

ELECTRONIC SUPPLEMENTARY MATERIAL

Geographical disparities in adult intensive care beds in the English National Health Service – A retrospective, observational panel data study

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A. DEFINITIONS

Definitions of levels of ICU Care

The Department of Health (UK) defines the levels of care as below [1]:

- Level 2—High dependency unit (HDU). Patients needing single organ support (excluding mechanical ventilation) such as renal haemofiltration or inotropes and invasive BP monitoring.
- Level 3—Intensive care unit (ICU). Patients requiring two or more organ support (or needing mechanical ventilation alone).

B. MAPPING PROCESS OF DATA SOURCES

The data sources were mapped to the seven NHSE regions as below:

For ICU beds

The 2021 regional boundaries were used as a reference. For each of the previous nine years, the data at hospital or area level was mapped to the 2021 boundaries. When data was divided into fewer regions (2016-2018), these were mapped onto the 2021 boundaries and hospital data moved appropriately.

For population estimates

To move from nine regions to seven regions, population estimates from North East, Yorkshire and the Humber were combined together and data for East and West Midlands was combined together.

C. STATISTICAL METHODS

The fixed effect regression model can be expressed as the following [2]:

$$y_{it} = \alpha_i + \beta x_{it} + \delta_t + u_i + e_{it}$$

$i=7; t = 2012-2021$

where:

y_{it} = outcome variable i.e. ICU bed supply for region, i , at time, t

α_i = region specific intercept

x_{it} = independent variable i.e. estimated population in region, i , at time, t .

β = regression coefficient

δ_t = time fixed effects, apply to all regions, in a specific year

u_i = regional fixed effects, but constant across time (unobserved component)

e_{it} = overall error term

A fixed effects panel model is a type of regression model designed to analyze data that follows the same region over time. Panel data, also known as longitudinal data, includes observations for multiple regions tracked over several time periods.

Controlling for Unobserved Heterogeneity:

In our analyses, there are factors specific to each region that don't change over time—such as geographic, demographic features or regional preferences—that can influence the supply of ICU beds. A fixed effects model controls for these unobserved, time-invariant factors by allowing each region to have its own intercept. Essentially, it "differences out" these constant characteristics so that the estimated effects of the population size are not biased by them.

Within-region Variation:

The model relies on variation within each region over time rather than differences between regions.

D. FIGURES

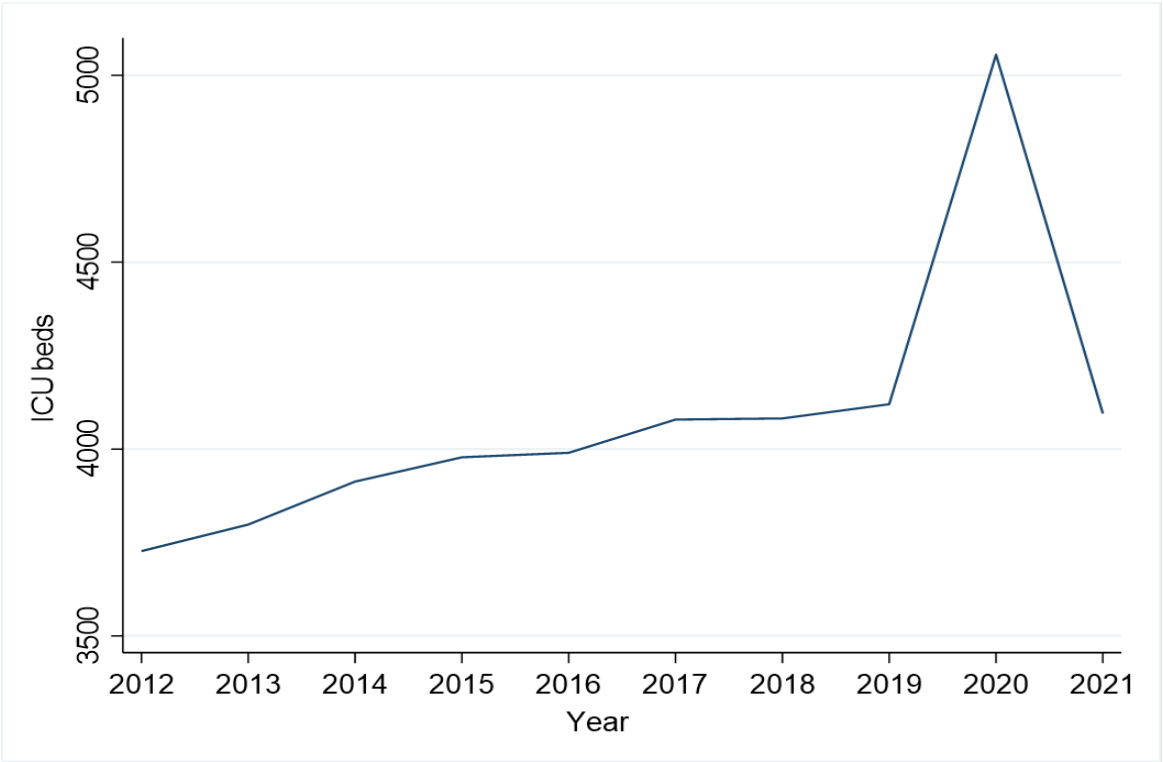


Figure S1: ICU beds trends

The ICU bed spike in 2020 is due to the Covid-19 pandemic which resulted in general and acute beds being converted to ICU beds.

