Technical and scale efficiency in public and private Irish nursing homes – a bootstrap DEA approach

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Manuscript accepted for publication in the ***Health Care Management Science***.
The final publication is available at *http://link.springer.com/article/10.1007/s10729-016-9389-8*

Abstract

This article provides methodological and empirical insights into the estimation of technical efficiency in the nursing home sector. Focusing on long-stay care and using primary data, we examine technical and scale efficiency in 39 public and 73 private Irish nursing homes by applying an input-oriented data envelopment analysis (DEA). We employ robust bootstrap methods to validate our nonparametric DEA scores and to integrate the effects of potential determinants in estimating the efficiencies. Both the homogenous and two-stage double bootstrap procedures are used to obtain confidence intervals for the bias-corrected DEA scores. Importantly, the application of the double bootstrap approach affords true DEA technical efficiency scores after adjusting for the effects of ownership, size, case-mix, and other determinants such as location, and quality. Based on our DEA results for variable returns to scale technology, the average technical efficiency score is 62%, and the mean scale efficiency is 88%, with nearly all units operating on the increasing returns to scale part of the production frontier. Moreover, based on the double bootstrap results, Irish nursing homes are less technically efficient, and more scale efficient than the conventional DEA estimates suggest. Regarding the efficiency determinants, in terms of ownership, we find that private facilities are less efficient than the public units. Furthermore, the size of the nursing home has a positive effect, and this reinforces our finding that Irish homes produce at increasing returns to scale. Also, notably, we find that a tendency towards quality improvements can lead to poorer technical efficiency performance.

Key Words: DEA, bootstrapping, technical Efficiency, nursing homes, long-term care, public versus private, Ireland

JEL codes: I19, L33, D24, H51

1. Introduction

Defining, measuring and improving organizational efficiency in nursing home care provision is an important research area as nearly every developed country is faced with the prospect of a population that is getting older, and eventually smaller, given current population age structures, increasing life expectancy, and birth rates which are under the replacement rate.

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The Irish case is of particular interest for a number of reasons. First, Ireland's population is ageing quickly, and it is the increase in the 'oldest' old that is going to be most dramatic. The 65+ and 85+ age cohorts are forecast to increase by 38% and 46% respectively in the years 2011-2021 (BDO 2014: 22), and this growth is projected to accelerate into the future. Second, the mixed public-private nursing home care system in Ireland; and third, Irish policy-makers have moved away from the traditional public provision of nursing home care in favour of incentivising private delivery. As the costs of long-term care are expected to increase considerably as the population ages – a challenge shared by many countries – the estimation of technical efficiencies is essential in assessing whether nursing homes can utilise their resources more efficiently in order to reduce their costs of care. In the context of the fiscal constraints facing the Irish exchequer, efficiency and 'value for money' are increasingly dominant considerations in relation to all areas of public spending, including health care. Taxpayers, policymakers, regulators, and indeed, society as a whole, need corroboration that long-term health care services are being efficiently provided.

Despite the importance of efficiency measurement in nursing home care provision, it is only recently that the more advanced parametric and mathematical programming frontier techniques have been applied to estimate not only efficiency scores, but also the effects of possible efficiency determinants in the long-term care sector. Gertler and Waldman (1994) reported that for-profit homes were more efficient than non-profit units, but quality was higher in the latter. Ozcan *et al*. (1998) used DEA to determine the technical efficiency of skilled nursing facilities in the United States and concluded that profit status homes had higher efficiencies than non-profits. Anderson *et al*. (1999) employed parametric techniques and found that chain affiliation and not-for-profit homes reduced efficiency. Björkgren *et al.* (2001) used DEA and reported inefficient resource allocation in nursing home units in Finland. Borge and Haraldsvik (2009) also applied DEA and found that high fiscal capacity, a low degree of user-charge financing, and a fragmented local council are associated with low efficiency in the elderly care sector in Norway. Other studies which used similar methods and data in the measurement of efficiency in long-term care provision are: Laine *et al.* (2005), Wang and Chou (2005), Knox *et al.* (2007), Farsi *et al.* (2008), Garavaglia *et al.* (2011), Chang and Cheng (2013), and DeLellis and Ozcan (2013).[1]

The aim of this paper is to provide robust estimates of both technical and scale efficiency scores for the long-stay nursing home sector in Ireland. Our analysis is input-oriented and hence looks at the amount by which inputs can be proportionally reduced, with output fixed. Here output is given by the number of total patient days. We measure and appraise technical efficiency in both public and private (including voluntary) long-term care units using detailed primary data which were collected via face-to-face interviews for the years 2008-2009. This study is the first attempt to evaluate the efficiency of nursing home services using Irish data.

Moreover, we are concerned with the question of how ownership affects the technical efficiency of nursing homes in Ireland. This is motivated by a number of considerations. First, as reasoned by Rosko *et al.* (1995), managers in both for-profit and non-profit nursing

[1] Appendix Table A.1 details the most important studies which estimate efficiency models for the nursing home sector. See also sections 3 and 5 for further details on those studies.

home facilities may pursue self-enhancing objectives (excess staff, travel, slack time etc.) which may increase inputs and costs, and hence reduce efficiency. Furthermore, the same authors maintain that, as posited by property rights theorists, the profit motive creates a strong incentive to monitor and restrain this type of behaviour, resulting in the more efficient operation of for-profit firms. However, many previous studies have found significant but sometimes contradicting results with respect to the impact of ownership on efficiency in the long-term care sector. Second, we contend that Ireland serves as an interesting laboratory in which the effects of ownership on efficiency performance can be investigated – the mixed public-private nursing home care system in Ireland is unusual. In 2007, about 36% of all private and voluntary nursing homes received a fixed/block contract per bed to supply some of their beds capacity to the State, and our sample of non-public facilities is drawn only from these homes. For these private-voluntary long-stay care units, which are compared with the public nursing homes in this study, payment is not based on bed use or occupancy. This implies that all of the nursing homes examined in this research – both public and private – are in receipt of a quasi-subvention from the State to varying degrees, and are therefore cushioned from the imperative of minimising costs and producing efficiently. Third, in the late 1990's, Irish policy-makers began incentivising private nursing home care delivery through the provision of capital allowances. Within a short period of time, the private sector's share of total long-stay beds capacity doubled to 80%, and the question arises whether such a policy is justified from a productive efficiency point of view. As a result, this study suggests some implications for policy-makers of supporting private facilities to develop the long-stay beds capacity required to meet current and future older person care needs.

Besides ownership, we also take into account other potential determinants of efficiency such as case-mix, size, location, and quality. The more complicated the case-mix status of elderly people, the more likely additional inputs are required which in turn decreases technical efficiency. Quality is another important factor affecting efficiency in the nursing home sector. However, it "is a multidimensional phenomenon, with no measure capable of accounting for all the many facets of quality provided in a nursing home" (Kleinsorge and Karney, 1992: 61).

This study contributes to the efficiency literature by providing methodological and empirical insights into the estimation of technical efficiency in the nursing home sector. Regarding our method, using a primary data set for Irish nursing homes, we first apply an input-oriented DEA model to identify technical and scale inefficiencies in public and for-profit facilities facing the same production frontier. We compare the obtained mean technical and scale efficiency scores and also the distribution of these scores for both public and private (and voluntary) nursing homes. Then, we employ both the homogenous bootstrap and two-stage double bootstrap DEA methods to obtain confidence intervals for the bias-corrected DEA scores. Crucially, the double bootstrap model integrates the effects of efficiency determinants as explanatory variables in estimating the true efficiencies. Hence, the novel (in terms of nursing home applications) two-stage double bootstrap method affords estimates of the parameters of the efficiency determinants as well as bias-corrected DEA scores after controlling for the effects of efficiency factors. To the best of our knowledge, only Borge and Haraldsvik (2009) have previously applied the double bootstrap method in evaluating technical efficiency in nursing homes.

The structure of this paper is organized as follows: section 2 presents an overview of the nursing home market in Ireland and section 3 presents the theoretical background and relevant literature that underpins the evaluation of technical efficiency in the nursing home sector. Section 4 discusses the DEA and bootstrap DEA methods employed, and section 5 provides detail on our data set and the variables used. Section 6 presents our empirical findings, and section 7 concludes.

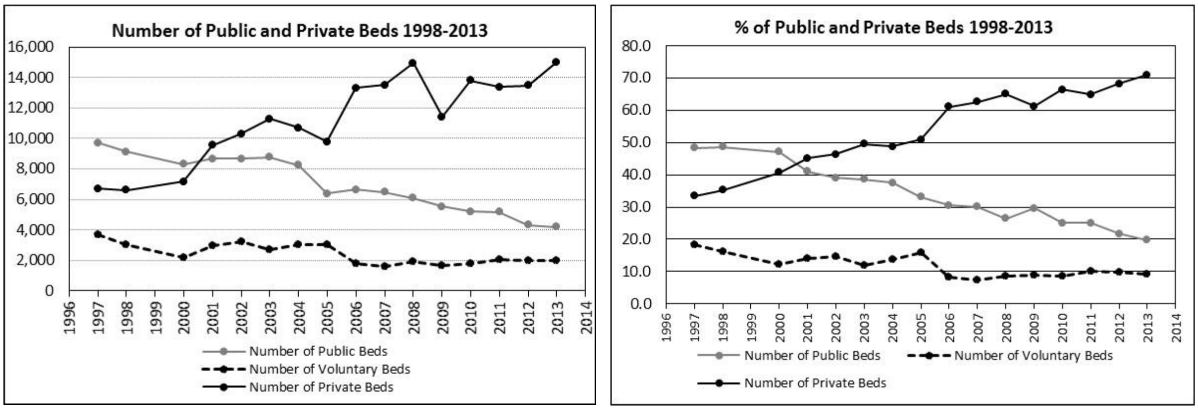
2. The Irish Nursing Home Sector

Unlike other European Countries where more integrated models of older care services and supports exist, the model of care for elderly people remains underdeveloped in Ireland. This is reflected in limited intermediate/ or step-down options. As a result, significant demands continue to be placed on the nursing home sector to meet the care needs of the older population.

Formally, there are three categories of nursing homes in the Republic of Ireland (RoI), namely: 'for profit', 'not-for-profit' and 'public' – or private, voluntary, and public units respectively. In 2013, there were 307 private nursing homes, 50 voluntary (or not-for-profit) homes and 110 public long-stay institutions and facilities in Ireland. *Voluntary* nursing homes include those homes run by charities and the homes run by religious orders for their older nuns and priests. More generally, however, Irish nursing homes are classified into two groups: 'public' and 'private and voluntary' nursing home sectors. Also, it should be emphasized that this study focuses on long-stay care, and does not include limited stay patients.

