Online Appendix

Appendix A. Illustrations of long-term care robot types in Japan

Transfer aid robot, wearable (Cyberdyne)

Prof. Sankai, University of Tsukuba / CYBERDYNE Inc.

Transfer aid robot, not wearable (Robear)

Grin and bear it: the Robear robot can lift elderly people or hospital patients off their bed into a wheelchair

Monitoring robot (silhouette monitoring censor, by Kingsecurity)

Communication robot (PALRO)

Communication robot (PARO)

Appendix B. *Kaigo* Neediness Index

Level 1

1. Requires some form of help in taking care of the surroundings (such as cleaning).
2. Requires some form of assistance for complex movements such as standing up.
3. Requires some form of support for walking and remaining in a standing position.
4. Mostly able to eat and use the bathroom independently.
5. Exhibits problematic behavior or decline in understanding.

Level 2

1. Requires some form of help for all tasks to take care of the surroundings.
2. Requires some form of assistance for complex movements such as standing up.
3. Requires some form of support for walking and remaining in a standing position.
4. Requires some form of support for eating and using the bathroom.
5. Exhibits problematic behavior or decline in understanding.

Level 3

1. Unable to take care of the surroundings on one's own.
2. Unable to do complex movements such as standing up.
3. At times unable to walk or remain in a standing position.
4. Unable to use the bathroom independently.
5. Exhibits several instances of problematic behavior and all-round decline in understanding.