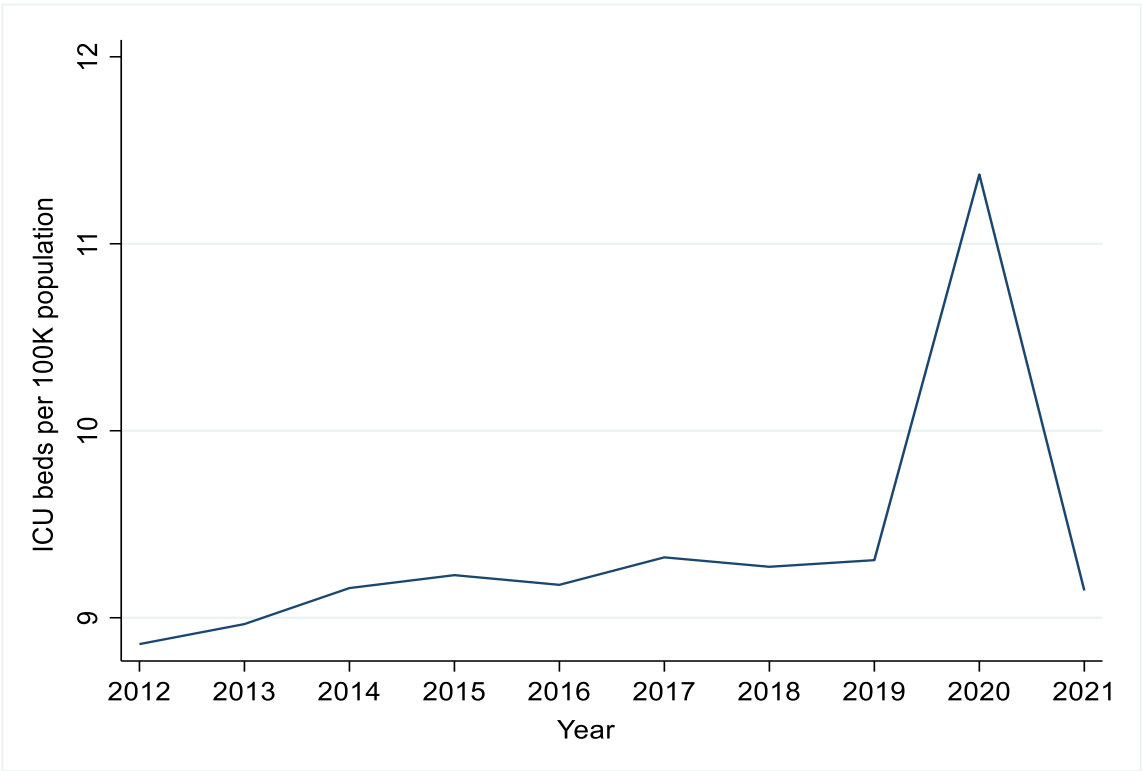


Figure S2: Trends in ICU beds per 100k population

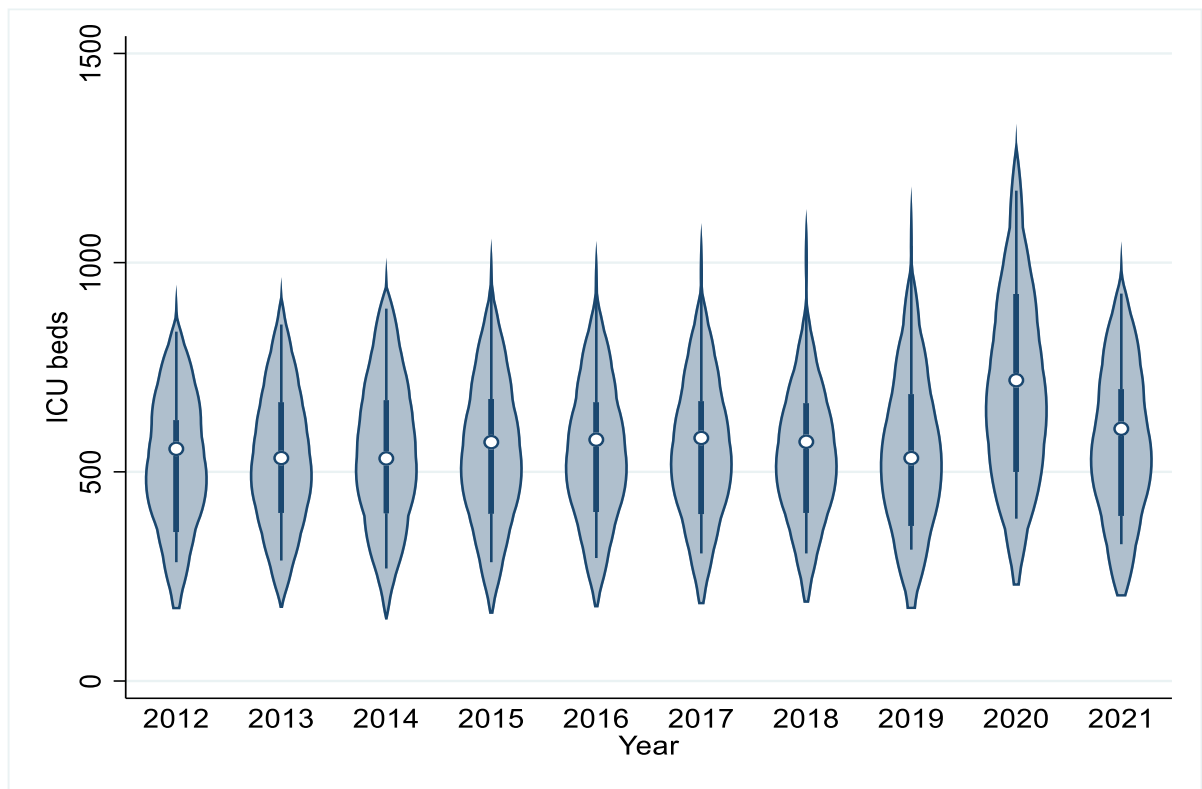


Figure S3: *Violin plots of ICU beds by year

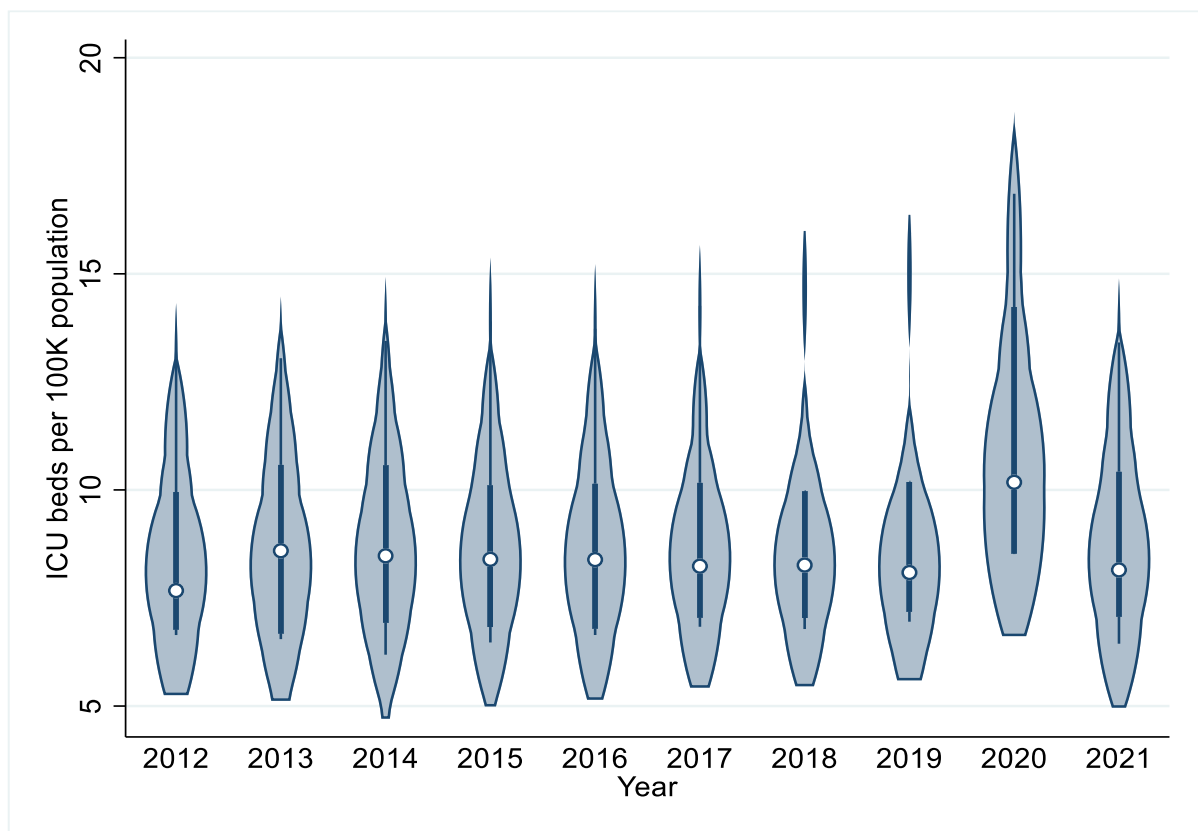


Figure S4: *Violin plots of ICU beds per 100k population by year