Traditionally, public nursing homes were the dominant setting for long-term residential care in Ireland, but have now been replaced by privately owned and operated-units. Between 1998 and 2011, the government provided capital allowances in the nursing home care market to stimulate private supply. It was argued that this new policy initiative would lead to greater efficiencies, effectiveness, and responsiveness to consumer needs than would have obtained through continued direct government provision of nursing home services. Canniffe (1999) suggested that investments in private nursing homes became a legitimate way of reducing exposure to income tax for middle to high income tax-payers. Resultantly, a secular trend has been the rapid increase in private sector beds provision as a proportion of total long-stay beds. From Figure 1, the number of private beds doubled from 6,609 to 13,375 between 1998 and 2011. In 1998, the State provided 9,138 public beds – 48% of the country's long-term care beds. However, by 2001 the public sector was relegated to the role of secondary player in the nursing home care market. In 2013, private and voluntary nursing homes provided 80% of the overall long-stay beds capacity, with the remainder supplied by public units. According to the most recent Nursing Homes Ireland (NHI) data, private and voluntary homes have "collectively invested up to €2bn developing necessary capacity, undertaking infrastructural improvements and transforming nursing home care" (although they do not specify a time frame).

Figure 1 Mix of Public, Private and Voluntary Beds 1998-2013[2]



Data source: Annual Survey of Long Stay Units, Department of Health and Children.

In Ireland, the State's Nursing Home Support Scheme (NHSS)[3] is the mechanism by which the cost of long-stay care for the majority of nursing home residents is funded. The NHSS/ Fair Deal provides financial support for people who have been independently assessed as having a requirement for long-term residential care, and is founded on the core principles that long-term care should be affordable, and that a person should receive the same level of State support whether they choose a public or private nursing home. Applicants approved for funding under the NHSS have their income and assets assessed to determine the contribution to be made by the applicant to the cost of their long-term residential care and, consequently, the level of State support, if any. A key feature of the scheme is resident choice. Once an applicant has been approved for the scheme, they are free to choose any public or registered private nursing home covered under the scheme, entering into a contract for care with their chosen home.

The Irish population is ageing, and is doing so relatively quickly. According to 'Population and Labour Force Projections 2016-2046' (CSO, 2013), the number of people aged 65 and over in Ireland will increase by 167%, from 532,000 in 2011 to over 1.4 million by 2046. Clearly, the Irish nursing home sector will need to increase its current capacity of 21,175 long-stay beds very considerably to meet this projected demand. More significantly, the cohort requiring the highest level of care, aged 85 and over, is growing more rapidly, and this growth is forecast to accelerate into the future. The Irish population aged 85+ is expected to jump dramatically from 58,200 to 266,900 in the period 2011-2046 – an increase of 359%. This projected surge in demand is going to present severe challenges for the supply of Irish nursing home care services, and achieving greater effectiveness and efficiencies in resource use will become increasingly dominant considerations.

Table 1 compares public expenditure on long-term care (LTC) as a percentage of GDP, and by type of care, for selected EU countries in 2010. Ireland spends 1.1% of its GDP on LTC provision, and only 17% of this public expenditure is allocated to the informal

[2] The national response rate for 1999 was very low – most likely, due to the restructuring of the Eastern Health Board. Hence, data for this year are not included here.
[3] The NHSS has been in existence since 1993. It had been known previously as the Nursing Home Subvention Scheme before it was transformed, and re-launched as the Nursing Home Support Scheme – "A Fair Deal" in October 2009.

environment – home-care packages to support the elderly person to reside in their own home – with the balance spent on formal or residential facilities (i.e. nursing homes). In contrast, Sweden invests more of its GDP on long-term care provision than any other EU country, with roughly half of this funding allocated to informal care. It is important to note also that, in 2009, Sweden had 7.5% of its population aged 65+ in formal LTC – compared to 4.5% in Ireland and 3.4% in Germany (BDO, 2014: 3). However, given the projected increases in its elderly population, it is likely that Ireland will be spending appreciably more on long-term care provision. At an operational level, the direct cost of the NHSS to the Irish exchequer was estimated to be in the region of €975m in 2014. However, the annual cost of funding this scheme is expected to exceed €1.2bn by 2021, and €2bn by 2041. This is based on future population projections, current values and before inflation (BDO, 2014: iii). Thus, with limited public resources, achieving greater efficiencies will be paramount in order to meet future demand for nursing home care services.

Table 1 Comparative Public Expenditure on LTC as a % of GDP and by Type of Care (2010).

Country	Public Expenditure on LTC as % of GDP	Informal (%)	Formal or Residential (%)
Sweden	3.8	52	48
Netherlands	3.8	48	52
Portugal	0.3	76	24
Czech Republic	0.8	74	26
Ireland	1.1	17	83
Lithuania	1.2	59	41
Germany	1.4	61	39
EU – 27	1.8	58	42

Data source: DG ECFIN (2012).

3. Theoretical Framework

We focus on the measurement of technical efficiency (TE) as opposed to economic or cost efficiency owing to the difficulty of obtaining reliable information on the costs of inputs for nursing homes in Ireland. As the output of the nursing homes in our study is defined as total patient days, we choose an input-oriented approach to measuring technical efficiency in order to assess if, and by how much, capital and, in particular, labour inputs can be reduced while achieving the same level of output. Input-oriented TE has also been more widely used, relative to the other efficiency measures, in empirical studies on the nursing home sector (e.g. Nyman and Bricker 1989; Nyman *et al.* 1990; Fizel and Nunnikhoven 1992; Chattopadhyay and Heffley 1994; Kooreman 1994; Ozcan *et al.* 1998; Bjorkgren *et al.* 2001; Laine *et al.* 2005; Wang and Chou 2005; Borge and Haraldsvik 2009; Garavaglia *et al.* 2011; Chang and Cheng 2013; DeLellis and Ozcan 2013).[4] Table A1 presents an overview of the studies which applied different techniques for estimating efficiency in the nursing home sector in

[4] It should be noted that under the assumption of CRS, both the input-oriented and output-oriented technical efficiency will be the same.

various countries. It is evident that technical efficiency (as opposed to allocative efficiency) is the most common measure used here.

Additionally, we measure scale efficiency (SE) as it is possible that the nursing homes are technically efficient but the scale of operations may not be optimal. The constant returns to scale (CRS) assumption is only appropriate when all nursing homes are operating at optimal scale. When the technology allows variable returns to scale (VRS) along the frontier, scale efficiency is achieved only at the point where the average productivity of the observed input-mix attains a maximum. The point of maximum average productivity on the VRS frontier corresponds to CRS. When, for example, an individual nursing home unit operates under diminishing returns to scale, it would need to reduce the scale of its operations (both its input and output bundles) in order to attain both technical and scale efficiency.

According to Farsi *et al*. (2008), Chattopadhyay and Ray (1996) and Worthington (2004), the literature on measuring efficiency in the nursing home industry dates back to the 1980s, and in the earlier econometric studies, the estimated relation reflected an average (based on best-fit) rather than an efficient or frontier cost function. Thus, inefficiencies were confounded with pure random shocks. For this reason, in the last two decades, the literature on the nursing home sector has moved towards a more appropriate approach to the measurement of efficiency. This can be achieved by applying a linear programming frontier technique such as DEA. The approach was introduced by Charnes *et al.* (1978), based on the pioneering work of Farrell (1957), when they proposed an input orientation with CRS. DEA constructs a nonparametric piecewise-linear convex frontier using sample data where nursing home units which use the fewest inputs in producing a given level of output are identified. A nursing home is considered to be technically efficient, with regard to its inputs usage, if it lies on the frontier (isoquant). DEA is the dominant approach to efficiency measurement in healthcare (Hollingsworth 2003, 2008). In relation to nursing homes, DEA was used to estimate technical efficiencies in the USA by Nyman and Bricker (1989), Nyman *et al.* (1990), Fizel and Nunnikhoven (1992), Kleinsorge and Karney (1992), Chattopadhyay and Heffley (1994), Chattopadhyay and Ray (1996), Ozcan *et al.* (1998), and DeLellis and Ozcan (2013); and by Kooreman (1994) for the Netherlands; Bjorkgren *et al*. (2001), and Laine *et al.* (2005) for Finland; Borge and Haraldsvik (2009) for Norway; Garavaglia *et al.* (2011) for Italy; and Wang and Chou (2005) and Chang and Cheng (2013) for Taiwan.

Other nursing home studies have employed the econometric stochastic frontier analysis (SFA) approach, originally proposed by Aigner *et al*. (1977), to the parametric estimation of the efficient cost function using data on input prices (e.g. Hoffler and Rungeling, 1994; Vitaliano and Toren, 1994; Anderson *et al.*, 1999; Crivelli *et al*. 2002; Knox *et al.*, 2007; and Farsi *et al*., 2008). This frontier is usually estimated using a maximum likelihood method which assumes that any deviation from the technology (frontier) is composed of two parts, one representing randomness (or statistical noise) and the other inefficiency.

In this study, to estimate input-oriented TE, we apply the DEA method as, in contrast to SFA, it does not impose a specific functional form on the production technology of the nursing home sector. It also allows for analysis of the productivity of nursing home units which is composed of both technical efficiency and scale efficiency (Banker *et al*. 1984). In order to identify the nature of the scale inefficiencies, we employ the non-increasing returns to scale extension of the VRS DEA model. As referred to above, DEA is the most widely applied method to evaluate technical efficiency in the nursing home sector.

The main criticism of the conventional DEA method is that it implicitly assumes that all of the distance between an observed firm and the optimal isoquant for the efficient firms reflects inefficiency. However, the distance of an observation from the efficient boundary reflects both inefficiency and noise. This is because the observed input-output data could be subject to measurement error, or there could be noise in the data due to omitted input or output variables. The homogenous bootstrap method provides an attractive alternative to the conventional DEA approach. Its use in nonparametric envelopment estimators was developed by Simar and Wilson (1998, 2000). We use this technique to correct for any bias in our conventional DEA efficiency scores and to estimate confidence intervals for them, recognising that our data are subject to random error. In the nursing homes efficiency literature, only Garavaglia *et al.* (2011) have previously implemented the homogenous bootstrap procedure.

