replaced with a market share variable as the more interesting variable to regulators.