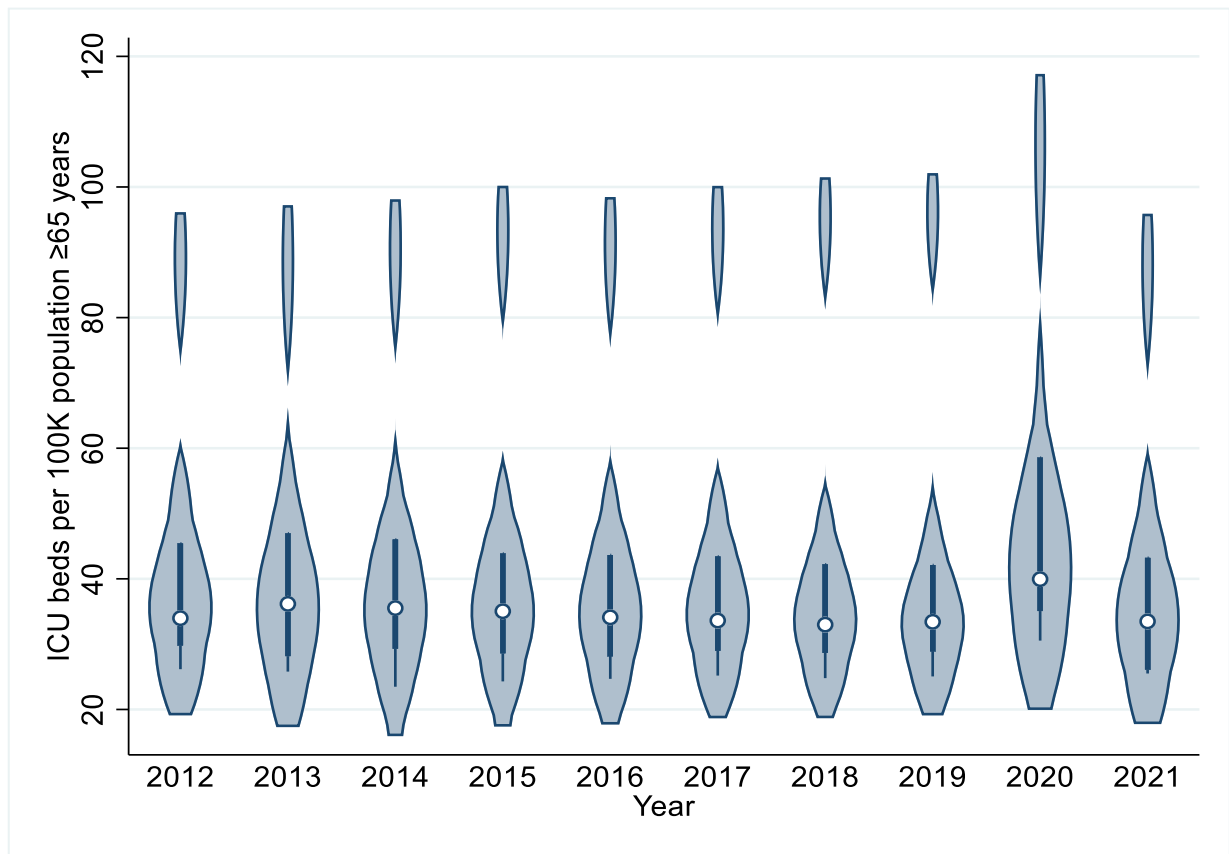


Figure S5: *Violin plots of ICU beds per 100k population aged 65 years and over by year

*Violin plots: Open circle indicates median, thick vertical line indicates first and third interquartile range, thin vertical line is the range. The wideness shows the distribution density of the data.

