Supplementary Material

Contents

Appendix 1 - Efficiency measurement ................................................................. 2
Appendix 2 - Search terms and lateral searching methods ...................................... 5
Appendix 3 - Detailed description of the included studies ....................................... 6
References ............................................................................................................... 22
Appendix 1 - Efficiency measurement

All production requires the use of resources such as equipment and buildings (often referred to as capital), personnel (as labour), and land and raw materials. We can regard production as a process by which these resources are transformed into goods or services. Measures of efficiency can be defined as “ex post measures of how well firm managers have solved different optimisation problems” [1]. To measure how well a decision-making unit (DMU) perform in producing outputs (goods or services) from inputs (resources) and we need to know about their managerial behaviour (optimisation problems), for which the existing sets and functions has few implications for behaviour. For instance, revenue function does not mean that DMU managers will choose outputs in order to maximise revenues. Instead, different DMU managers tends to behave in different ways depending on what they can and cannot choose and on what they value. Some of the simplest optimisation problems that DMU managers face involve minimising inputs, maximising outputs, and/or maximising productivity [1].

Efficiency answers the question if any waste can be eliminated without worsening any inputs or outputs [2]. It is considered inefficient if the desired outcome can be achieved with less throughputs or the throughputs could produce more outcome desired.

Following are concepts of measuring efficiency which is also applied in health care:

Economic efficiency, or overall efficiency, refers to an economic state in which objectives are achieved in relation to the inputs (economic resources) used. It is estimated by the value of inputs employed and value of outputs delivered. Economic efficiency can be measured when price information is available and optimisation assumption—eg. cost minimisation, profit/revenue maximisation—is appropriate [3]. When the objective is revenue maximisation, a production function or output-oriented approach can be used to estimate revenue efficiency. When the cost minimisation is more appropriate, a cost function or input-oriented approach can be applied to measure cost-efficiency.
Technical efficiency refers to the measures of how well technologies are chosen and used [1]. It measures the ability of a DMU to avoid waste by minimising inputs as output level will allow or maximising outputs as input usage will allow. Technical efficiency can be categorised in terms of non-scale and scale effects. The former is considered as pure technical efficiency which technical efficiency under a variable return to scale (VRS) production technology. Scale efficiency measures the ability to eliminate waste by operating at the optimal productive scale. It is about operation size and how various sizes influence productivity and efficiency of the DMU. A DMU is referred to be at optimal scale only when it attains the highest possible productivity (ratio of output to input) with the available technology.

Allocative efficiency reflects the ability of a DMU to use their available inputs in optimal proportions given the available production technology and their respective prices. It is about
choosing between technically efficient combinations of inputs used to produce the maximum possible outputs.

Two major methods to measure efficiency are non-parametric and parametric methods. The non-parametric method is a piecewise-linear convex hull approach to frontier estimation originally proposed by Farrell [4], developed by Charnes et al. [5]; Banker et al. [6] and Fare et al. [7]. Data Envelopment Analysis (DEA), the predominant representative of non-parametric method, applies linear programming approach to estimate the production technology. DEA is often described as a non-parametric method as it does not involve any error terms. As such, it does not involve any assumptions about the functional form of the technology or the parameters (means, variances) of the distributions of those error terms. DEA requires assumptions regarding the regularity properties of the production frontier. For example, if the production possibilities set is not convex then the DEA model is known as a Free Disposal Hull model. DEA’s assumption on functional form is that the cost or production frontier is locally linear.