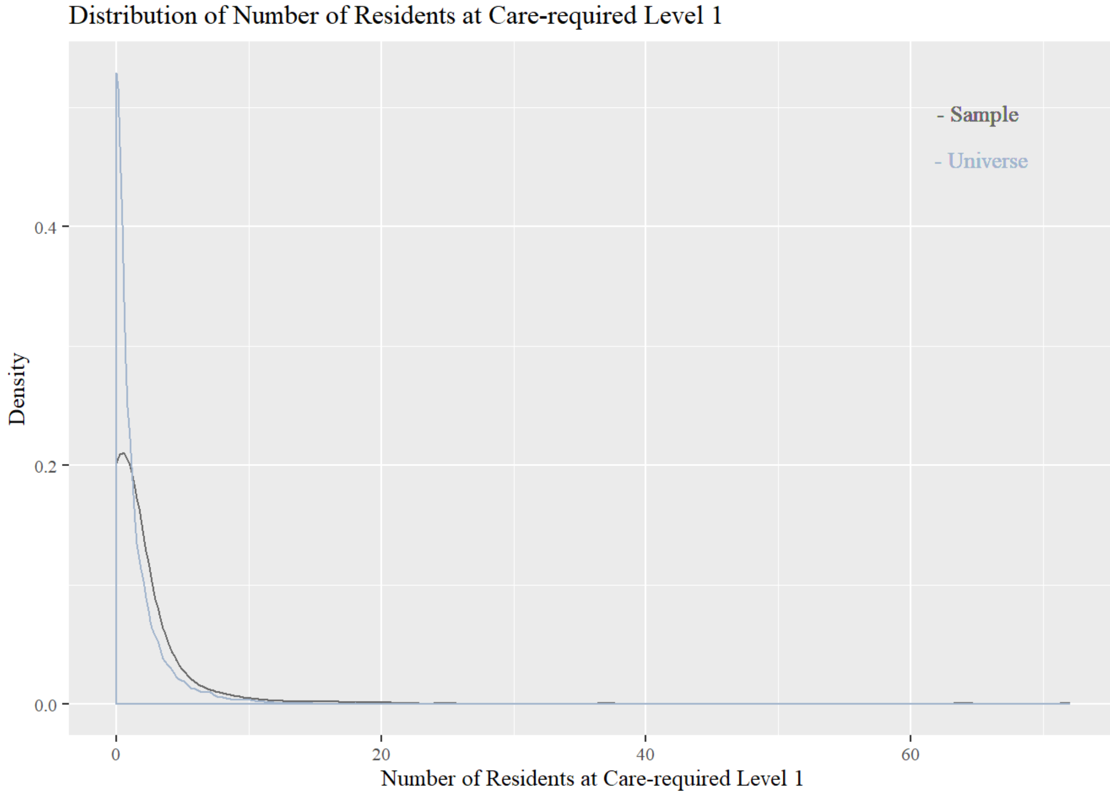
Level 4

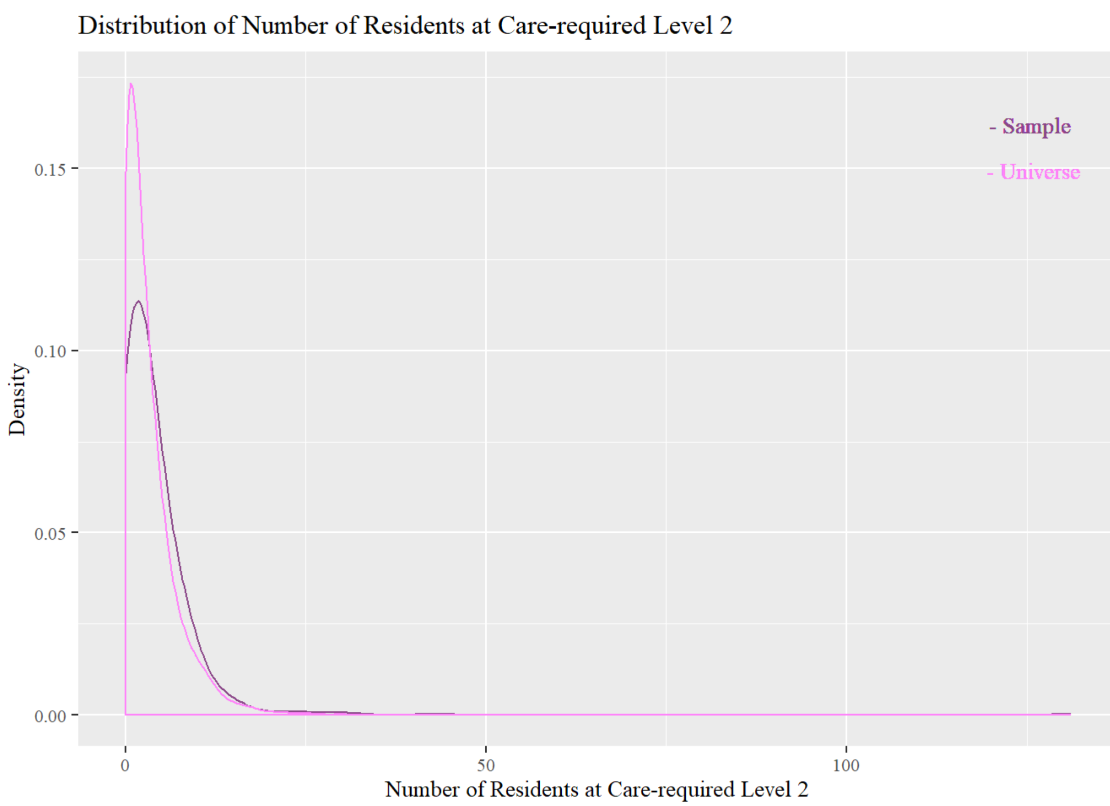
1. Hardly able to take care of one's surroundings.
2. Hardly able to do complex movements such as standing up.
3. Unable to walk or remain in a standing position on one's own.
4. Unable to use the bathroom.
5. Exhibits many instances of problematic behavior or decline in understanding.