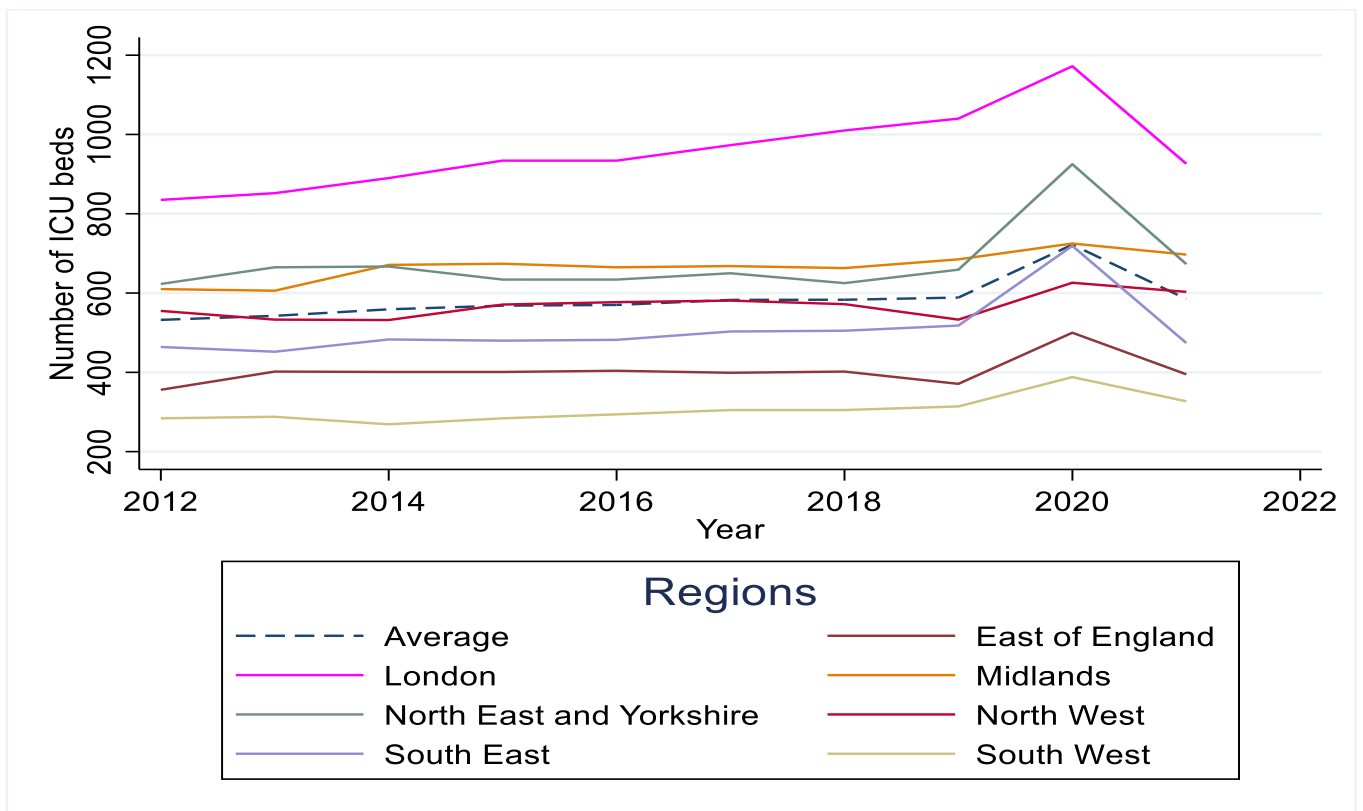


Figure S6: Trends in the number of ICU beds between regions (*Average is the mean)

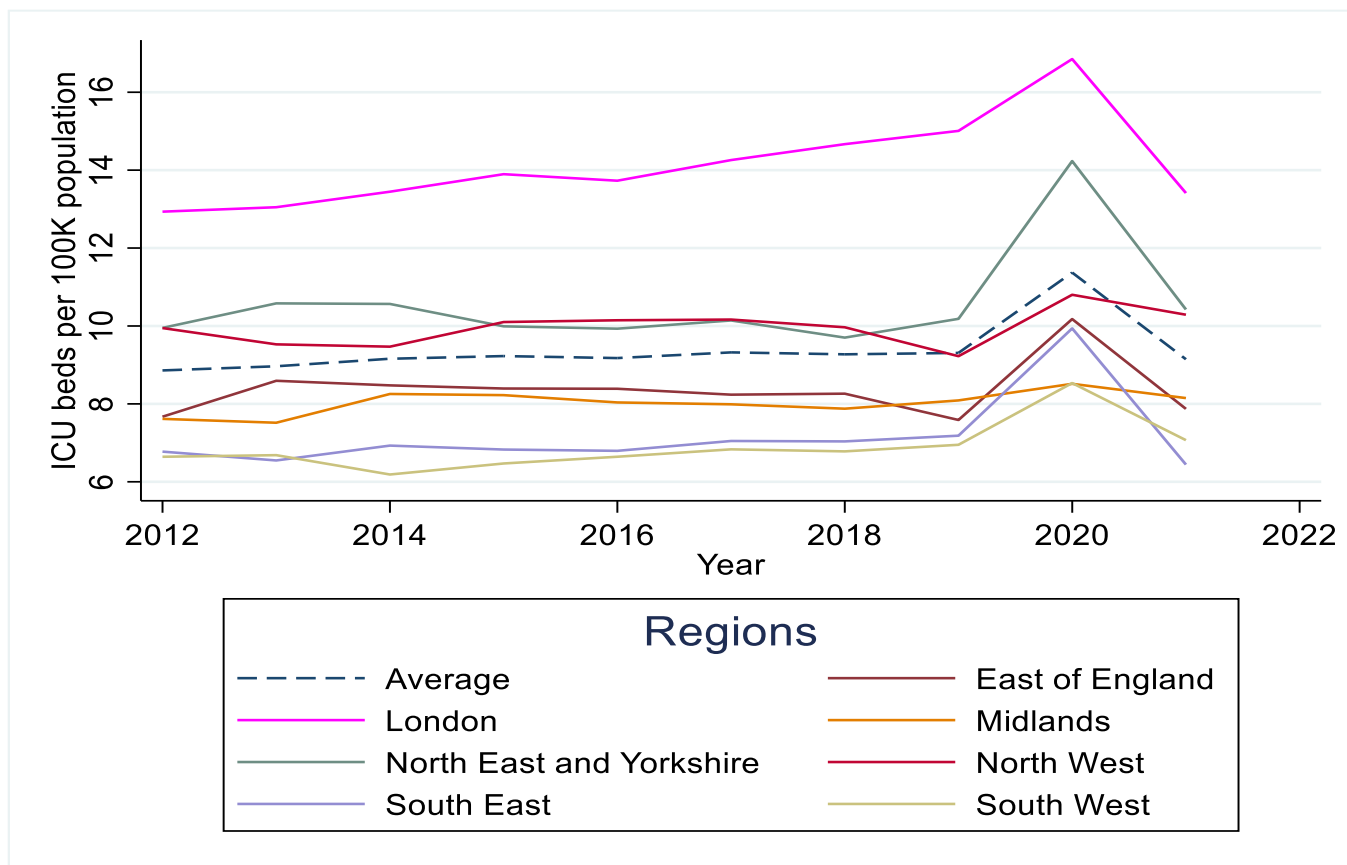


Figure S7: Trends in ICU beds per 100k population between regions (*Average is the mean)