Furthermore, a number of previous DEA studies have employed a two-stage approach wherein nonparametric DEA efficiency estimates from the first stage are regressed on a vector of efficiency determinants in a parametric analysis in the second stage. These papers typically use either ordinary least squares (OLS), Tobit or logistic regression techniques in the second stage, and rely on conventional methods for inference. However, Simar and Wilson (2007, 2011) assert that whatever the second-stage regression technique employed, conventional inference methods fail to give valid inference due to the fact that in the second-stage, true efficiency remains unobserved and must be replaced with DEA estimates of efficiency, and these are serially correlated by construction, and are also biased.[5]

Previous two-stage DEA nursing home efficiency studies include Nyman *et al.* (1990), Fizel and Nunnikhoven (1992), Kooreman (1994), Ozcan *et al.* (1998), Wang and Chou (2005), and Garavaglia *et al.* (2011). In these models, the determining factors posited are drawn from the following set of variables: ownership, case-mix (e.g. % of Medicare/Medicaid patients, % of patients aged 85+, average length of stay), quality, occupancy rate, size, urban/rural location or region, and the Herfindahl index of market concentration or the number of homes in the vicinity (to measure competitive pressures).

Similarly, this article also examines how the ownership of the nursing home, size, case-mix, and other determinants such as location, and quality affect the technical efficiency scores. However, to investigate the effects of these variables, we apply the double bootstrap procedure developed by Simar and Wilson (2007) in the second stage, which not only enables robust estimation of the parameters of efficiency determinants, but also re-estimates the efficiency scores to take account of these determining variables. To our knowledge, only Borge and Haraldsvik (2009), who examine the impact of three key determinants of efficiency in public homes in Norway, and the recent study by Iparraguirre and Ma (2015), which investigates efficiency in the provision of social care for older people in England, have previously applied this technique in evaluating efficiency in the elderly care sector.

[5] The efficiency score is a point estimate without a probability distribution around it as required by the Tobit method or any other parametric regression technique. Using the DEA point estimates in a second stage analysis may cause biased and inconsistent estimates of the parameters of the explanatory/ determining variables.

4. Estimation Method

4.1 DEA model for nursing homes

We first apply the input-oriented constant returns to scale (CRS) DEA method to obtain the technical efficiency (TE) scores for each nursing home i by solving the following linear programming problem:

$$\begin{aligned} &\text{Min}_{\theta,\lambda}\ \theta \\ &\text{Subject to:} \quad -q_i + Q\lambda \geq 0 \\ &\qquad\qquad\quad \theta x_i - X\lambda \geq 0 \\ &\qquad\qquad\quad \lambda \geq 0 \end{aligned}$$

Where: θ is the TE score for the i-th nursing home unit; λ is a $I \times 1$ vector of constants; q_i denotes the output of the i-th unit; x_i is a vector of inputs of the i-th unit; $Q\lambda$ and $X\lambda$ denote a projected point due to radial contraction of the input vector x_i. The objective is to try to find the minimum θ that reduces the input vector x_i to θx_i while guaranteeing at least the output level q_i. Therefore, the value of θ will range between 0 and 1, with a score of 1 implying a point on the frontier where the nursing home is technically efficient.

To account for variable returns to scale (VRS), the CRS linear programming problem is extended by adding the convexity constraint $I1'\lambda = 1$ proposed by Banker *et al*. (1984). This constraint ensures that an inefficient nursing home is only 'benchmarked' against units of a similar size. To obtain the scale inefficiency, the CRS TE scores are divided by the VRS TE scores, and any difference in measured technical efficiency can be attributed to the presence of scale inefficiency. In order to obtain the non-increasing returns to scale (NIRS) TE scores, the constraint proposed by Färe *et al*. (1983, 1985) can be added, by substituting the $I1'\lambda = 1$ in the VRS DEA model with $I1'\lambda \leq 1$. When the NIRS and CRS measures are equal to one another but differ from the VRS measure, increasing returns to scale holds at the corresponding efficient projection on the VRS frontier. On the other hand, if the VRS and NIRS measures are equal but differ from the CRS measure, diminishing returns to scale holds at the relevant point on the VRS frontier. The three measures coincide only at an MPSS (most productive scale size). Note that the CRS and NIRS frontiers are mere artefacts that permit us to examine different points on the VRS frontier.

4.2 Bootstrapping

We apply both the homogenous and the two-stage double (semi-parametric) bootstrap methods to first, address the main drawback of the conventional DEA approach – that it does not account for random errors. Hence, the bootstrap techniques are employed to examine the robustness of our estimated conventional DEA technical efficiency scores. Second, we apply the double bootstrap procedure to investigate the impact of ownership on technical efficiency, together with other posited determinants. In this method, the bias-corrected efficiency scores incorporate the effects of the determining variables.

Following Garavaglia *et al*. (2011), we use the procedure for homogenous bootstrapping in non-parametric frontier models developed by Simar and Wilson (1998, 2000) to validate our efficiency estimates. By sampling repeatedly from the obtained CRS and VRS DEA efficiency scores described in section 4.1, we construct an empirical sampling distribution for the DEA TE efficiencies of the nursing home units. The bias in the DEA efficiencies can then be estimated and 95% confidence intervals can be built using this empirical distribution.[6]

To obtain unbiased estimates of the parameters of our posited determining variables, and additionally to get bias-corrected bootstrap DEA TE scores, we adopt Algorithm 2 of the double bootstrapping method set out by Simar and Wilson (2007). To begin, a truncated regression model is estimated using our conventional DEA TE scores from section 4.1 as the dependent variable, and the efficiency determinants as explanatory variables. Next, the bootstrap is applied to correct first for the bias problem in the original DEA scores. Empirical sampling distributions are obtained by taking $L1$=100 drawings of residuals from a truncated normal distribution. The truncated regression model is re-estimated for each drawing to give bias-corrected efficiency scores. Then, the DEA TE scores are re-calculated (performing $L1$ additional DEA analyses – one for each drawing) after adjusting the input values for the ratio of original DEA TE estimates to the bias-corrected DEA TE scores. The second objective is to correct for the serial correlation problem. The truncated regression model is re-run – this time with the bias-corrected technical efficiency scores as the dependent variable. Similar to before, L=2,000 drawings of residuals are taken from a truncated normal distribution. After re-estimating the truncated regression model for each drawing, we obtain a set of estimates for the parameters of the determining variables and construct confidence intervals.

5. Data, Variables and Descriptive Statistics

5.1 Data set

In this study, we use primary data collected for nursing homes in Ireland between 2008 and 2009 and some detail regarding our sample is presented in Table 2. We focus on public homes as well as the private and voluntary units that provide long-stay care only and are contracted by the State in Ireland. All nursing homes examined are either funded fully or to some significant degree by the exchequer. In order to identify the private and voluntary long-stay units that the State purchases care from, a parliamentary question (29365/07) was submitted in 2007. The reply specified the name of each nursing home and the number of contract beds which the unit supplied. The population of Irish nursing homes with public and State contracted beds divided into 125 public, 151 private and 6 voluntary units. Furthermore, we filtered the population of 157 private and voluntary nursing homes by imposing a threshold criterion whereby 10% or more of a unit's total beds provision had to be State-contracted for inclusion in our sample. From Figure 2, the share of contract beds is below 50% for the vast majority of private and voluntary nursing homes in this research – the average share is 27%. Hence, these units are rather more private/ profit-orientated, and we expect that their efficiency levels could differ significantly compared to the public nursing homes which are fully subsidised by the State.

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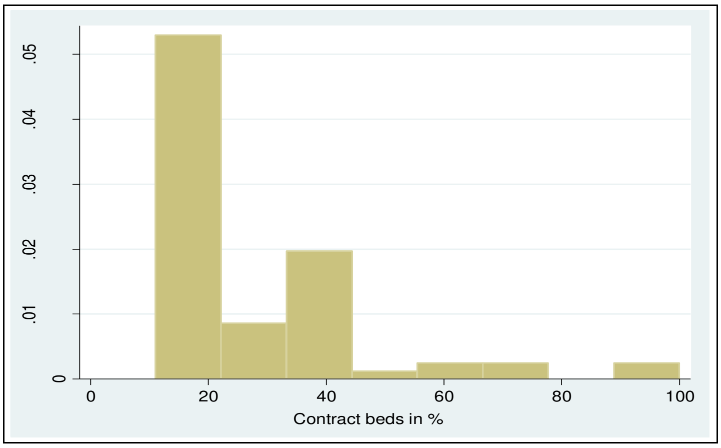
[6] It should be noted that the method developed by Simar and Wilson (2000) is relatively robust with regard to the chosen bandwidth of the confidence intervals.

Figure 2 Distribution of Irish private-voluntary nursing homes in relation to % of State-contracted beds



Data source: Primary data collected via face-to-face interviews, 2008-2009.

After permission to undertake this research was approved at Assistant Director of Nursing level, Local Health Managers (LHM) were then contacted to discuss nursing home access. The LHM's stipulated that 51 named public homes could not be approached due to privacy considerations related to the "medico-social status of the residents." Accordingly, the 'effective' population reduced to 74 public and 106 private and voluntary units. All 180 nursing homes were contacted, and 59 public, 90 private, and 3 voluntary units agreed to partake in this research – thus, comprising our sample. Cross-sectional data were then collated during July 2008–September 2009 via face-to-face interviews. Relative to the effective population, a very high response rate was achieved – 59 out of 74 (80%) public nursing homes, and 93 out of 106 (88%) private and voluntary units.

Table 2 Data collection and data sample

Population/ sample	Public nursing homes	Private and voluntary nursing homes with contract beds
Overall population	125	157
Effective population	74	106
Sample	59	93
Response rate	80%	88%

5.2 Output and input variables

Output

The definition and measurement of output is an enduring topic in the health economics literature. It should be noted, however, that the conceptual output – improved health status, or even more generally, improved quality of life – is difficult to measure (Kooreman, 1994). Furthermore, the concept of 'value-added' as a result of engaging with the 'service' has proved more challenging in health care, because of the much greater heterogeneity of service users and the intrinsic measurement difficulties. A fundamental issue is that it is rarely possible to observe a baseline – for example, the health or quality of life status that would have obtained in the absence of nursing home intervention.