Level 5

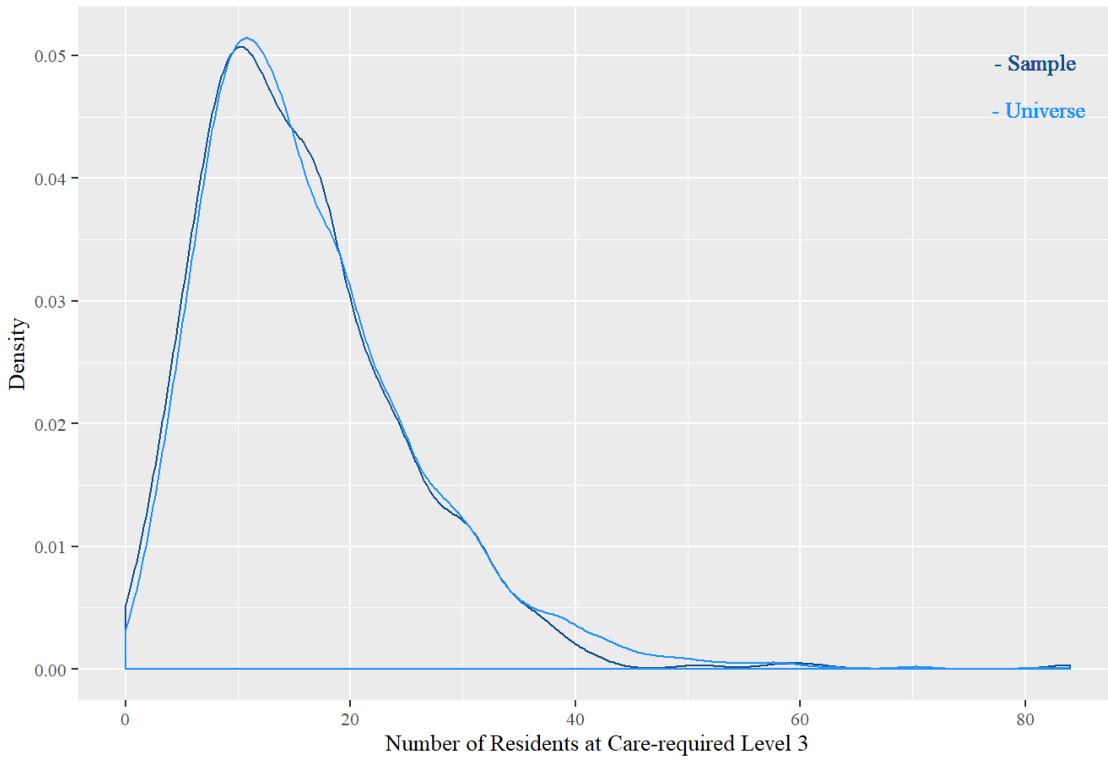
1. Hardly able to take care of one's surroundings.
2. Hardly able to do complex movements such as standing up.
3. Hardly able to walk or remain in a standing position.
4. Unable to use the bathroom and eat.
5. Exhibits many instances of problematic behavior or decline in understanding.

Appendix Figure 1: Distributions of residents and care workers showing the representativeness of the survey data, compared to the universe of nursing homes in Japan