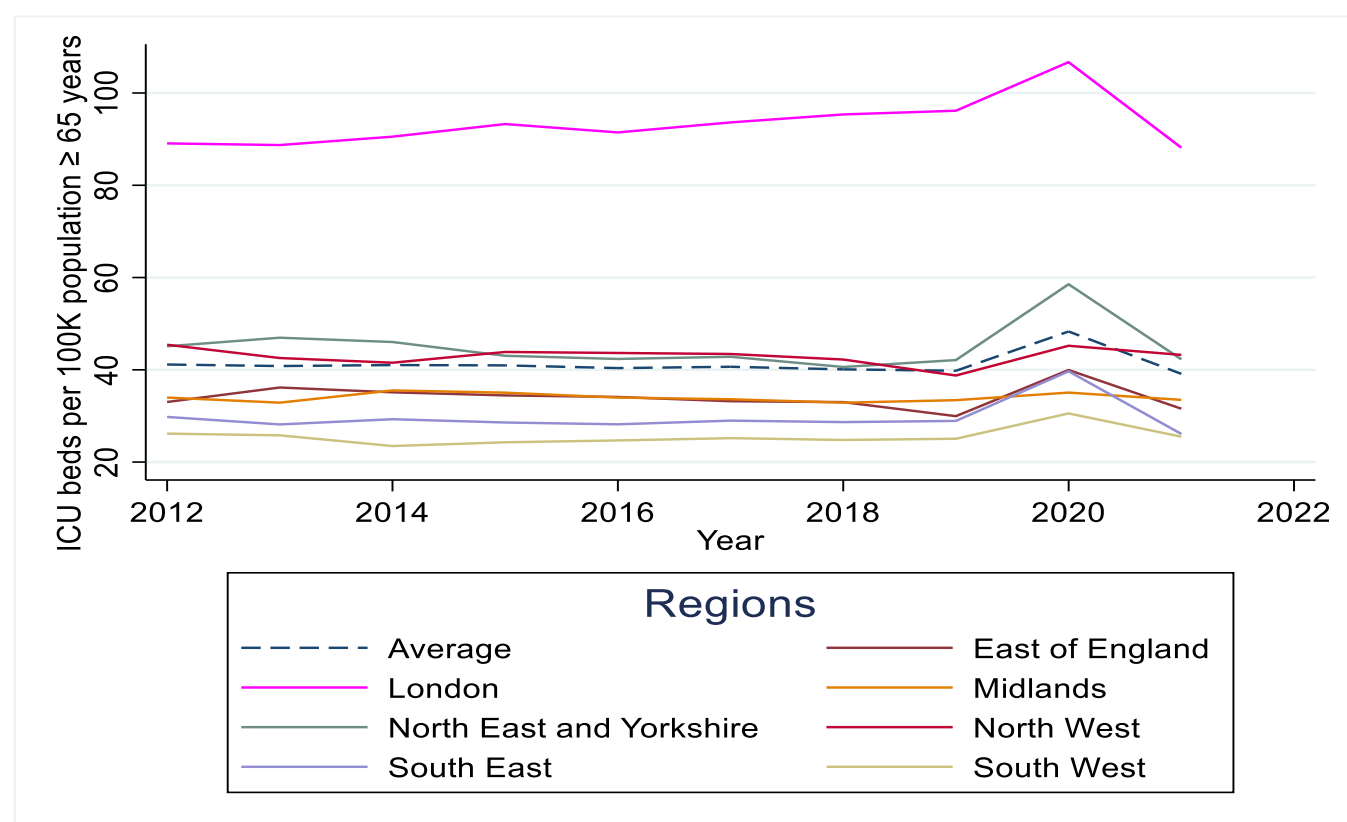


Figure S8: Trends in ICU beds per 100k population aged 65 years and over between regions (*Average is the mean)