One solution to this challenge is to measure output on a "quantifiable basis" (Hollingsworth, 2003). Similarly, the nursing home literature reflects the use of quantifiable indicators of output – Delellis and Ozcan (2013) observe that the number of patient days in a home or the number of residents are the predominant measures used. In this research, we define the output of a nursing home unit as total patient days. This measure has been applied in other nursing home efficiency studies – including, Fizel and Nunnikhoven (1992), Chattopadhay and Heffley (1994), Chattopadhay and Ray (1996), Bjorkgren *et al*. (2001), and Borge and Haraldsvik (2009) for DEA; and Hoffler and Rungeling (1994) using the SFA method. Furthermore, while we do not adjust total patient days for case-mix at this stage of the analysis, case-mix is incorporated as an efficiency determinant in the double bootstrap estimations (see Section 5.3 below) similar to the approach adopted by Borge and Haraldsvik (2009).

Capital input

Capital in the nursing home sector is difficult to measure as it is a durable input. Unlike labour inputs, which are utilised in the production process within a specific accounting period, capital assets are purchased in one period and used in the production process throughout the life of the asset or until it is replaced by a new asset. In principle, an efficiency model should use the capital flow consumed in the current period as a production input. However, as information on capital flow is difficult to obtain in the nursing home sector (and also in other health care sectors), we approximate the capital input by using the number of beds available in the nursing home unit.

This measure has been employed in other nursing home efficiency studies – including, Ozcan *et al*. (1998), Bjorkgren *et al*., (2001), Laine *et al.* (2005), Wang and Chou (2005), and Delellis and Ozcan (2013). Moreover, data for the nursing home sector in Ireland have shown that managers are able to significantly increase or decrease beds capacity over consecutive years. In section 2, we highlighted how the Irish Government, between 1998 and 2011, provided capital allowances in the nursing home care market to stimulate private supply. It is no coincidence that this period witnessed a trend in the rapid rise in private sector beds provision as a proportion of total long-stay beds (see Figure 1). Also, the private and voluntary nursing home units in Ireland with State-contracted beds have an incentive to increase their capital investment in order to receive higher public funding. Therefore, we posit that including the number of beds in our production model as a proxy capital input is very important in the Irish case.

Labour inputs

We measure labour inputs by the number of staff employed in each nursing home unit, using both primary and secondary inputs – medical staff and non-medical staff, respectively. The former being measured by the number of full-time nurses, while the latter is measured by the number of full-time health care attendants.[7] Among the efficiency studies which have used medical staff (full-time equivalents) as an input in their DEA models are Nyman *et al.*

[7] In order to test the sensitivity of our results in relation to the labour measures used, we substitute for the number of staff with the salaries of full-time nurses and the salaries of health care attendants for the primary and secondary inputs respectively. Here, our findings are robust across the number of staff employed and salaries variables. Results for the latter are available on request.

(1990), Ozcan *et al.* (1998), Bjorkgren *et al.* (2001), Laine *et al.* (2005), and Delellis and Ozcan (2013). Nurses have a formal qualification in clinical care delivery, sometimes to postgraduate level. In addition, their pivotal role is given legal standing in Ireland's Health Act 2007, which compels a nursing home to have a nurse on the premises at all times. The literature suggests that nurses can affect patient outcomes, thus highlighting their contribution in the care delivery process (Aaronson *et al*., 1994; Blegen *et al*., 1998; Harrington *et al*., 2000). Nurses are supported in the care delivery process by health care attendants who undertake non-clinical duties. The non-medical personnel have a significant impact on the daily care of the patients, including the quality of care provision.

The inclusion of both primary and secondary labour measures allows us to assess their relative importance in the efficiency of nursing home care provision in Ireland. Therefore, depending on how the labour input is defined, we employ three alternative model specifications. In *Model 1*, labour is measured solely by the number of medical staff in the nursing home unit. Alternatively, in *Model 2*, labour is measured by the number of non-medical staff only, whereas *Model 3* includes both medical and non-medical staff variables. In each of the model specifications, capital is proxied by the number of beds, and output is defined as total patient days. Table 3 summarises the three model specifications.

Table 3 Model Specifications

Input / Output Variable	Description	Model 1	Model 2	Model 3
Output	Total patient days	yes	yes	yes
Labour (Primary Input)	Medical staff	yes	no	yes
Labour (Secondary Input)	Non-medical staff	no	yes	yes
Capital Input	Number of beds	yes	yes	yes

5.3 Efficiency determinants

Ownership

As discussed earlier, the ownership status of Irish nursing homes is an important efficiency determinant in the context of examining the implications of government policy in Ireland which sought to increase the number of private relative to public nursing home beds between 1998 and 2011. While all of the private facilities in our sample supply at least 10% of their total beds capacity to the State on a fixed/block contract basis, the average share of contract beds is below 30% and hence these private units can be considered mostly profit-orientated. Thus, there is a likely to be a real dichotomy in the motivations of public and private nursing homes in this study. However, the effective State subsidy for the provision of contract beds implies that the private Irish nursing homes in our sample might be cushioned to varying degrees from the imperative of minimising costs and producing efficiently.

'Ownership' is measured as a dummy variable, with a value of 1 assigned to private nursing home facilities. In relation to nursing homes in the USA, Nyman and Bricker (1989), Nyman *et al.* (1990), Fizel and Nunnikhoven (1992), Chattopadhyay and Heffley (1994), and Ozcan *et al.* (1998) find for-profit homes to be more technically efficient than non-profit units. From Nyman *et al.* (1990), non-profit nursing homes use about 6% more inputs per patient than for-profit facilities, and in Fizel and Nunnikhoven (1992), for-profit nursing homes have higher mean levels of efficiency and a more efficient production frontier than non-profit homes. Additionally, Ozcan *et al.* (1998: 221) observe that "consistent with much of the previous literature, this study found for-profit facilities to be more efficient than nonprofits, when allowed to face the same frontier. However it is generally accepted that these groups face different technological use and goal orientations." In Europe, the majority of long-term care beds are provided by the non-competitive public sector. Thus, the question of whether ownership status affects the efficiency of the nursing home is not widely considered. Nonetheless, similar to the US, Garavaglia *et al.* (2011), in an Italian study which focuses specifically on the Lombardy region, find public institutions to be less efficient than private facilities – but their results suggest that this gap is closing. However, Crivelli *et al.* (2002) find that public nursing homes in Switzerland are just as cost efficient as private units. Wang and Chou (2005) report a similar finding for the technical efficiency of nursing homes in Taiwan.

Location

Additionally, we investigate 'location' as a possible determinant of technical efficiency. Here, a value of 1 is given if the nursing home is located inside the Dublin (capital city) area, and zero otherwise. *A priori*, we might expect that nursing homes located in Dublin are more technically efficient than nursing homes in other areas. Due to greater competition for medical and non-medical staff relative to other regions in Ireland, labour costs are higher in Dublin. Consequently, as wage rates increase, nursing home managers react by using their labour inputs more efficiently (Zinn, 1993; Rosko *et al.*, 1995).[8] Furthermore, as Dublin represents a special case compared to other regions and cities in Ireland, it is important to account for this – almost 40 % of all nursing homes in our sample are located in the Dublin area (see Table 5 below). This is our predominant choice of location indicator. Additionally, an urban/ rural dummy variable was not included in the analysis due to the presence of collinearity. In Nyman and Bricker (1989: 589), a variable representing whether the firm is located in an urban area was used to control for any effects of intensity of competition among rival firms on the efficiency score. They had no expectations regarding the sign of this variable's coefficient, but found that efficiency decreases in for-profit homes only, located in an urban area. Fizel and Nunnikhoven (1992: 433) include an urban/ rural dummy to capture the effect of concealed factors, including possibly the quality of labour, while Chattopadhyay and Heffley (1994) use dummy variables to represent counties with low population densities and percentages of the population living in urban areas compared to other counties, to control for "market characteristics." Ozcan *et al.* (1998: 217) include a regional location variable to account for regulatory and environmental characteristics that may influence a nursing home's efficiency. No significant location effect is found in these studies.

[8] In many industries, firms respond to increases in wage rates by substituting more capital for labour. However, this is difficult to achieve in the labour intensive nursing home industry. Thus, the effect of higher input prices points to fewer labour inputs being demanded.

Size

The environmental variable 'size' was considered as an important determinant of efficiency by Nyman *et al.* (1990), Chattopadhyay and Ray (1996), Filippini (1999), and Wang and Chou (2005). In this research, we also consider the effect of size on technical efficiency, where the size of the nursing home is approximated using the number of beds. The majority of nursing homes in our sample of Irish long-stay units have less than 100 beds at their disposal, and the mean is centred around 50 beds. Hence, we divide our sample into 3 size categories as follows: size_1' (0-49 beds), 'size_2' (50-99 beds) and 'size_3' (100 beds and over). Thus, we include two 'size' dummy variables where 'size_1' is the reference category.

We argue that if Irish nursing homes are scale-inefficient, then size must have a positive effect on overall technical efficiency when measured using CRS technology. Also, it should be noted that the concept of scale inefficiency (i.e. IRS or DRS) is also closely related to the concept of economies or diseconomies of scale. According to Ozcan *et al.* (1998: 214), where economies of scale occur, larger nursing home units facing decreasing average costs over the relevant range of outputs should experience efficiency advantages. Efficiencies due to economies of scale can result from specialization of labour. Beyond a threshold, diseconomies may arise due to managerial inefficiency. Therefore, if economies of scale exist, a strong economic case could be made for the consolidation of small nursing homes into larger ones (Filippini, 1999). As most of our sample of Irish nursing homes are small (almost 90% of all units have less than 100 beds), there is reason to believe that many facilities are operating in the range of increasing returns to scale, and hence are experiencing decreasing average costs – indicating the importance of increasing their size. Nyman *et al.* (1990) found that size had a positive impact on efficiency up to a threshold of 170 beds. Also, Wang and Chou (2005) categorize size by the number of beds provided, as follows: Small <100, medium 100-499, and large >500. However, they find a significant negative relationship – larger nursing homes are less technically efficient.

Quality

'Quality' is another potentially important determinant of technical efficiency in the provision of nursing home care (e.g. see Laine *et al.*, 2005; Delellis and Ozcan, 2013). In this research, we use the qualifications of the medical staff at the facility level as a proxy for 'quality' – a value of 1 is ascribed if the nursing home employs at least one nurse who has a diploma in gerontology or a postgraduate qualification in elderly care, and zero otherwise. Given that the average number of medical staff across all the nursing homes with less than 100 beds in our sample (99 nursing homes out of 111) is 9 nurses, we posit that the employment of at least one nurse with a formal specialization in the care of the elderly might significantly improve the quality of care, if not necessarily productive efficiency. The use of nurses with more advanced expertise in the caring process enhances the quality experience for the elderly person, and could lead to improved work practices, resulting in better efficiencies in the nursing home. However, the link between increased quality and higher efficiency is ambiguous. Fizel and Nunnikhoven (1992: 433) observe that "because increased quality is likely to require additional input units per unit of output, homes providing higher quality of care may have lower efficiency scores." Increasing quality may require additional labour and capital resources, whilst a tendency towards efficiency improvements and cost containment can lead to a poorer performance in quality. On the other hand, better quality can be associated with better economic performance and lower production costs, i.e. better efficiency.