The parametric method has stochastic frontier analysis (SFA) as the predominant representative. SFA involves the use of econometric methods to measure either primal or dual representations of the production technology. It was first developed simultaneously by Aigner et al. [8], Meeusen and Van den Broeck [9] and Battese and Corra [10]. Since then, SFA has evolved and become an increasingly popular method. SFA assumes the functional form of the frontier (e.g. translog or linear), the regularity properties of the frontier (e.g. monotonicity or concavity), and the distributions of error terms representing inefficiency and statistical noise (e.g. means or variances). The maximum likelihood method is usually used to estimate the unknown parameters of these functions and error distributions. The choice of functional representation is based on available data. For example, if only data on quantities of inputs and outputs are available, we can only estimate production frontiers, input and/or output distance functions. If we can only have access to the data on output quantities and input prices, we can only estimate cost frontiers.
Appendix 2 - Search terms and lateral searching methods

Base on terms related to “aged care facilities” (U.S. National Library of Medicine, https://meshb-prev.nlm.nih.gov/#/treeSearch), the type of facilities will be covered in our study are: Assisted living facilities, Home for the Aged, Nursing homes. Studies presented measurement approaches of aged care facility efficiency, which include, but are not limited to, Data envelopment analysis (DEA), Stochastic frontier analysis (SFA), Least-square econometric production models, Total factor productivity (TFP) indices.

Our search terms string for all the databases were: (efficiency* OR productiv* OR performance OR inefficiency*) AND (“data envelopment” OR DEA OR stochastic OR SFA OR parametric OR econometric* OR non-parametric OR nonparametric OR malmquist) AND (aged OR ageing OR aging OR ”aged care” OR residential OR retirement OR ”nursing home” or ”long term care” OR ”assisted living”). Our search results as below.

| Search strategy (1995 -2017; English only) | Medline | Econlit | Web of science |
|--------------------------------------------|--|---|---|
| #1 efficienc* OR productiv* OR performance OR inefficien* | Abstract | 850,359 | 135,964 | 3,943,844 |
| "data envelopment" OR DEA OR stochastic OR SFA OR parametric OR econometric* OR non-parametric OR nonparametric OR malmquist | Abstract | 67,570 | 49,136 | 418,570 |
| #2 age* OR "aged care” OR residential OR retirement OR ”nursing home” or ”long term care” OR ”assisted living” | Abstract | 2,201,135 | 80,731 | 2,163,357 |
| #4 #1 AND #2 AND #3 | Abstract | 896 | 866 | 1860 |
### Appendix 3 - Detailed description of the included studies

| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|----------------------------------|---------------------|-------------------|------------|-------------|------------------|--------------|
| 1   | Anderson     | 1999 | USA     | NH (653, 1995)                  | VRS, ITE            | SFA (cost function, Bayesian, translog, 1 stage) | I1 = Total expense | O1 = Admissions | Z1 = For-profit status Z2 = Chain | 3            |
| 2   | Anderson     | 2003 | USA     | NH (487, 1996)                  | VRS, ITE            | DEA (1 stage)       | I1 = Residential costs I2 = Overhead expense I3 = Property expense I4 = Other cost I5 = Total operating cost I6 = Ancillary services cost | O1 = Total bed days O2 = Maximum bed days available O3 = Utilisation rate (O1/O2) | 11           |
| 3   | Bjorkgren    | 2001 | Finland | LTC unit (64, 1995)             | CRS, ITE            | DEA (production function, multiple regression, 2 stages) | I1 = FTE RNs I2 = FTE LPNs I3 = FTE aids I4 = Beds | O1 = Case-mix adjusted resident days | 2            |
| 4   | Bjorkgren    | 2004 | Finland | LTC unit                       | VRS, ITE            | DEA (production function, 1 stage) | I1 = FTE RNs I2 = FTE LPNs I3 = FTE aids I4 = Beds | O1 = Case-mix resident days | 3            |
| 5   | Chang        | 2013 | Taiwan  | NH (22; 2004-09)               | CRS & VRS, ITE      | DEA (truncated distribution, Tobit, 2 stages) | I1 = Number of employees I2 = Floor area (m2) I3 = Beds | O1 = Residents O2 [QOC] = Falls O3 [QOC] = Emergencies | Z1 = Licensed nurses Z2 = Occupancy rate Z3 = Government-expense NH Z4 = Self-expense NH Z5-9 = Year 2004-8 | 2            |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|--------------------|------------------|-----------|-----------|-------------------|--------------|
| 6   | Chattopadhyay [16] | 1996 | USA | NH (140; 1982-83) | CRS & VRS, OTE | DEA (2 stages) | I1 = Dietary staff hours  
I2 = Housekeeping staff hours  
I3 = Laundry staff hours  
I4 = Nursing Director hours  
I5 = RN hours  
I6 = LPN hours  
I7 = Aides hours  
I8 = Non-labour expenses | O1 = Medicare resident days  
O2 = Medicaid resident days  
O3 = Private resident days  
O4 = Other resident days  
O6 = ADL index (not claimed as quality) | | 1 |
| 7   | Chen [17] | 2004 | USA | NH (4,635; 1994) | VRS, ITE | OLS (hybrid cost function, Tobit, 2-stages) | I1 = Wage  
I2 = Housekeeping staff hours  
I3 = Laundry staff hours  
I4 = Nursing Director hours  
I5 = RN hours  
I6 = LPN hours  
I7 = Aides hours  
I8 = Non-labour expenses | O1 = Medicare resident days  
O2 = Medicaid resident days  
O3 = Private resident days  
O4 = Other resident days  
O5 = FTEs contribute to QOL  
O6 = FTEs contribute to QOC  
O7-10 [QOL] = QOL in involving groups for residents/families  
O7-10 [QOC] = Restrains; Catherisation; Drug error; Deficiencies (%)  
Z1 = ADL index (not claimed as quality)  
Z2-3 = Profit; Non-profit  
Z4-5 = Hospital based; Chain affiliation  
Z6 = HHI  
Z7-8 = Metropolitan; Urban  
Z9-16 = 8 geographic area dummies  
Z17-19 = 3 dichotomous variables to indicate the measures of state Medicaid payment policy | | 1 |
| No. | First author | Year | Country     | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|-------------|----------------------------------|---------------------|-------------------|------------|-------------|---------------------|--------------|
| 8   | Crivelli [18]| 2002 | Switzerland | NH (886; 1998)                   | VRS, ITE            | SFA (cost function, translog) | I1 = Price of labour  
I2 = Price of capital | O1 = Total resident days | Z1 [QOC] = Average assistance time  
Z2 = Average reimbursement  
Z3 = Care persons/ resident ratio (not claimed as quality)  
Z4 = No. of services provided  
Z5 = Apartment NH  
Z6 = Cantonal dummy variables  
Comparative variables:  
Z7-9 = Public; Private non-profit; Private for profit  
Z10-14 = 5 types of regulatory settings | 1 |
| 9   | DeLellis [19]| 2013 | USA         | NH (1,430; 2008)                 | VRS, ITE            | DEA (linear programming modelling; 2 stages) | I1 = FTE RNs  
I2 = FTE LPNs  
I3 = FTE aids  
I4 = FTE others  
I5 = Beds | O1 = No. Medicare residents  
O2 = No. Medicaid residents  
O3 = No. Other residents | Comparative variables:  
Z1-2 = Urban-Rural  
Z3-4 = Chain-No chain  
Z5-6 = Income <, > $34,000  
Z7-8 = For-Not for profit  
Z9-10 = HHI < and > average  
Z11-12 = No. agencies in the county (z, < 15)  
Comparative variables [QOC]: Residents with Z13 = Catheter | 1 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|--------------------|------------------|------------|-------------|---------------------|--------------|
| 10  | Dervaux [20] | 2006 | France  | NH (100; N/A)                    | CRS & VRS, orientation N/A | DEA (indirect output distance function, cost indirect revenue function) | I1 = FTE auxiliary personnel I2 = Beds I3 = Capital price I4 = Labour price I5 = Price for other charges (per day) | O1-6 = Case-mix resident days, by classification 1-6 (ADL & resource needs) | 3            |