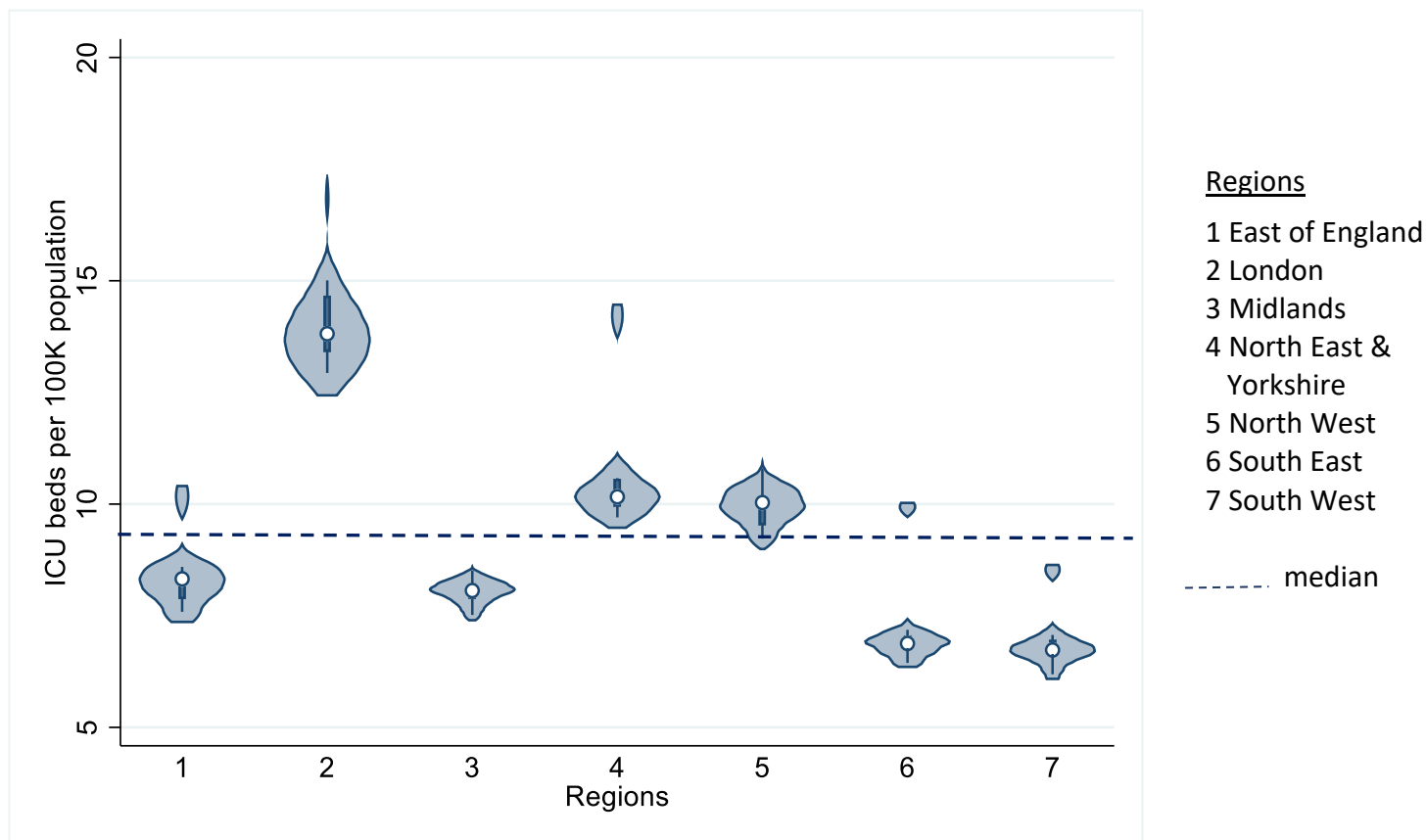


Figure S9: *Violin plots of ICU beds per 100k population by region

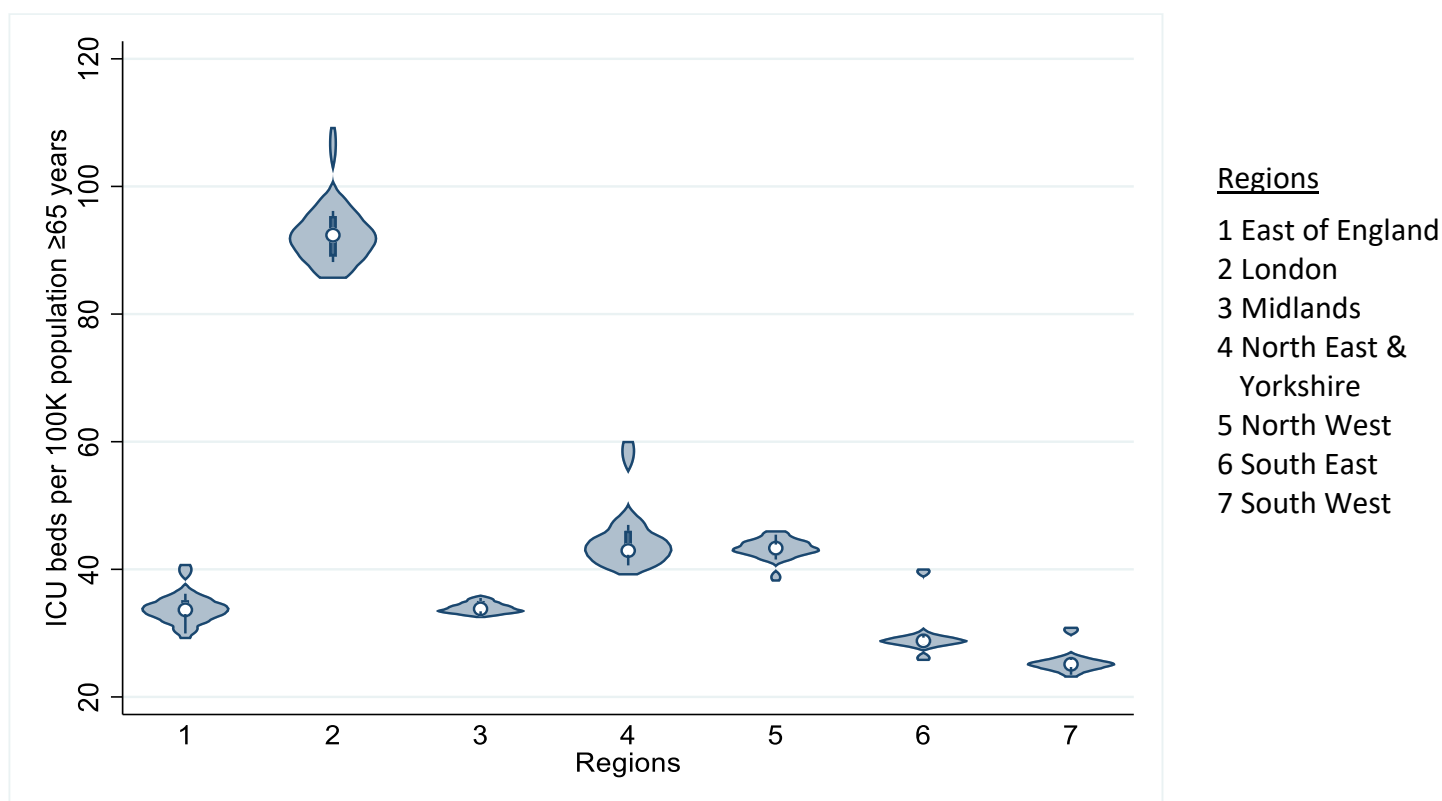


Figure 10: *Violin plots of ICU beds per 100k population aged 65 years and over, by region

*Violin plots: Open circle indicates median, thick vertical line indicates first and third interquartile range, thin vertical line is the range. The wideness shows the distribution density of the data