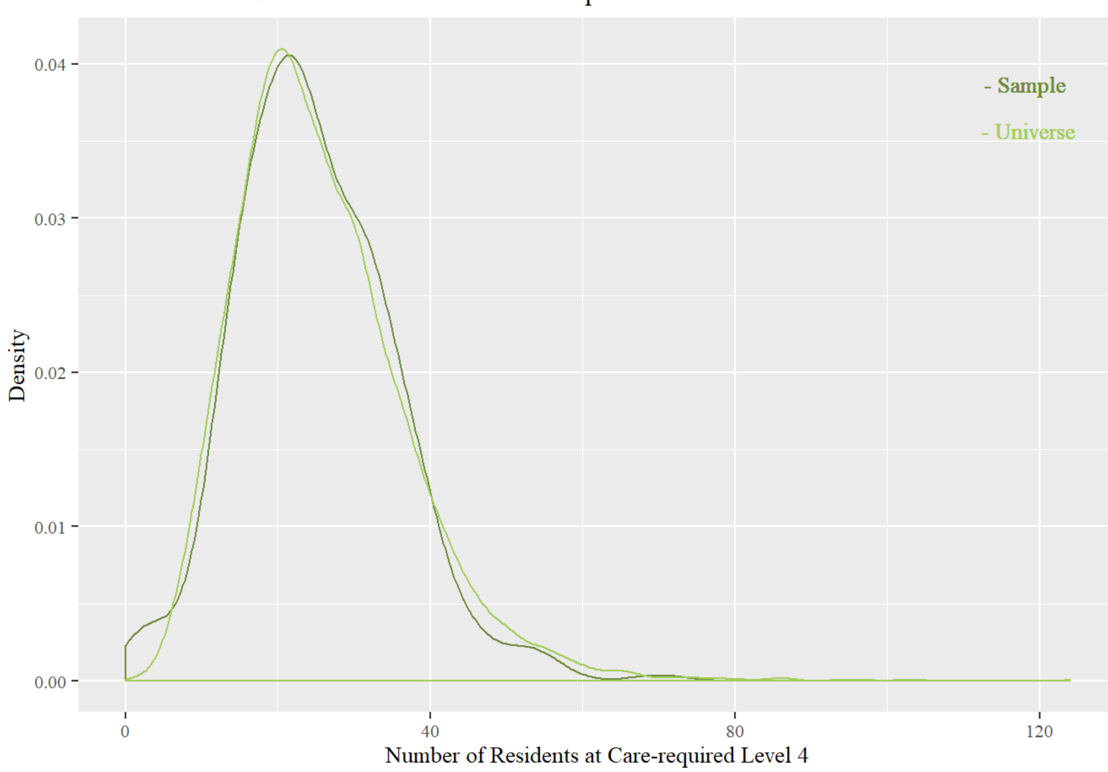




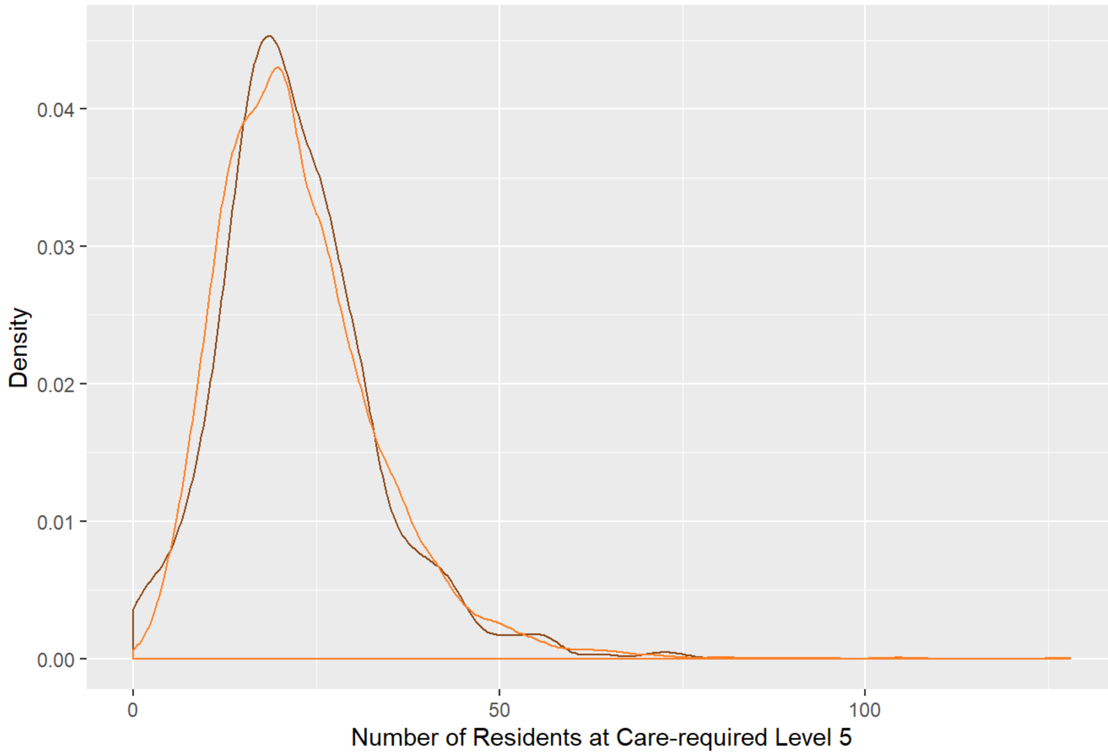
Distribution of Number of Residents at Care-required Level 3