Most previous studies have restricted quality measures to include pressure sores or ulcers, catheters, and use of restraints (e.g. Rosko *et al.*, 1995), and to deficiencies or inspection scores (e.g. Nyman and Bricker, 1989; and Fizel and Nunnikhoven, 1993). However, the quality variables used by Kooreman (1994) include the presence of a patients' council, the presence a council of patients' relatives, and the presence of a procedure for handling complaints. Laine *et al.* (2005) analyse the association between quality of care and technical efficiency in long-term care in Finland. They consider 41 quality variables separately, involving 38 clinical quality of care indicators, implying adverse care processes and outcomes (e.g. prevalence of falls, %; incidence of new pressure ulcers, %), and 3 structural quality measures (proportion of registered nurses, %; proportion of rooms with own toilet, %; proportion of single rooms, %). In relation to the structural quality variables, they found that the lower the proportion of registered nurses and the proportion of single rooms, the better the efficiency; whereas wards operated more efficiently when they had a higher number of rooms with en-suite toilets. Similarly, the quality indicators used by Delellis and Ozcan (2013) were primarily clinical in nature (e.g. physical restraints, the percentage of bedridden residents, unplanned weight change). However, only one of the analysed quality indicators (bladder incontinence) was lower in efficient nursing homes. Hence, this study provides evidence that higher efficiency in nursing homes does not necessarily have to be attained by sacrificing quality.

Case-mix

Similar to Nyman *et al*. (1990) and Kooreman (1994), we measure case-mix for the 'percentage of patients aged 85 and over'. The more complicated the case-mix status of elderly people, the more likely more inputs are required, which could lead to lower efficiency performances (Nyman and Bricker, 1989; Nyman *et al*., 1990; Chattopadhyay and Heffley, 1994; Ozcan *et al.*, 1998). "The percentage of the population above 84 years in age is thought to be negatively related to efficiency due to a higher severity of illness" (Ozcan *et al.*, 1998: 217). Kooreman (1994) also uses an index of the average length of stay to represent case-mix, while 10 indicators in all are employed by Nyman *et al*. (1990) – other variables include measures of ADLs,[9] turnover of patients, the % of patients with decubiti; and the % of patients who are confused. In other nursing home studies, Fizel and Nunnikhoven (1992) apply the % of skilled beds as an indicator of case-mix, while Garavaglia *et al*. (2011) use the % of patients who are in low severity classes. Nyman *et al*. (1990) and Kooreman (1994) found a negative case-mix effect on productive efficiency – as case-mix increases, efficiency scores fall. A novel feature of this study is the inclusion of a case-mix indicator directly in the double-bootstrap setting – hence, the bias-corrected efficiency scores incorporate the effect of the case-mix variable, if any.

Another approach to modelling the effects of case-mix is also to include the patient characteristics (for patients at different nursing home units) as a type of input in the

[9] Activities of daily living (ADLs).

production frontier. However, this approach may be inconsistent with economic theory, as patients are not inputs which are transformed to make the final product (total patient days). Instead, patients or residents consume care to (hopefully) produce improvements in their quality of life. The characteristics of residents will influence the production of nursing home care in order to produce these improvements, hence resident characteristics may be better viewed as factors which shape the environment within which the production of nursing home care occurs, rather than inputs in the production process (see Hollingsworth and Peacock, 2008: 35-36). If resident characteristics are included as inputs in the DEA model, DEA would show the unit with the lowest value for a given case-mix variable to be efficient, and use this value as a reference point for assessing the efficiency of other providers. Clearly, deeming a unit to be efficient in such a case is undesirable. Hence, in this study, we use the case-mix variable as an efficiency determinant.

5.4. Descriptive statistics

Table 4 provides summary statistics for the output and input variables for all nursing homes, but also for public and private-voluntary units respectively.[10] In relation to output, the nursing homes in our sample on average produced 54,588 total patient days, with a minimum of 16,200 days for private homes and about 7920 days for public nursing homes. The maximum output is 165,900 patient days for public nursing homes.

Table 4 Summary Statistics for Output and Inputs

Variable	No. Obs.	Mean	Standard Deviation	Minimum	Maximum
Output (total patient days)					
Public	39	51,959	38,771	7920	165,900
Private	73	55,991	29,308	16,200	148,800
All Homes	112	54,588	32,795	7920	165,900
Primary Labour (medical staff)					
Public	39	15.15	16.74	1	82
Private	73	9.33	5.82	1	30
All Homes	112	11.34	11.21	1	82
Secondary Labour (non-medical staff)					
Public	38	19.92	13.56	3	61
Private	72	18.86	10.49	2	50
All Homes	110	19.92	11.59	2	61
Capital Input (number of beds)					
Public	39	58.59	40.37	18	175
Private	73	56.03	24.43	22	128
All Homes	112	56.92	30.76	18	175

With regard to labour inputs, whereas 16 nurses are employed on average in the public nursing homes, only 9 nurses are employed in the private homes. Hence, the average number of medical staff employed in the public nursing home sector is almost twice the

[10] The final number of observations reported in Table 4 is lower than reported earlier (see Table 2) due to missing observations for medical staff, and for some efficiency determining variables (see Table 5 below).

number of nurses employed in the private-voluntary facilities. Moreover, the finding, that public units employ more medical staff, holds, regardless of the size of the unit. When we split our sample of nursing homes into three different size categories, the number of nurses in public homes with 50-100 beds and 100+ beds is double that for equivalently-sized private-voluntary units. On the other hand, there is almost no difference between private and public nursing homes in the mean number of non-medical staff employed. We note further that, on average, the number of nurses is broadly similar to the number of health care attendants for public long-stay units. In contrast, the ratio of medical to non-medical personnel in private-voluntary homes is approximately 1:2. This ratio suggests that substitution may be occurring between medical and non-medical staff in private units, and consequently, this could have an effect on their technical efficiency levels. As for the capital input, the average number of beds provided in all nursing homes is 58, and the number is slightly higher for public homes on average.

Table 5 presents the summary statistics for the efficiency determinants described in section 5.3. As nearly all of these factors are dummy variables, only their means (percentages) are presented. Additionally, we provide a breakdown for public and private nursing homes. As can be seen, 65% of all nursing homes are private units. Also, the facilities in our sample are equally distributed between the Dublin area and other regions, but there is a higher percentage of private nursing homes (58%) located in Dublin relative to public units (40%). Interestingly, 75% of the public long-term care residential facilities in our sample have at least one nurse with a specialization in the care of the elderly (a diploma in gerontology), compared to 25% of the private-voluntary homes. In relation to the size of the nursing home units, whereas 48.2% of all facilities have less than 50 beds, this percentage is higher for public homes (56%) than for private units (44%), thus indicating that if size is a relevant variable, the greater scale inefficiencies will occur in public units. Furthermore, only 15% of public, and 10% of private-voluntary nursing homes belong to the largest size category (≥ 100 beds). Regarding our case-mix variable, the percentage of residents aged ≥ 85 years is similar, on average, for public and private long-stay units – 30% for public, and 26% for private facilities.

Table 5 Summary Statistics for Efficiency Determinants (in %)

Variable and description	Public		Private		All homes	
	No. Obs.	Share	No. Obs.	Share	No. Obs.	Share
Ownership (=1 if private, = 0 if public)	n/a	n/a	n/a	n/a	112	65.18
Location (=1 if Dublin area and 0 otherwise)	39	38.46	73	57.53	112	50.89
Qualification (=1 if a nurse has diploma in gerontology)	39	74.36	73	24.66	112	41.96
Size_1 (0 - 49 beds)*	39	56.41	73	43.84	112	48.21
Size_2 (50 - 99 beds)	39	28.21	73	46.57	112	40.18
Size_3 (≥ 100 beds)	39	15.38	73	9.59	112	11.61
Case-mix	39	29.91	73	26.19	112	27.48

Note: *Denotes the reference category.

6. Empirical Results

6.1 Conventional DEA results

Table 6 summarises the results of our estimated TE and SE scores for nursing homes in Ireland for both the CRS and VRS DEA technologies.[11] The results are obtained for three alternative model specifications which differ in their inclusion of labour inputs (see also Table 3). The CRS DEA model implicitly assumes that nursing homes are scale-efficient. However, as discussed earlier, nursing homes may be operating at sub-optimal scales. Where scale inefficiencies are present, the CRS TE scores will underestimate the 'true' VRS DEA TE scores. This is confirmed by the estimates in Table 6 where the VRS TE scores are, on average, higher than for the CRS approach. Thus, our findings show that scale inefficiencies are present in the Irish nursing home sector, similar to the results obtained for nursing homes studies in other countries (e.g. see Kooreman, 1994; Chattopadhyay and Ray, 1996).

Table 6 Summary Statistics for DEA Efficiency Scores for Public and Private Nursing Homes

	Model 1			**Model 2**			**Model 3**		
	No. Obs.	Mean	St. Dev.	No. Obs.	Mean	St. Dev.	No. Obs.	Mean	St. Dev.
				CRS TE					
Public	39	0.498	0.180	38	0.479	0.178	38	0.497	0.181
Private	73	0.578	0.224	72	0.549	0.209	72	0.577	0.223
All homes	112	0.550	0.212	110	0.525	0.201	110	0.549	0.212
				VRS TE					
Public	39	0.606	0.194	38	0.585	0.195	38	0.618	0.197
Private	73	0.623	0.198	72	0.598	0.195	72	0.627	0.200
All homes	112	0.617	0.196	110	0.594	0.194	110	0.624	0.198
				Scale efficiency (SE)					
Public	39	0.828	0.185	38	0.827	0.182	38	0.810	0.186
Private	73	0.913	0.162	72	0.905	0.154	72	0.906	0.168
All homes	112	0.883	0.175	110	0.878	0.168	110	0.873	0.180

Focusing on the estimates of the VRS DEA model, the mean TE scores for all nursing homes for *Models 1*, *2* and *3* are 0.62, 0.59 and 0.62 respectively. These scores appear low when compared, for example, to the studies by Bjorkgren *et al*. (2001) and Laine *et al*. (2005) who found mean TE estimates of around 0.85 and 0.72 respectively, for long-term care residential units in Finland. While the output variable used in these studies is adjusted by case-mix, the results nevertheless provide a useful benchmark against which to assess the productive efficiency performance of Irish nursing homes. Similarly, Borge and Hardaldsvik (2009) reported a mean input-oriented DEA technical efficiency estimate of 0.84 for Norwegian nursing homes, where their output variable is measured using the total number of residents. This finding is in line with an earlier Norwegian study by Kalseth (2003). Beyond the Scandinavian countries, Nyman and Bricker (1989) obtained an average TE estimate of

[11] The total number of observations for *Models 2* and *3* is further reduced to 110, as there are two observations missing for the number of medical staff.