E. TABLES

Table S1 – Summary statistics of ICU beds in England

Year	Min	25th percentile	Median	75th percentile	Max
2012	284	356	555	623	835
2013	288	402	533	665	852
2014	269	401	532	671	890
2015	284	401	571	674	934
2016	294	404	577	665	934
2017	305	399	581	668	973
2018	305	402	572	663	1010
2019	314	371	533	685	1040
2020	388	500	719	925	1172
2021	327	395	603	697	926

Table S2 – Summary statistics for ICU beds per 100k population (A) and per 100k population aged 65 years and over (B) by year

(A)

Year	Minimum	25th percentile	Median	75th percentile	Maximum
2012	7	7	8	10	13
2013	7	7	9	11	13
2014	6	7	8	11	13
2015	6	7	8	10	14
2016	7	7	8	10	14
2017	7	7	8	10	14
2018	7	7	8	10	15
2019	7	7	8	10	15
2020	9	9	10	14	17
2021	6	7	8	10	13

(B)

Year	Min	25th percentile	Median	75th percentile	Max
2012	26	30	34	45	89
2013	26	28	36	47	89
2014	23	29	36	46	91
2015	24	29	35	44	93

2016	25	28	34	44	91
2017	25	29	34	43	94
2018	25	29	33	42	95
2019	25	29	33	42	96
2020	31	35	40	59	107
2021	26	26	33	43	88

Table S3: The characteristics of bed supply and population groups by regions, between 2012-2021

Region: East of England

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	10,474	12,302	11,962	12,162	12,264	12,312	12,515	10,983	10,420	10,662
ICU beds	356	402	401	401	404	399	402	371	500	395
ICU beds proportion	0.034	0.033	0.034	0.033	0.033	0.032	0.032	0.034	0.048	0.037
Population ≥18 years (all)	4,640,746	4,678,428	4,730,846	4,776,467	4,816,165	4,843,991	4,865,339	4,889,615	4,912,789	5,017,676
Population ≥65 years	1,078,070	1,111,502	1,141,694	1,163,868	1,184,408	1,202,161	1,218,475	1,238,506	1,251,262	1,251,082
Percentage of population ≥65 years	23.2%	23.8%	24.1%	24.4%	24.6%	24.8%	25.0%	25.3%	25.5%	24.9%
Hospital beds per 100k population										
Population ≥18 years (all)	225.7	263.0	252.9	254.6	254.6	254.2	257.2	224.6	212.1	212.5
Population ≥65 years	971.5	1106.8	1047.8	1044.9	1035.4	1024.2	1027.1	886.8	832.7	852.2
ICU beds per 100k population										
Population ≥18 years (all)	7.7	8.6	8.5	8.4	8.4	8.2	8.3	7.6	10.2	7.9
Population ≥65 years	33.0	36.2	35.1	34.5	34.1	33.2	33.0	30.0	40.0	31.6

k = thousand

Region: London

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	16,776	16,680	17,105	17,072	16,762	16,975	16,586	16,939	15,150	15,596
ICU beds	835	852	890	934	934	973	1,010	1,040	1,172	926
ICU beds proportion	0.050	0.051	0.052	0.055	0.056	0.057	0.061	0.061	0.077	0.059
Population ≥18 years (all)	6,455,442	6,529,758	6,618,717	6,720,843	6,803,159	6,823,642	6,886,060	6,929,562	6,954,893	6,904,131
Population ≥65 years	937,411	960,336	982,922	1,001,366	1,021,124	1,039,161	1,059,213	1,081,515	1,098,453	1,050,443
Percentage of population ≥65 years	14.5%	14.7%	14.9%	14.9%	15.0%	15.2%	15.4%	15.6%	15.8%	15.2%
Hospital beds per 100k population										
Population ≥18 years (all)	259.9	255.4	258.4	254.0	246.4	248.8	240.9	244.4	217.8	225.9
Population ≥65 years	1789.6	1736.9	1740.2	1704.9	1641.5	1633.5	1565.9	1566.2	1379.2	1484.7
ICU beds per 100k population										
Population ≥18 years (all)	12.9	13.0	13.4	13.9	13.7	14.3	14.7	15.0	16.9	13.4
Population ≥65 years	89.1	88.7	90.5	93.3	91.5	93.6	95.4	96.2	106.7	88.2

k = thousand

Region: Midlands

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	20,049	18,800	19,135	18,964	18,596	18,343	18,188	19,998	18,065	19,279
ICU beds	610	606	671	674	665	668	663	685	725	697
ICU beds proportion	0.030	0.032	0.035	0.036	0.036	0.036	0.036	0.034	0.040	0.036
Percentage of ICU beds occupied	83.61%	87.95%	85.25%	83.98%	83.46%	83.23%	80.39%	79.56%	54.90%	70.20%
Population ≥18 years (all)	8,009,425	8,061,208	8,127,969	8,194,617	8,273,726	8,360,725	8,416,219	8,467,513	8,513,287	8,552,371
Population ≥65 years	1,794,976	1,843,175	1,888,731	1,923,362	1,956,911	1,987,151	2,016,267	2,049,454	2,067,658	2,081,205
Percentage of population ≥65 years	22.4%	22.9%	23.2%	23.5%	23.7%	23.8%	24.0%	24.2%	24.3%	24.3%
Hospital beds per 100k population										
Population ≥18 years (all)	250.3	233.2	235.4	231.4	224.8	219.4	216.1	236.2	212.2	225.4
Population ≥65 years	1116.9	1020.0	1013.1	986.0	950.3	923.1	902.0	975.8	873.7	926.3
ICU beds per 100k population										
Population ≥18 years (all)	7.6	7.5	8.3	8.2	8.0	8.0	7.9	8.1	8.5	8.1
Population ≥65 years	34.0	32.9	35.5	35.0	34.0	33.6	32.9	33.4	35.1	33.5