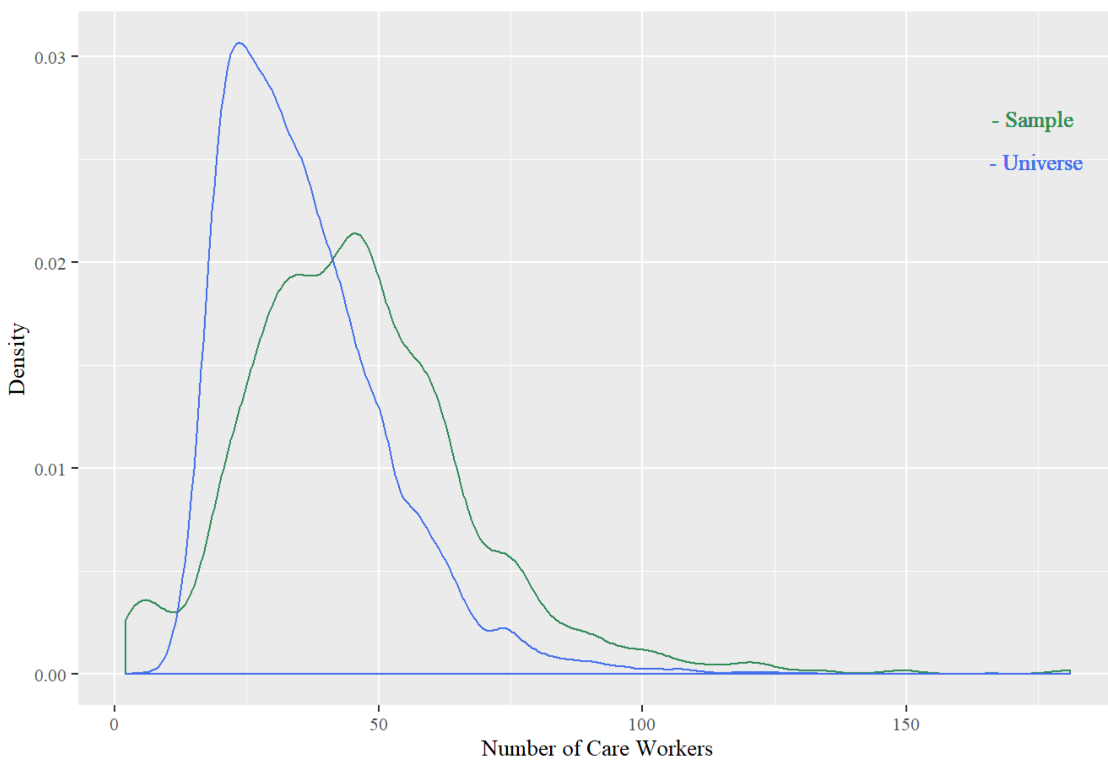
Distribution of Number of Residents at Care-required Level 4