0.89 for Wisconsin nursing homes in the USA. Furthermore, in relation to the efficiency scores for private and public facilities, Irish nursing homes again appear to perform poorly compared to previous studies. For example, in *Model 1*, the mean TE scores for the Irish public and private long-stay units in our sample are 0.61 and 0.62 respectively. In contrast, Chattopadhyay and Heffley (1994) obtained average TE estimates of 0.71 and 0.92 respectively, for non-profit and for-profit facilities in Connecticut. Similarly Ozcan *et al.* (1998) found mean productive efficiency scores of 0.80 for non-profit homes, and 0.84 in for-profit units in skilled nursing facilities in the USA.

The average scale efficiencies are also presented in Table 6. For *Models 1* and *3*, the mean SE for all nursing homes is about 0.88. As the scale efficiency is on average higher than the technical efficiency, this implies that the *total* inefficiency of the nursing homes is driven to a greater extent by pure technical inefficiency rather than as a result of scale inefficiency.

Furthermore, comparing the VRS DEA results for the three alternative model specifications in Table 6 provides insights into the impact of the different labour inputs on the technical efficiency of Irish nursing homes. We find that when TE is estimated using non-medical staff only (*Model 2*), the mean TE score is slightly lower than the scores obtained for *Models 1* and *3* where the input of medical staff is taken into account. Moreover, the results for *Models 1* and *3* are very similar. Overall, this implies that employing more nurses leads to more efficient outcomes.

Importantly, comparing the mean VRS TE and SE scores in Table 6, private nursing homes are on average more technically and more scale efficient than public nursing homes. However, there is no statistically significant difference in the mean TE scores between the two ownership types based on the mean-comparison (one tailed) t-test and the Mann-Whitney test (see appendix Table A.2). The null hypothesis, that the mean TE scores for public and private nursing homes are the same, is not rejected in the case of all three models for VRS technology. In contrast, the SE scores are significantly higher for private nursing homes compared to public homes for all three model specifications.

While no statistical difference in the mean VRS TE scores between public and private units was found, there are important differences in the distribution of TE scores between the two groups of nursing homes. Table 7 presents the percentage distribution of TE and SE scores partitioned into public and private nursing home sectors. Fifty-two percent of private units (in *Model 1*) display TE scores which are below 0.60 indicating that they could reduce their inputs usage by up to 40% for the same level of patient days. In comparison, 56% of public nursing homes have TE scores lower than 0.60. However, while 13% of public homes are fully technically efficient, only 7% of private facilities are found to have a technical efficiency score equal to 1. On the other hand, a large majority of private nursing homes (74%) display SE scores between 0.90 and 0.99, compared to only 51% of public units.

Table 7 Frequency Distribution of Efficiency (VRS DEA) by Ownership

	Model 1				**Model 2**				**Model 3**			
Range	private		public		private		public		private		public	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
					Technical efficiency							
1.00	5	7	5	13	4	6	4	11	6	8	5	13
0.90-0.99	5	7	0	0	3	4	0	0	4	6	0	0
0.80-0.89	4	5	1	3	5	7	1	3	4	6	1	3
0.70-0.79	8	11	4	10	8	11	4	11	8	11	5	13
0.60-0.69	13	18	7	18	11	15	6	16	13	18	5	13
Below 0.60	38	52	22	56	41	57	23	61	37	51	22	58
Total	73	100	39	100	72	100	38	100	72	100	38	100
					Scale efficiency							
1.00	3	4	1	3	1	1	1	3	4	6	1	3
0.90-0.99	54	74	20	51	57	79	20	53	50	69	16	42
0.80-0.89	5	7	4	10	4	6	3	8	7	10	5	13
0.70-0.79	2	3	2	5	2	3	5	13	2	3	4	11
0.60-0.69	3	4	7	18	2	3	5	13	3	4	7	18
Below 0.60	6	8	5	13	6	8	4	11	6	8	5	13
Total	73	100	39	100	72	100	38	100	72	100	38	100

We also compare the TE scores obtained for the non-increasing returns to scale (NIRS) and VRS DEA models in order to identify whether those nursing homes which are scale-inefficient produce at increasing or decreasing returns to scale. Those nursing homes which are both technically and scale efficient are operating at optimal scale. All other units are operating at either increasing or decreasing returns to scale. As we can see from Table 8, 91% of all homes exhibit increasing returns to scale, and hence should increase their operations (all inputs) to become scale efficient. The results are very similar for *Models 2 and 3*.

Table 8 Public and Private Nursing Homes that Exhibit Sub-Optimal Scales in *Model 1*

	All homes		Public		Private	
	No.	%	No.	%	No.	%
Constant Returns to Scale (CRS)	4	4	1	3	3	4
Increasing Returns to Scale (IRS)	103	91	36	92	67	92
Decreasing Returns to Scale (DRS)	5	5	2	5	3	4
Total	112	100	39	100	73	100

6.2. Homogenous bootstrap DEA results

Table 9 presents the homogenous bootstrap DEA mean efficiency scores and sample confidence intervals for *Model 1*, together with the average scores obtained using the conventional DEA method (see also Table 6).[12] Any bias in the conventional DEA efficiencies is reflected in the difference between these scores and the bootstrap DEA efficiency scores. We can see that our DEA mean TE estimates for Irish nursing homes exceed the mean bootstrap bias-corrected efficiencies, thus indicating a positive bias. Furthermore, both the conventional DEA TE and SE scores are consistently above the bootstrap upper bounds, and outside the confidence interval. This result implies that our conventional DEA CRS and VRS efficiencies are over-estimates of the true efficiency scores, and that the bias is significant. Hence, the inefficiencies which we observe in Irish nursing homes underplay the true picture. Focusing on the estimates for the VRS DEA model, the mean bootstrap bias-corrected TE score for all nursing homes for *Model 1* is 0.56.[13] Additionally, the relativities in terms of the proportionality between the conventional DEA mean efficiencies and the homogenous bootstrap (bias-adjusted) mean efficiencies remain the same across the CRS and VRS DEA models. Expressing the bootstrap CRS TE as a ratio of the bootstrap VRS TE gives the estimates of the bootstrap bias-corrected SE scores in Table 9, and our original findings regarding the existence of scale inefficiencies (presented in Table 6) are still valid.

Table 9 Homogenous Bootstrap DEA Efficiency Scores and Sample Confidence Intervals for *Model 1*

	DEA	Homogenous bootstrap DEA		
	Mean score	Mean score	Lower Bound	Upper Bound
		CRS TE		
Public	0.498*	0.446	0.407	0.488
Private	0.578*	0.522	0.475	0.568
All homes	0.550*	0.496	0.451	0.541
		VRS TE		
Public	0.606*	0.541	0.494	0.596
Private	0.623*	0.562	0.515	0.613
All homes	0.617*	0.555	0.507	0.607
		Scale efficiency (SE)		
Public	0.828*	0.827	0.823	0.825
Private	0.913*	0.913	0.907	0.912
All homes	0.883*	0.883	0.878	0.882

* denotes conventional DEA efficiency estimate is outside the bootstrapped 95% confidence interval, i.e. it is significantly different from the bias-corrected efficiency score.

In terms of the statistical difference in the means of the bootstrapped bias-corrected TE and SE scores between private and public nursing units, the results confirm our earlier findings and are available on request. While the private nursing homes are significantly more scale efficient on average than the public units, there is no statistically significant difference in the means of the VRS bias-corrected TE scores between the two ownership groups. Also,

[12] The estimations were performed using the FEAR software package (see e.g. Wilson, 2008). As the results obtained for *Models 2* and *3*, using the bootstrap procedure, are very similar to those provided for *Model 1*, they are not presented but are available on request.

[13] The bias-corrected efficiency scores for *Models 2* and *3* are 0.53 and 0.55 respectively.

in relation to the frequency distribution for the bootstrap bias-adjusted TE and SE scores, we find a very similar pattern to that presented for the conventional DEA efficiency scores in Table 6.

Figure 3 presents the distribution of the original conventional DEA TE scores and the distribution of the bias-corrected DEA TE scores using the homogenous bootstrap method, for *Model 1*, for both CRS and VRS technologies. It is apparent that the kernel density functions do not differ a lot with regard to the estimation method (i.e. conventional DEA versus the bootstrap method). However, as found earlier, we can see some differences in the distribution of the CRS versus the VRS TE scores for both the conventional DEA and bootstrap methods. Whereas the means of the two distributions are very similar, the variance in the CRS model is considerably wider than in the VRS model, indicating possible discrepancies in technical efficiencies due to scale inefficiencies.

Figure 3 Kernel Density Functions for both Conventional DEA and Homogenous Bootstrap Bias-Corrected DEA TE Scores

6.3 Double bootstrap DEA results

Table 10 presents the estimated parameters of the efficiency determinants obtained using the double-bootstrap DEA method. The estimations were performed for both CRS and VRS technologies and for all three models.[14] We focus here on the CRS results in particular as this technology is commonly used in two-stage analyses in the wider efficiency measurement literature, mainly for two reasons. First, the CRS TE scores provide a measure of the overall efficiency of each nursing home unit, i.e. aggregating pure technical efficiency and scale efficiency, while the VRS approach only measures pure technical efficiency as discussed earlier. Second, the CRS TE scores exhibit more variability compared to the VRS measure, and this is supported in our case in Figure 3.