k = thousand

Region: North East and Yorkshire

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	19,667	20,726	20,405	19,937	19,216	19,183	18,678	17,693	16,484	17,060
ICU beds	623	665	667	634	634	650	625	659	925	673
ICU beds proportion	0.032	0.032	0.033	0.032	0.033	0.034	0.033	0.037	0.056	0.039
Population ≥18 years (all)	6,261,133	6,285,478	6,312,769	6,345,137	6,384,389	6,408,965	6,442,459	6,470,910	6,499,112	6,456,771
Population ≥65 years	1,381,312	1,416,034	1,449,037	1,472,938	1,497,058	1,517,590	1,538,708	1,564,785	1,579,945	1,591,893
Percentage of population ≥65 years	22.1%	22.5%	23.0%	23.2%	23.5%	23.7%	23.9%	24.1%	24.3%	24.7%
Hospital beds per 100k population										
Population ≥18 years (all)	314.1	329.7	323.2	314.2	301.0	299.3	289.9	273.4	253.6	264.2
Population ≥65 years	1423.8	1463.6	1408.2	1353.5	1283.6	1264.0	1213.9	1130.7	1043.3	1071.7
ICU beds per 100k population										
Population ≥18 years (all)	10.0	10.6	10.6	10.0	9.9	10.1	9.7	10.2	14.2	10.4
Population ≥65 years	45.1	47.0	46.0	43.0	42.3	42.8	40.6	42.1	58.5	42.3

k = thousand

Region: North West

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	16,650	15,406	15,131	15,045	15,224	15,011	14,988	15,511	14,340	14,995
ICU beds	555	533	532	571	577	581	572	533	626	603
ICU beds proportion	0.033	0.035	0.035	0.038	0.038	0.039	0.038	0.034	0.044	0.040
Population ≥18 years (all)	5,579,593	5,593,740	5,618,117	5,652,470	5,686,931	5,715,351	5,738,946	5,777,736	5,795,875	5,860,330
Population ≥65 years	1,221,740	1,252,587	1,280,752	1,301,465	1,321,967	1,337,708	1,354,625	1,375,111	1,384,396	1,394,911
Percentage of population ≥65 years	21.9%	22.4%	22.8%	23.0%	23.3%	23.4%	23.6%	23.8%	23.9%	23.8%
Hospital beds per 100k population										
Population ≥18 years (all)	298.4	275.4	269.3	266.2	267.7	262.6	261.2	268.5	247.4	255.9
Population ≥65 years	1362.8	1230.0	1181.5	1156.0	1151.6	1122.2	1106.5	1128.0	1035.8	1075.0
ICU beds per 100k population										
Population ≥18 years (all)	9.9	9.5	9.5	10.1	10.1	10.2	10.0	9.2	10.8	10.3
Population ≥65 years	45.4	42.6	41.5	43.9	43.6	43.4	42.2	38.8	45.2	43.2

k = thousand

Region: South East

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	14,505	12,394	14,570	14,621	14,725	14,799	14,293	14,203	13,358	13,493
ICU beds	464	452	483	480	482	503	505	518	719	474
ICU beds proportion	0.032	0.036	0.033	0.033	0.033	0.034	0.035	0.036	0.054	0.035
Population ≥18 years (all)	6,848,582	6,902,592	6,969,602	7,029,838	7,093,104	7,136,960	7,176,124	7,210,838	7,234,655	7,357,795
Population ≥65 years	1,557,705	1,605,184	1,648,772	1,679,619	1,710,438	1,735,766	1,761,765	1,791,216	1,812,004	1,816,502
Percentage of population ≥65 years	22.7%	23.3%	23.7%	23.9%	24.1%	24.3%	24.6%	24.8%	25.1%	24.7%
Hospital beds per 100k population										
Population ≥18 years (all)	211.8	179.5	209.1	208.0	207.6	207.4	199.2	197.0	184.6	183.4
Population ≥65 years	931.2	772.1	883.7	870.5	860.9	852.6	811.3	792.9	737.2	742.8
ICU beds per 100k population										
Population ≥18 years (all)	6.8	6.5	6.9	6.8	6.8	7.0	7.0	7.2	9.9	6.4
Population ≥65 years	29.8	28.2	29.3	28.6	28.2	29.0	28.7	28.9	39.7	26.1

k = thousand

Region: South West

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hospital beds	10,495	12,345	10,343	10,274	10,452	10,353	10,232	10,358	9,799	10,105
ICU beds	284	288	269	284	294	305	305	314	388	327
ICU beds proportion	0.027	0.023	0.026	0.028	0.028	0.029	0.030	0.030	0.040	0.032
Population ≥18 years (all)	4,275,498	4,308,162	4,346,897	4,389,099	4,425,316	4,462,839	4,497,413	4,517,219	4,546,239	4,625,689
Population ≥65 years	1,085,294	1,116,361	1,145,800	1,168,954	1,190,935	1,210,974	1,230,200	1,253,129	1,270,301	1,282,117
Percentage of population ≥65 years	25.4%	25.9%	26.4%	26.6%	26.9%	27.1%	27.4%	27.7%	27.9%	27.7%
Hospital beds per 100k population										
Population ≥18 years (all)	245.5	286.6	237.9	234.1	236.2	232.0	227.5	229.3	215.5	218.5
Population ≥65 years	967.0	1105.8	902.7	878.9	877.6	854.9	831.7	826.6	771.4	788.2
ICU beds per 100k population										
Population ≥18 years (all)	6.6	6.7	6.2	6.5	6.6	6.8	6.8	7.0	8.5	7.1
Population ≥65 years	26.2	25.8	23.5	24.3	24.7	25.2	24.8	25.1	30.5	25.5

k = thousand

Table S4 – Summary statistics for ICU beds per 100k population (A) and per 100k population aged 65 years and over (B) by region

(A)

Region	Minimum	25th percentile	Median	75th percentile	Maximum
East of England	8	8	8	8	10
London	13	13	14	15	17
Midlands	8	8	8	8	9
North East and Yorkshire	10	10	10	11	14
North West	9	10	10	10	11
South East	6	7	7	7	10
South West	6	7	7	7	9

(B)

Region	Minimum	25th percentile	Median	75th percentile	Maximum
East of England	30	33	34	35	40
London	88	89	92	95	107
Midlands	33	33	34	35	36
North East and Yorkshire	41	42	43	46	59
North West	39	42	43	44	45
South East	26	28	29	29	40
South West	23	25	25	26	31

F. REFERENCES

- [1] Department of Health. Comprehensive critical care: a review of adult critical care services. London : 2000.
- [2] Bell A, Fairbrother M, Jones K. Fixed and random effects models: making an informed choice. Qual Quant 2019;53:1051–74. <https://doi.org/10.1007/s11135-018-0802-x>.