Z14-15 = Restrain: Total & Excluding physician order
Z16-17 = Pneumococcal and Influenzas vaccinations
Z18 = On pain management
Z19 = Pressure sores
Z20 = Bedfast
Z21 = Depression
Z22-23 = Incontinent of bladder-bowel
Z24 = Weight change Facility:
Z25-26 = Acuity - ADL index
Z27 = Average No. ADL limitations
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|---------------------|-------------------|------------|------------|-------------------|--------------|
| 11  | Di Giorgio   | 2015 | Switzerland | NH (45; 2001-05) | VRS, ITE | SFA (cost function, True random effect models with and without Mundlak correction) | I1 = Price of labour  
I2 = Price of capital  
I3 = Price of material | O1 = Total resident days | Z1 [QOC] = ADL index  
Z2 [QOC] = Nursing staff ratio (Ratio of No. of employed / guideline (optimal) nurses)  
Z3-6 = Year 2002-05  
Z7 = Institutional forms | 4 |
| 12  | Dormont      | 2012 | France   | NH (1,171; 2007 - 740; 2003 & 2007) | VRS, ITE | SFA (translog cost function, maximum likelihood estimation, normal truncated, quantile, random effects, correlate random effects regressions, 2 stages) | I1 = Wages of nurses  
I2 = Wage of nursing auxiliaries  
I3 = Wage of non-nursing staff | O1 = Total resident days | Z1 = Ownership  
Z2 = Urbanisation level  
Z3 = No. years since last construction/renovation  
Z4-9 = % residents in GIR groups 1-6 (ADL & resource needs)  
Z10 = Receive Alzheimer residents  
Z11 = Have reimbursement choice  
Z12 = Have pharmacy  
Z13 = Institutional form  
Z14 = % social allowance  
Z15 = GDP per capita  
Z16 [QOC] = Staff/Residents ratio  
Z17 [QOC] = Non-nursing staff/ Nursing staff ratio | 10 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|---------------------|-------------------|------------|-------------|-------------------|--------------|
| 13  | Duffy [23]   | 2006 | USA     | LTC (69; N/A)                   | CRS, ITE            | DEA (1 stage)     | I1 = RN FTE / Resident days  
I2 = LVN FTE / Resident days  
I3 = Other FTE / Resident days  
I4 = Dietary expense  
I5 = Administrative expense  
I6-7 = Professional and other staff salaries per resident day  
I8 [QOC] = % non-ambulatory residents  
I9 [QOC] = % not self-feeding | O1 = Total resident days  
O2 [QOC] = % NO pressure ulcers |
| 14  | Dulai [24]   | 2016 | USA     | NH (761; 2009-919; 2012)        | VRS, ITE            | SFA (hybrid translog cost function, truncated, 1 stage)  
I1 = Price of RNs  
I2 = Price of LPNs  
I3 = Price of aids  
I4 = Price of management | O1 = Total resident days  
O2 = Discharges  
O3 = Case-mix (minutes)  
O4 [QOC] = Star rating for quality measures  
O5 [QOC] = Star rating from the health inspection | Z1 [QOC]= Average score of staffing ratings  
Z2 = % Medicare residents  
Z3 = % Medicaid residents  
Z4 = For-profit status  
Z5 = Chain  
Z6 = Time trend |
| 15  | Dulai [25]   | 2017 | USA     | NH (338; 2009-2013)             | VRS, ITE            | DEA (Tobit, bootstrap, 2 stages, )  
I1 = FTE RNs  
I2 = FTE LPNs  
I3 = FTE aids  
I4 = FTE management  
I5 = Beds | O1 = Total resident days  
O2 = Discharges  
O3 = Casemix (minutes)  
O4 [QOC] = Average score of quality measures ratings | Z1 [QOC]= Average score of staffing ratings  
Z2 = % Medicare residents  
Z3 = % Medicaid residents  
Z4 = For-profit status |
| No. | First author | Year | Country type, sample size, year | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|--------------------------------|---------------------------------|-------------------|------------------|-----------|------------|-------------------|--------------|
| 16  | Farsi [26]   | 2004 | Switzerland NH (36; 1993-2001) | VRS, ITE                        | SFA (cost function, translog, random effects, 2 stages) | I1 = Price of labour  
I2 = Price of capital  
O5 [QOC] = Average score of health inspection ratings | Z5 = Chain  
Z6 = Time trend |
| 17  | Farsi [27]   | 2005 | Switzerland Non-profit NH (36; 1993-2001) | VRS, ITE                        | SFA (cost function, translog, fixed effects, random effects (GLS) with and without Mundlak formulation, pooled frontier, true random effects with and without Mundlak formulation) | I1 = Price of labour  
I2 = Price of capital  
O1 = Total resident days | Z1 [QOC] = ADL index  
Z2 [QOC] = Nursing staff ratio (Ratio of No. of employed / guideline (optimal) nurses)  
Z3 = Linear time trend |