The results in Table 10 present strong statistical evidence in relation to the impact of *ownership* on the technical efficiencies of Irish nursing homes. For all three models, the ownership parameter coefficient is negative and statistically significant at the 1% level using CRS technology, and at the 5% or 10% level when VRS is applied – implying that private

[14] The estimations for the double bootstrap DEA were performed using the rDEA package within the R platform.

homes are less technically efficient than the public units. This result is at variance with much of the previous long-term care literature where private or for-profit facilities are found to be more efficient than non-profit units, when allowed to face the same production frontier (see section 5.3 for discussion, and e.g. Nyman and Bricker 1989; Nyman *et al.* 1990; Fizel and Nunnikhoven, 1992; Chattopadhyay and Heffley 1994; and Ozcan *et al.* 1998). We argue that the effective State subsidy for the provision of contract beds can lead to less efficient outcomes for the private Irish nursing homes analysed in this study. Also, the Irish Government policy of introducing capital allowances to stimulate private delivery could have led to the self-selection of "inefficient" facilities into the private nursing home sector in Ireland. Finally, Irish private nursing homes hire on average less nurses than the public units. Due to the substitution of non-medical for medical staff in private nursing homes, private facilities may be less efficient than public homes. Employing less nurses relative to health-care attendants can lead to lower average TE scores.

We find mixed results for the *location* variable as a determinant of technical efficiency. Location has a positive and statistically significant effect on the TE scores under CRS technology, indicating differences in technical efficiency between nursing homes in the Dublin area and those in other regions in Ireland. However, we do not find any significant effect of this variable for the VRS measure. In addition, for all models assuming CRS technology, and for *Model 1* under VRS, we find evidence of a statistically significant and negative impact of the *qualification* variable on the TE scores for our sample of Irish long-stay units. Hence, as discussed in section 5.3, and similar to Nyman and Bricker (1989), Fizel and Nunnikhoven (1992), Kooreman (1994), and Laine *et al.* (2005), we find that a tendency towards quality improvements can lead to lower technical efficiency.

Surprisingly, in contrast to other studies, the *case-mix* variable is not found to be statistically significant for most model specifications and is only weakly significant for CRS technology in *Model 1*. This result may be due to the low variability in the case-mix variable shown in Table 5. Regarding the *size* variable, nursing home units with a larger number of beds are significantly more technically efficient than the nursing homes with less than 50 beds. A similar effect was observed by Nyman *et al.* (1990). This result corroborates our earlier findings that Irish nursing homes are scale-inefficient and most of them produce on the IRS part of the production frontier. Thus, in order to be fully productive (both technically and scale efficient), they should increase their size (i.e. scale of operations).

Table 10 Estimates of TE Determinants using Double Bootstrap DEA Method

	CRS TE			VRS TE		
	Estimated coefficient	Lower Bound	Upper bound	Estimated coefficient	Lower Bound	Upper bound
Model 1						
Constant	-34.02***	-77.33	-19.53	1.647***	1.128	2.054
Ownership (1=private)	-14.86***	-35.17	-8.558	-0.317**	-0.592	-0.042
Location (1=Dublin)	6.874**	1.025	19.06	-0.024	-0.332	0.290
Qualification	-8.479***	-22.48	-2.774	-0.305**	-0.616	-0.029
Size_2 (50 - 100 beds)	15.12***	7.723	34.233	0.857***	0.540	1.171
Size_3 (> 100 beds)	2.381	-17.44	20.191	0.988***	0.533	1.441
Case mix	0.199*	0.022	0.439	0.006	-0.008	0.016
No. observations	112			112		
Model 2						
Constant	-32.65***	-76.24	-18.89	1.837***	1.185	2.514
Ownership (1=private)	-12.22***	-33.99	-3.912	-0.296*	-0.542	-0.021
Location (1=Dublin)	6.491**	1.321	16.696	-0.016	-0.275	0.258
Qualification	-6.934**	-19.78	-0.935	-0.169	-0.502	0.158
Size_2 (50 - 100 beds)	12.65***	5.535	23.502	0.876***	0.457	1.256
Size_3 (> 100 beds)	3.713	-24.53	16.077	0.887***	0.423	1.284
Case mix	0.219*	0.021	0.466	-0.001	-0.014	0.011
No. observations	110			110		
Model 3						
Constant	-33.99***	-69.75	-19.49	1.671***	1.139	2.136
Ownership (1=private)	-13.33***	-32.71	-5.965	-0.288*	-0.547	-0.049
Location (1=Dublin)	5.582**	0.305	14.60	-0.025	-0.306	0.285
Qualification	-7.250	-26.60	1.841	-0.254	-0.569	0.139
Size_2 (50 - 100 beds)	13.60***	3.899	27.66	0.873***	0.488	1.167
Size_3 (> 100 beds)	5.205	-12.32	27.24	1.004***	0.610	1.426
Case mix	0.247	-0.102	0.816	0.004	-0.009	0.016
No. observations	110			110		

*** significant at the 1% level, ** significant at the 5% level, and * significant at the 10% level.

Table 11 presents the double bootstrap bias-corrected efficiency scores and the corresponding 95% confidence intervals. The bias-corrected efficiency scores are adjusted for the effects of the efficiency determinants. Also, the conventional (non-bootstrap) DEA efficiency estimates are given in the first column of the table. The double bootstrap results confirm again that the nursing home units in this study are on average technically inefficient for both CRS and VRS technologies. Moreover, the conventional TE scores are upward biased when compared with the double bootstrap bias-corrected TE scores, indicating overestimates of the true mean efficiency values. Hence, similar to the homogenous bootstrap DEA results (in Table 9), the nursing homes in our sample are even more inefficient than was found using the conventional DEA method. Furthermore, the bias is significant at the 5% level for the VRS TE estimates – the conventional DEA mean VRS TE estimates are outside the bootstrap upper bounds, which implies that they are significantly different from the bias-corrected VRS TE scores.

The main difference between these results and the efficiency scores presented earlier for the conventional DEA (Table 6) and the homogenous bootstrap DEA (Table 9) methods is that the CRS and VRS TE scores are very similar on average. Accordingly, the mean (bias-corrected) SE scores obtained for the double bootstrap DEA model are very close to 1, indicating that the nursing home units are almost fully scale efficient. This is at variance with our earlier results where the VRS TE scores were greater than the CRS scores, and scale inefficiencies were apparent. Also, given that the nursing homes are almost fully scale efficient, the (low) mean CRS TE score observed for the double-bootstrap model is due to pure technical inefficiency only and not scale inefficiency. We find that the conventional DEA scale efficiencies are downward biased relative to the double bootstrap bias-corrected SE scores (indicating underestimates of the true mean SE values), and the bias is significant at the 5% level (i.e. the conventional DEA mean SE estimates are outside the bootstrap lower bounds). This result is unsurprising as the double bootstrap model adjusts the observed CRS and VRS TE scores for the effects of size and other determinants, to give bias-corrected TE scores. We already saw, in Table 10, a statistically strong determining effect for the 'size' variable. Hence, controlling directly for the determinants of efficiency in the double-bootstrap model, and in particular adjusting for the size of the facilities, the nursing homes become scale efficient. This result is also in line with our earlier findings where we observe that Irish nursing homes should increase their size to take advantage of economies of scale.

Table 11 Double Bootstrap DEA Efficiency Scores for *Model 1*

	DEA	Two-stage double bootstrap DEA		
	Mean score	Mean score	Lower Bound	Upper Bound
		CRS TE		
Public	0.498	0.475	0.457	0.511
Private	0.578	0.553	0.534	0.598
All homes	0.550	0.526	0.507	0.568
		VRS TE		
Public	0.606*	0.522	0.474	0.586
Private	0.623*	0.549	0.499	0.621
All homes	0.617*	0.539	0.490	0.609
		Scale efficiency (SE)		
Public	0.828*	0.914	0.874	0.971
Private	0.913*	0.995	0.948	1.058
All homes	0.883*	0.966	0.922	1.028

* denotes conventional DEA efficiency estimate is outside the bootstrapped 95% confidence interval, i.e. it is significantly different from the bias-corrected efficiency score.

7. Conclusions

This research contributes to the literature on efficiency in the long-stay care sector by providing methodological and empirical insights into the estimation of technical efficiency. Using a rich primary data set and applying robust estimation methods, the paper delivers relevant and interesting findings from the first investigation of the technical and scale efficiency levels and the impact of efficiency determinants for public and private nursing homes in Ireland.

Across all Irish nursing homes we found considerable technical inefficiencies. Based on our conventional VRS DEA model where the number of nurses is used as the only labour input (*Model 1*), the estimated average TE score is 0.62 for all nursing homes, with only 7% of all private and 13% of all public units being fully technically efficient. This result indicates that nursing homes in Ireland should on average decrease their level of inputs by 38% in order to produce efficiently. We also find that the number of medical staff is the most important labour input since the TE scores estimated using the number of nurses as the only labour input (*Model 1*) are higher than those obtained when using the number of health care attendants only (*Model 2*).

Moreover, the bootstrap DEA results suggest that the conventional DEA TE scores are overestimated. The bias-corrected VRS mean TE scores, for all nursing homes in *Model 1*, are very similar when we compare the homogenous and double bootstrap results, with values of 0.56 and 0.54 respectively. These scores are around 10% lower than the score obtained using the conventional DEA method. The overestimates of the true DEA TE scores imply that Irish nursing homes are even more inefficient than the conventional DEA findings would suggest.

Regarding scale efficiency, in the conventional DEA and the homogenous bootstrap DEA models, the CRS TE scores are lower on average than the scores obtained using VRS technology, indicating that scale inefficiencies exist in the nursing home sector in Ireland. The estimated average SE score is 0.88 for all nursing homes in *Model 1*, which is higher than the VRS mean TE score. Furthermore, according to the conventional NIRS DEA frontier, the overwhelming majority of facilities produce on the increasing returns to scale part of the production frontier, indicating the existence of economies of scale. This implies that Irish nursing homes are not operating in the economically feasible region as they could still decrease their average costs and move to the point of minimum marginal costs by extending their scale of production. Additionally, only 4% of all nursing homes are fully productive (both technically and scale efficient) and operating at optimal scale.

Moreover, focusing further on the double bootstrap DEA results, the most striking feature is the very high average scale efficiency scores obtained – 0.97 for all nursing homes and equal to unity for private homes. However, this result is in line with our other findings. Based on our conventional DEA estimates, Irish nursing homes are scale inefficient and they produce at increasing returns to scale. Crucially, the double bootstrap model integrates the effects of explanatory variables in estimating the true efficiencies. Controlling directly for the determinants of efficiency in the double bootstrap model, and in particular adjusting for the size of the facilities, the nursing homes become scale efficient.