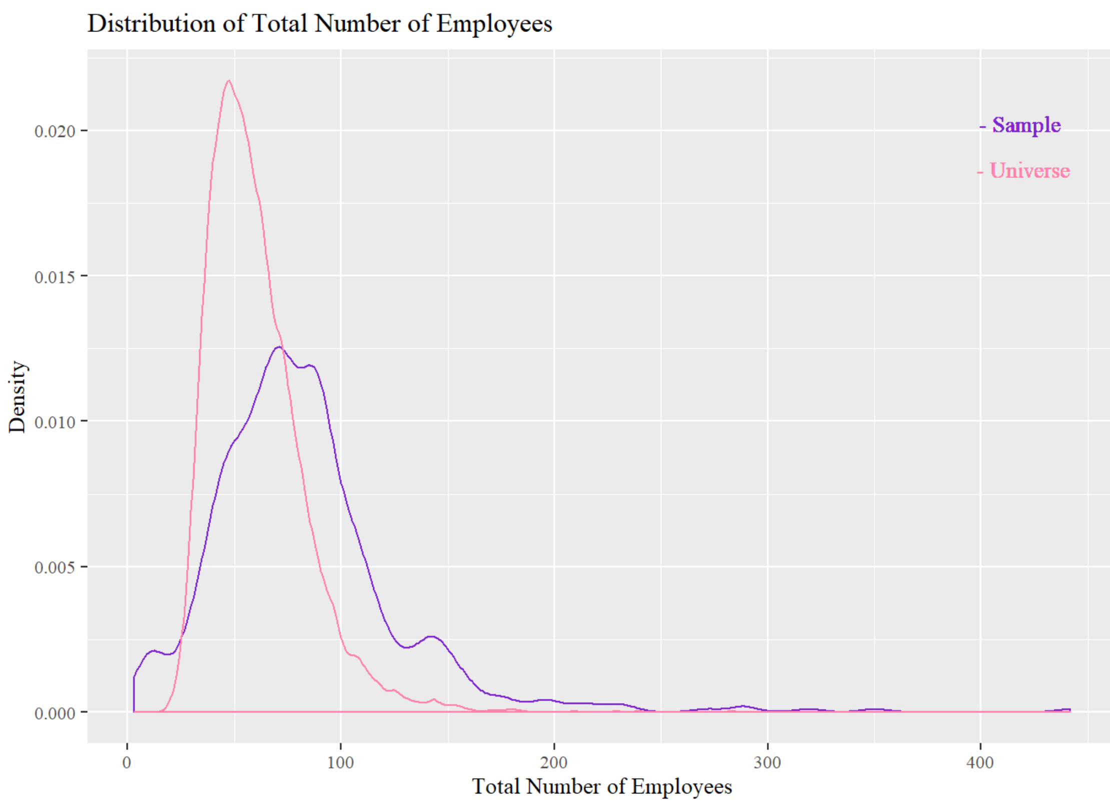


Distribution of Number of Residents at Care-required Level 5

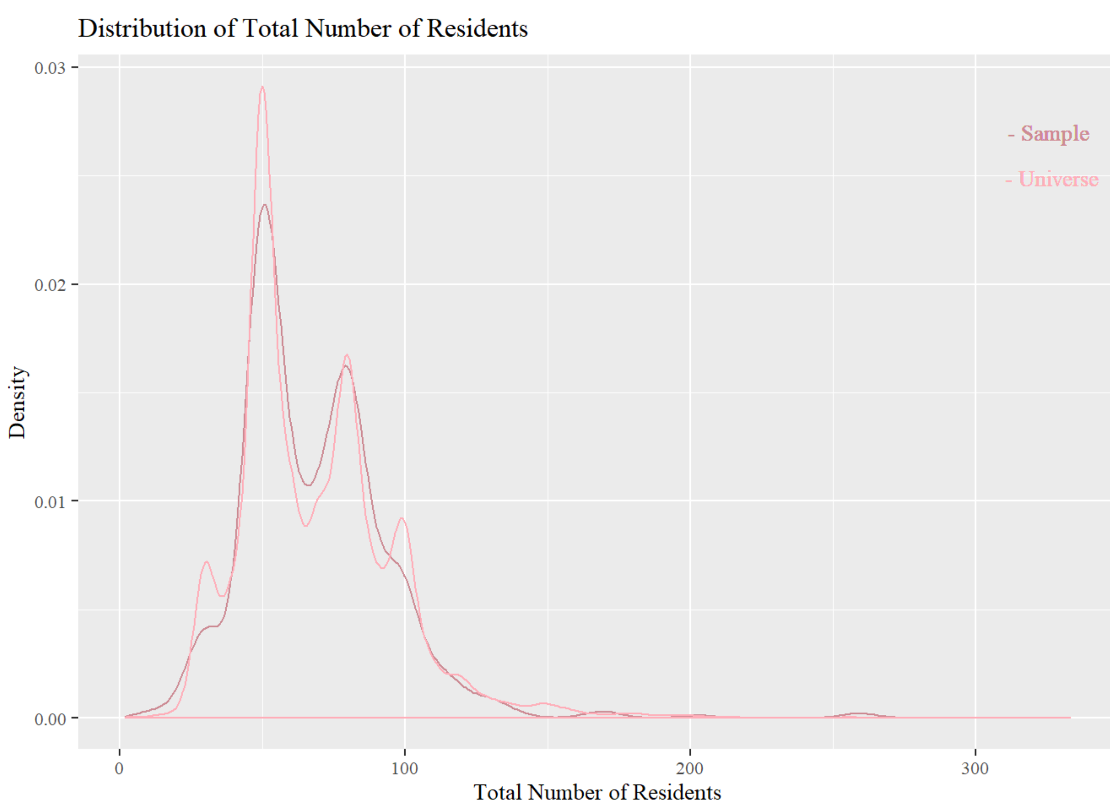


Distribution of Number of Care Workers



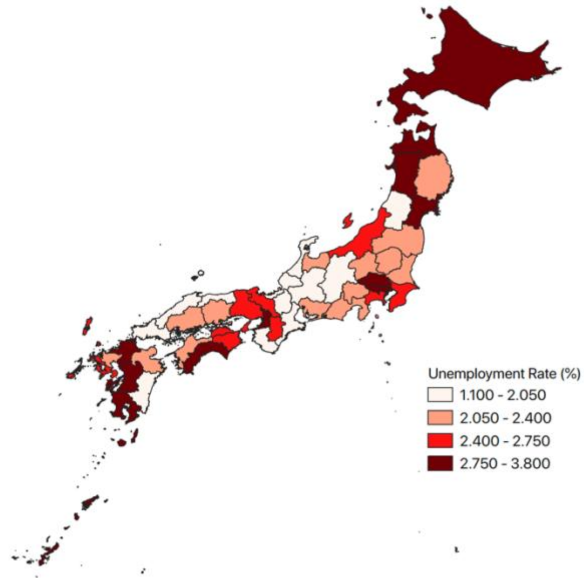


Distribution of Total Number of Employees
- Sample
- Universe
Density
0.020
0.015
0.010
0.005
0.000
0
100
200
300
400
Total Number of Employees



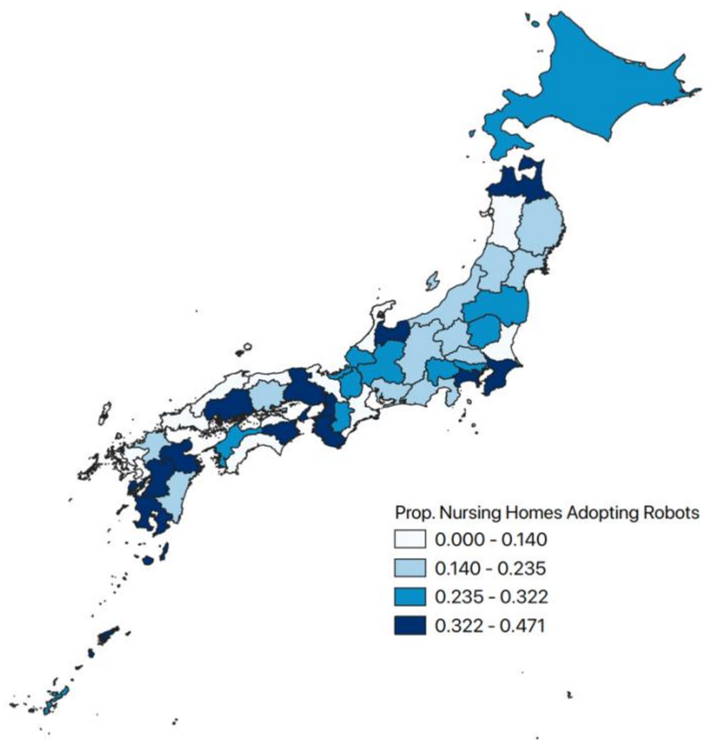
Distribution of Total Number of Residents
- Sample
- Universe
Density
0.03
0.02
0.01
0.00
0
100
200
300
Total Number of Residents

Appendix Figure 2: Unemployment rate by prefecture



Source: Statistical Data on Prefectures (Ministry of Internal Affairs and Communications)
Map source: GADM ver. 3.6, Center for Spatial Sciences at the University of California, Davis

Appendix Figure 3: Map of proportion of robot adoption by prefecture



Source: LTC survey 2017
Map source: GADM ver. 3.6, Center for Spatial Sciences at the University of California, Davis