2  
6
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|---------------------|-------------------|------------|-------------|---------------------|--------------|
| 18  | Farsi [28]   | 2008 | Switzerland | NH (356; 1998-2002) | VRS, ITE | SFA (cost function, pooled frontier model, random effect model using GLS method, true random effect model) | I1 = Price of labour  
I2 = Price of capital | O1 = Total resident days | Z1 [QOC] = Average assistance time  
Z2 = Average reimbursement  
Z3 = Apartment NH  
Z4 [QOC] = Care persons/ resident ratio (Dummy: >0.424: High quality facility)  
Z5 = Linear time trend | 3 |
| 19  | Filippini [29] | 2001 | Switzerland | Non-profit NH (36; 1993-95) | VRS, ITE | Translog cost function | I1 = Price of labour  
I2 = Price of capital | O1 = Total resident days | Z1 [QOC] = ADL index  
Z2 [QOC] = Nursing staff ratio (Ratio of No. of employed / guideline (optimal) nurses)  
Z3 = Apartment NH  
Z4 = Time variable | 1 |
| 20  | Fried [30]   | 1998 | USA | Nursing facilities (496; 1988) | CRS & VRS, ITE | DEA (cost approach, 2 stages) | I1 = Total expenses (payroll and not payroll) | O1 = Total resident days  
O2 [QOC] = % non-medicaid resident days | Z1 = Ownership  
Z2 = Beds  
Z3 = % lower severity | 1 |
| 21  | Garavaglia [31] | 2011 | Italy | NH (40; 2005-07) | CRS, ITE | DEA (homogenous bootstrap, 2 stages, Tobit regression, Kruskull-Wallis test for hypothesis) | I1 = Health and nursing costs  
I2 = Residential costs | O1 = Case-mix  
O2 [QOC] = Extra nursing hours  
O3 [QOC] = Residential charges | Z1 = Ownership  
Z2 = Beds  
Z3 = % lower severity | 1 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|--------------------------------|---------------------|-------------------|------------|-------------|-------------------|--------------|
| 22  | Hsu [32]     | 2015 | Canada  | LTC (627; 1996-2011)            | VRS, orientation N/A| Translog production function SFA; production function SFA, quantile regression; fixed effects model; GLE model | I1-5 = Hours of RNs, RPNs, therapists, aides, general staff hours  
I6 = Care expense  
I7 = Operational expense  
I8 = Drug and medical equipment expense | O1 = Adjusted resident days |  | 4 |
| 23  | Knox [33]    | 1999 | USA     | NH (921; 1994)                  | DRS, profit orientation | Cobb-Douglas profit function, OLS, least trimmed squares | I1 = Price of labour (average LVN and Aid hourly wage)  
I2 = Floor area  
I3 = Occupancy rate | Profit function:  
O2 = ADL index (as output price variable) |  | 1 |
| 24  | Knox [34]    | 2003 | USA     | NH (1,017; 1994 - 983; 1998)    | VRS, ITE, profit orientation | Modified reduced-form, translog cost- and profit-function regression techniques (both OLS and robust distance L one norm RDL1), 3 steps | I1 = Price of labour (average LVN and Aid hourly wage)  
I2 = Floor area  
I3 = Beds | Cost function:  
O1 = Total resident days  
Profit function:  
O2 = ADL index (as output price variable) |  | 6 |
| No. | First author | Year | Country   | Facility type, sample size, year | Efficiency measures    | Estimation Methods                                                                 | Inputs (I)                                                                                       | Outputs (O)                                     | Other variables (Z)                                                                 | No. of models |
|-----|--------------|------|-----------|----------------------------------|------------------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------------------------|---------------|