Turning our attention to the results from the estimation of the efficiency determinants, the size variable has a strongly significant and positive effect on technical efficiency (underlying our double bootstrap scale efficiency results). This suggests that larger nursing homes could increase their technical efficiencies due to specialisation as indicated by Ozcan *et al.* (1998) and Filippini (1999). Also, location is found to be statistically significant using CRS technology only and is not a significant factor when VRS is applied, implying again that the scale economies could be better utilised in the Dublin area compared to other regions in Ireland.

An important finding of this study is that ownership has a statistically significant and negative effect on the TE scores of Irish nursing home units, indicating that private facilities are less productively efficient than the public units. As discussed earlier, this result is at odds with much of the previous literature. Nonetheless, this finding might be explained in the Irish case by the structure of the nursing home sector where many private long-stay units are effectively subsidised by the State in the form of fixed contracts per bed, capital allowances (from 1998 until 2011), and the dominance of the NHSS/ Fair Deal funding mechanism. Interestingly, quality (as measured by employing at least one nurse with a formal qualification in the care of the elderly) negatively affects the technical efficiency of nursing homes. Similar to other studies (e.g. Fizel and Nunnikhoven, 1992; and Laine *et al.*, 2005), increasing quality may require additional labour and capital resources – hence, homes providing higher quality of care may have lower efficiency scores.

Another novelty of this article was the inclusion of a case-mix indicator directly in the double-bootstrap setting to measure the technical efficiency of nursing homes. We consider this to be a more robust approach than treating case-mix as an output or an input variable, or as an environmental variable in traditional two-stage procedures, as has been done in other studies. However, we find little statistical evidence for the determining effect of our chosen case-mix variable, and a greater range of indicators in this area is probably required. Nonetheless, a complication here is that the case-mix profile is rather similar across the nursing homes in Ireland. This is illustrated in our earlier descriptive statistics for the private and public nursing homes, respectively.

The findings of this study inform policymakers that the majority of Irish nursing homes are not only technically inefficient but they should also increase their economies of scale by increasing their size. Given that private-voluntary nursing homes, who supply care to the state on a fixed contract per bed basis, are less technically efficient than the public homes, our results suggest that public provision of long-term care in Ireland should be re-targeted rather than incentivising private delivery. This is based on the following findings: the significant and negative private ownership effect, and the much higher ratio of nursing to non-medical staff in public units. Alternatively, the government should introduce appropriate regulation for the nursing home sector which would promote the objective of efficiency in resource allocation. In particular, the nursing home units in Ireland should be incentivised to increase their scale of operation in order to improve their technical efficiency and to produce at optimal scale.

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Appendix

Table A.1 Previous evaluations of efficiency in the nursing home sector

Author(s)	Technique	Country and sample	Output variable	Average efficiency and other findings
Anderson, Lewis and Webb (1999)	Bayesian SFA (stochastic production frontier model).	653 nursing homes, United States nation-wide for the year 1995.	Number of patients admitted.	For-profit homes have much higher mean efficiency scores than the non-for-profit homes, with TE scores of 0.90 and 0.73, respectively.
Björkgren, Häkkinen and Linna (2001)	DEA (CRS and VRS) – input-oriented TE, SE, AE and CE.	64 nursing homes in Finland collected for the year 1995.	Case-mix adjusted patient days.	The mean CE was 0.77 for model 1 and 0.74 for model 2. The means of the TE scores were 0.85 and 0.87 and the means of AE were 0.86 and 0.89. Larger units operated more efficiently than smaller units.
Borge and Haraldsvik, (2009)	DEA (CRS and VRS) – input- and output-oriented TE; double bootstrap model.	Each local government area and the national level efficiency potential.	Number of patients by service.	The mean TE score is 0.84 (for input-orientation) and 0.85 (for output-orientation).
Chang and Cheng (2013)	DEA (CRS and VRS) – input-oriented TE	132 nursing homes in Taiwan during 2004-2009.	Number of residents; Number of falls; Number of times the resident uses emergency services.	The average TE is 0.90.
Chattopadhyay and Heffley (1994)	DEA (CRS and VRS) – input - oriented TE.	140 nursing homes from Connecticut, USA during the year 1982-83	Total patient days.	The mean efficiency score for non-profit homes is 0.71 compared to 0.92 for-profit homes.
Chattopadhyay and Ray (1996)	DEA (CRS, VRS and NIRS) – output-oriented TE	140 nursing homes from Connecticut, USA during the year 1982-83	Total patient days.	The mean level of TE was 0.80 for non-profit homes and 0.94 for-profit homes. The mean levels of scale efficiency are 0.96 for no-profit homes and 0.97 for those operating for profit.
Crivelli, Filippini, and Lunati (2002)	SFA (cost frontier) – CE and SE.	Cross Sectional Data of 886 nursing homes. Data given by the Swiss Federal Statistical office and its' for the period 1998.	Total patient days.	The mean CE was 0.79 (or 0.21 for cost inefficiency)
DeLellis and Ozcan (2013)	DEA (CRS and VRS) – input-oriented TE	10% of random sample of U.S. nursing homes	Number of *medicare* residents; Number of *medicaid* residents; Number of other residents.	The average efficiency was 0.87, with a statistically significant higher average efficiency for nursing homes in urban areas; in counties with a higher level of competition, higher average income, or higher number of home health agencies, and in not-for-profit and governmental facilities. Mostly favourable quality outcomes were found for efficient nursing homes.
Farsi, Filippini, Lunati (2008)	SFA (cost frontier) - CE	356 nursing homes in Switzerland, operating over the period from 1998 to 2002	Total patient days.	The mean CE for the final model used was 0.92 (or 0.081 for cost inefficiency).

Table A.1 continued

Fizel and Nunnikhoven (1992)	DEA (CRS – input-oriented TE)	163 Michigan nursing homes in USA, of which 104 are forprofit and 59 are non-profit homes.	Total patient days for skilled and intermediate-care patients.	Average efficiency 0.655. Chain homes have higher average efficiency scores (0.705) relative to independent operators (0.622).
Garavaglia, Lettieri, Agasisti and Lopez (2011)	DEA (CRS and VRS), – input-oriented TE; homogenous bootstrap model.	40 Italian nursing homes (with six public and 34 private facilities), over a 3-year period.	Case-mix, extra nursing hours and out-of-pocket charges	Mean TE scores is between 0.78 and 85. Quality of care is positively related to efficiency.
Hoffler and Rungeling (1994)	SFA (cost frontier) - CE	1079 nursing homes in the U.S. for the year 1985.	Skilled inpatient days; intermediate inpatient days and 'other' inpatient days.	For-profit homes have lower costs relative to non-profit homes.
Kleinsorge and Karney (1992)	DEA TE (output-oriented)	22 nursing homes in Kansas	Total patient days; State inspection score; Decubiti-free days care; operating income.	The nursing homes are found to be fully efficient with a score of 1.0.
Knox, Blankmeyer, Stutzman (2007)	SFA (Cobb Douglas)	Panel data of Texas nursing homes for 1999 and 2002	Number of Patient days.	Average Efficiency Scores 0.80-0.92. Non-profit facilities are notably less productive than facilities operated for profit.
Kooreman (1994)	DEA (CRS and VRS) – input-oriented TE	292 Dutch nursing homes.	Number of patients by care needs.	Average efficiency score 0.87
Laine, Finne-Soveri, Bjorkgren, Linna, Noro, Hakkinen (2005)	DEA (CRS) – input-oriented TE	114 public health centre hospitals and residential homes in Finland.	Total inpatient days adjusted by case-mix.	Mean TE 0.72.
• Nyman and Bricker (1989); • Nyman, Bricker and Link (1990)	DEA (CRS) – input-oriented TE	195 nursing homes in Wisconsin (U.S.) for the year 1979.	Patients by care needs.	Average efficiency score was 0.89. For-profit nursing homes are significantly more efficient than the not for profit nursing homes.
Ozcan, Wogen, and Mau (1998)	DEA – input-oriented TE.	Uses a 10% national sample of 324 skilled nursing facilities in the United States	Total inpatient days of *medicare* and *medicaid* clients; Total private-pay inpatient days.	The average efficiency of the for-profits is 0.840 and for the non-profits is 0.803. For-profit and medium skilled nursing facilities are more efficient than non-profit and low-skilled units.
Vitaliano and Toren (1994)	SFA (cost frontier) - CE	164 Skilled Nursing Facilities and 443 combination skilled and health related facilities during 1987 and 1990.	Patient days.	Average CE 71% No change in efficiency between 1987 and 1990, and it does not vary between for-profit and not-for profit homes.
Wang and Chou (2005)	DEA (CRS and VRS) – input-oriented TE	53 Long Term Care Institutions in Taiwan.	Number of residents; Number of quality outputs (e.g. accreditation of professional review committee; and accident rate)	Average Efficiency VRS TE score of 0.77.

Note: TE = technical efficiency, AE = allocative Efficiency, SE = scale efficiency, CE = cost efficiency. The table also draws partly on information presented in Iparraguirre and Ma (2015). The studies are presented in alphabetical order.

Table A.2 Mean comparison tests on the differences in DEA TE and SE between public and private nursing homes

	Model 1		**Model 2**		**Model 3**	
	Criterion value (z/t) (p value)	Decision with respect H_0	Criterion value (p value)	Decision with respect H_0	Criterion value (p value)	Decision with respect H_0
			CRS TE			
t-test H_o: $TE_{public} - TE_{private} = 0$	-1.935** (0.028)	reject	-1.741* (0.042)	reject	-1.903** (0.030)	reject
Mann-Whitney test	-2.000** (0.046)	reject	-1.861* (0.063)	reject	-1.983** (0.047)	reject
			VRS TE			
t-test H_o: $TE_{public} - TE_{private} = 0$	-0.439 (0.331)	accept	-0.350 (0.363)	accept	-0.237 (0.406)	accept
Mann-Whitney test	-0.437 (0.662)	accept	-0.450 (0.653)	accept	-0.261 (0.794)	accept
			Scale efficiency (SE)			
t-test H_o: $SE_{public} - SE_{private} = 0$	-2.500*** (0.007)	reject	-2.366** (0.010)	reject	-2.755*** (0.003)	reject
Mann-Whitney test	-3.988*** (0.000)	reject	-3.178*** (0.002)	reject	-3.916** (0.000)	reject

*** significant difference at the 1% level, ** significant difference at the 5% level, and * significant difference at the 10% level.