| 25  | Knox [35]    | 2007 | USA       | NH (1,017; 1999-2002)            | CRS, orientation N/A   | SFA (production function Cobb-Douglas, half normal maximum likelihood estimator, quantile regression) | I1 = Beds                                                                                      | O1 = Total resident days                        | Z1 = For-profit status Z2 = Year 1999                                           | 1             |
|     |              |      |           |                                  |                        | modified reduced-form, translog cost-and profit-function regression techniques (both OLS and robust distance L one norm), 3 steps | I2 = FTE hours of RNs, LVNs, Aids, other care staff, food staff                               |                                                                                               |                                                 |                                                                                  |
| 26  | Knox [36]    | 2006 | USA       | Non-profit NH (143; 1994 - 138; 1998 - 161; 1999) | VRS, ITE, profit orientation | modified reduced-form, translog cost-and profit-function regression techniques (both OLS and robust distance L one norm), 3 steps | I1 = Price of labour (average LVN and Aid hourly wage) I2 = Beds | Cost function: O1 = Total resident days Profit function: O2 = ADL index (as output price variable) | Z1 = Urban Z2 = Ownership Z3 = Chain Z4 = Religious Z5 = Occupancy rate Z6 = ADL index Z7-Z9 = Year 1998, 1999Z9? [QOC, not claimed QOL] = Quality rating (Dependent variable) | 3             |
|     |              |      |           |                                  |                        |                                                                                   |                                                                                               | Z1 = Occupancy rate Z2 = Facility type Z3 = Ward specification Z4 = Mean age Z5 [QOC] = Pressure sores Z6 [QOC] = % depression Z7 [QOC] = |                                                 |                                                                                  |
| 27  | Laine [37]   | 2005a| Finland   | LTC wards (122; 2001)            | CRS, ITE               | SFA (product function, truncated, 2 stages)                                        | I1 = Beds                                                                                      | O1 = Adjusted resident days                     |                                                                                  | 1             |
|     |              |      |           |                                  |                        |                                                                                   | I2-4 = FTE RNs; LPNs; aides                                                                    |                                                                                               |                                                 |                                                                                  |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|-------------------------------|--------------------|-------------------|------------|-------------|-------------------|--------------|
| 28  | Laine [38]   | 2005b| Finland | LTC ward (114; 2002)          | CRS, ITE           | DEA (Mann–Whitney test, 2 stages, correlation coefficients used to explore the association between quality and efficiency) | I1 = Beds I2-4 = FTE RNs; LPNs; aides | O1 = Adjusted resident days | Z1 [QOC] = % RNs Z2 [QOC] = % rooms with toilet Z3 [QOC] = % single rooms Z4-11 [QOC] = 7 ADL measures + % residents lack of training or range of motion Z12-14 [QOC] = % pressure sores (new, low, high risk) Z15-16 [QOC] = % catherisations (low, high risk) Z17-19 [QOC] = % restraints, bestfast, weight change Z20-21 [QOC] = % depression (with, without treatment) Z22-26 [QOC] = antipsychotic, anti-anxiety/hypnotic use Z27 [QOC] = % behavioural symptoms (total, low, high) Z28 [QOC] = % cognitive impairment | 1 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|--------------------|-------------------|------------|------------|---------------------|--------------|
| 29  | Laine [39]   | 2005c| Finland | LTC wards (113; 2001-2002)      | VRS, ITE           | SFA (cost function, translog, truncated, 2 stages) | I1 = Average wage rate | O1 = Adjusted resident days  
O2 [QOC] = % pressure sores  
O2 [QOC] = % depression without treatment | O1 = Residents | Z29 [QOC] = % >= 9 medications  
Z30-34 [QOC] = % bowel or bladder continence  
Z35 [QOC] = % UTI  
Z36-38 [QOC] = % injuries, falls, fractures | 1 |
| 30  | Lin [40]     | 2017 | Taiwan  | Senior care facilities (91; 2011) | CRS, ITE          | CCR, slacks-based measure, and epsilon-based measure DEA models, metafrontier efficiency analysis, least square regression, applied chain rules to regression; Production function, 2 stages | I1 = Nursing personnel  
I2 = Non-nursing personnel  
I3 = Floor area | O1 = Residents | Z1 = Facility type  
Z2 [QOC]= % restrains  
Z3 [QOC] = % depressants and hypnotic use | 3 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|--------------------|-------------------|------------|------------|-------------------|--------------|
| 31  | Min [41]     | 2016 | USA     | NH (2267; 2010)                 | CRS, ITE           | DEA (linear regression, 3-level modelling (NH, county, state), 2 stages) | I1 = FTE hours of RNs (per resident day)  
I2 = FTE hours of LPNs (per resident day)  
I3 = FTE hours of Aids (per resident day) | O1 [QOC] = % pain  
O2 [QOC] = % ADL decline  
O3 [QOC] = % pressure sores  
O4 [QOC] = % restraints  
O5 [QOC] = % UTI  
O6 [QOC] = % falls | Z1 = For-profit status  
Z2 = Chain  
Z3 = % Medicare residents  
Z4 = % Medicaid residents  
Z5 = Beds  
Z6 = Occupancy rate  
Z7 = Acuity index | 2 |
| 32  | Ni Nuasa [42] | 2016 | Ireland | NH (152; 2008-09)               | CRS & VRS, ITE     | DEA (bootstrap, 2 stages) | I1 = Medical personnel  
I2 = Non-medical personnel  
I3 = Beds | O1 = Total resident days | Z1 = Ownership  
Z2 = Location  
Z3 [QOC] = Qualification of nurse  
Z4-6 = Beds (0-49; 50-99; >=100)  
Z7 = Casemix (age) | 3 |
| 33  | Ozcan [43]   | 1998 | USA     | Skilled nursing facilities (324, 1990-91) | VRS, ITE           | DEA (Slack analysis, Post hoc logistic regression, 2 stages) | I1 = Beds  
I2 = FTEs  
I3 = Operational expenses | O1 = Medicare & Medicaid resident days  
O2 = Private resident days | Z1 = % Medicare residents  
Z2 = % Medicaid residents  
Z3 = Occupation rate  
Z4 = Region  
Z5 = % of population ≥ 84 years | 1 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|----------------------------------|--------------------|-------------------|------------|-------------|---------------------|--------------|
| 34  | Rosko [44]   | 1995 | USA     | NH (461; 1987)                   | CRS, profit orientation | DEA (X-efficiency theory, Tobit, 2 stages) | I1-5 = FTE RNs, LPNs, Aides, Rehab, Other | O1 = Skilled nursing facility days | O2 = Intermediate care facility days | Z1 = For-profit, Z2 = HHI, Z3 = County occupancy rate, Z4 = Per capita personal income, Z5 = Wage index, Z6 = % Medicare residents, Z7 = % Medicaid residents, Z8-9 = Beds, Beds squared, Z10 = Occupancy rate, Z11 = Resident case-mix index, Z12 = % residents > 85 years, Z13 = % Confused, Z14 = Independent living capacity, Z15 = Discharge rate, Z16-18 [QOC] = % pressure sores, restraint, catheter | 1 |
| 35  | Shimshak [45] | 2007 | USA     | NH (38; 2003)                   | VRS, ITE            | DEA (1 stage)     | I1 = FTEs                | O1 = Residents | O2-6 = Case-mix severity (assistance with bathing, dressing, transferring, toileting, and eating), O7-9 [QOC] = Residents without pressure sores, | 2 |


| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|---------------------|-------------------|------------|-------------|-------------------|--------------|
| 36  | Shimshak [46]| 2009 | USA     | NH (38; 2003)                   | CRS, ITE            | DEA (1 stage)     | I1-6 = FTE RNs, LPNs, Aides, ancillary non-nursing professional staff, ancillary non-nursing nonprofessional staff, and administrative staff | O1 = Residents O2-6 = Case-mix severity (assistance with bathing, dressing, transferring, toileting, and eating) O7-9 [QOC] = Residents without pressure sores, restraints, and catheterisations | Z1 = Ownership Z2 = Municipal supervision Z3 = Beds Z4 = Occupancy rate Z5 = Facility type Z6 = HHI | 7 |
| 37  | Shimshak [47]| 2010 | USA     | NH (91; 2003)                   | CRS, ITE            | DEA (1 stage)     | I1-6 = FTE RNs, LPNs, Aides, ancillary non-nursing professional staff, ancillary non-nursing nonprofessional staff, and administrative staff | O1 = Residents O2-6 = Case-mix severity (assistance with bathing, dressing, transferring, toileting, and eating) O7-9 [QOC] = Residents without pressure sores, restraints, and catheterisations | Z1 = Ownership Z2 = Municipal supervision Z3 = Beds Z4 = Occupancy rate Z5 = Facility type Z6 = HHI | 4 |
| 38  | Wang [48]   | 2005 | Taiwan  | LTC (53; 1995)                  | CRS & VRS, ITE      | DEA (OLS, 2 stages) | I1 = Beds I2-5 = No. of doctors, physical therapists, pharmacists, dietitians I6 = Non-medical staff I7 = Nursing staff | O1 = Residents O2 [QOC] = Administrative service performance O3 [QOC] = Life care performance O4 [QOC] = Health care performance O5 [QOC] = Accident rate | Z1 = Ownership Z2 = Municipal supervision Z3 = Beds Z4 = Occupancy rate Z5 = Facility type Z6 = HHI | 8 |
| No. | First author | Year | Country | Facility type, sample size, year | Efficiency measures | Estimation Methods | Inputs (I) | Outputs (O) | Other variables (Z) | No. of models |
|-----|--------------|------|---------|---------------------------------|--------------------|--------------------|------------|-------------|---------------------|---------------|
| 39  | Zhang [49]   | 2008 | USA     | NH (8,361; 1997-2003)           | DEA (bootstrap, truncated, 2 stages) | DEA                | I1 = General service expense | O1-3 = Resident days (Skilled nursing, intermediate nursing and other long-term care) | Z1 = Ownership  
Z2 = Profit status  
Z3 = Chain  
Z4-5 = % Medicare, Medicaid residents  
Z6 = Beds  
Z7 = Occupancy rate  
Z8 = RN/total nursing staff  
Z9 = RN hours/resident day  
Z10 = HHI  
Z11 = Medicaid reimbursement  
Z12-14 = Medicare police changes | 3 |

ADL = Activity of daily living; CCR = Charnes, Cooper, and Rhodes DEA model; CRS = constant returns to scale; DEA = data envelopment analysis; DRS = decreasing returns to scale; FTE = full-time equivalent; GLS = generalised least squares; GDP = gross domestic product; HHI = Herfindahl-Hirschman Index; ITE = input-oriented technical efficacy; LTC = long-term care; LPN = licensed practical nurse; LVN = licensed vocational nurse; N/A = not available; NH = nursing home; No. = number of; OLS = ordinary least squares; OTE = output-oriented technical efficacy; QOC = quality of care; QOL = Quality of life; RN = registered nurse; RTS = returns to scale; SFA = stochastic frontier analysis; UTI = urinary tract infection; VRS = variable returns to scale.
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