Appendix Table 1. Descriptive statistics by nursing home type

	Custodial nursing homes		Skilled nursing homes		Custodial and skilled nursing homes	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Adopt robots	0.262	0.016	0.230	0.031	0.256	0.014
Adopt aid robots	0.082	0.010	0.063	0.018	0.078	0.009
Adopt mobility robots	0.051	0.008	0.047	0.015	0.050	0.007
Adopt communication robots	0.178	0.014	0.136	0.025	0.170	0.012
Number of care workers	42.612	0.786	40.738	1.381	42.230	0.687
Number of nurses	6.585	0.148	13.277	0.385	7.948	0.166
Number of total staff	75.435	1.600	98.545	8.406	80.141	2.152
Number of care workers - regular employees	28.888	0.574	31.408	1.075	29.401	0.507
Number of nurses - regular employees	4.099	0.119	9.686	0.320	5.237	0.136
Number of total staff - regular employees	48.003	1.046	73.346	6.438	53.163	1.586
Number of residents	62.173	0.993	89.204	2.544	67.677	1.010
Care workers per resident	0.746	0.023	0.487	0.025	0.693	0.019
Nurses per resident	0.115	0.003	0.165	0.009	0.125	0.003

Appendix Table 2. Descriptive statistics by nursing home location

	Metropolis		Urban		Rural	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Adopt robots	0.287	0.038	0.248	0.017	0.256	0.033
Adopt aid robots	0.077	0.022	0.074	0.011	0.087	0.022
Adopt mobility robots	0.077	0.022	0.043	0.008	0.052	0.017
Adopt communication robots	0.189	0.033	0.166	0.015	0.169	0.029
Number of care workers	48.937	1.526	42.193	0.879	36.820	1.406
Number of nurses	9.874	0.611	7.752	0.185	7.081	0.315
Number of total staff	92.252	4.771	81.407	2.948	65.640	2.642
Number of care workers - regular employees	34.329	1.282	29.414	0.627	25.192	1.092
Number of nurses - regular employees	6.112	0.540	5.166	0.145	4.791	0.266
Number of total staff - regular employees	60.888	3.684	54.013	2.156	43.628	2.030
Number of residents	84.636	3.099	65.994	1.183	59.698	1.914
Care workers per resident	0.631	0.022	0.715	0.028	0.668	0.031
Nurses per resident	0.121	0.006	0.125	0.003	0.130	0.009

Notes: Japanese nursing homes are largest in the main metropolises, smaller in other urban areas, and smallest in rural areas. For example, the total number of residents averages 85 in metro areas, 66 in other urban areas, and 60 in rural areas (see Appendix Table 2). Unsurprisingly, the larger urban nursing homes are also more likely to adopt robots (28.7%), compared to 25% in other urban or rural nursing homes. Perhaps more surprisingly, the number of care workers and nurses per resident is slightly higher in rural compared to urban nursing homes, on average (see Appendix Table 2). The staffing composition as measured by percentage regular workers is very similar across urban or rural location, with the exception of nurses: metropolitan nursing homes have a lower share of regular nurses (62%) compared to other urban and rural nursing homes (67%).

Appendix Table 3. Average wage of care workers and nurses (in Japanese yen)

	Mean	Std. Dev.	Min	Max	Obs
All employees					
Care workers (monthly)	275,627	67,483	114,710	633,274	8,263
Nurses (monthly)	342,044	80,309	122,333	710,233	1,595
Manager (monthly)	576,028	390,100	121,750	5,065,000	809
Care workers (hourly)	965	279	715	6,400	1,991
Nurses (hourly)	1,398	287	780	2,400	245
Regular employees					
Care workers (monthly)	280,986	65,821	114,710	633,274	7,652
Nurses (monthly)	346,346	78,288	127,000	710,233	1,508
Non-regular employees					
Care workers (hourly)	965	281	715	6,400	1,953
Nurses (hourly)	1,398	288	780	2,400	236
Minimum wage (hourly)	902				

Note: The minimum wage noted above is the national weighted average. In Japan, the minimum wage is determined by the hour and at the prefecture level.

Appendix Table 4. Robot adoption

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent variable: Adopt robot								
			Other technology	*Management practices*	*Prefecture variables*	*Additional facility variables*	*Perceptions of labor shortage*	*Subsidy*	
Planned number of robots per nursing home in 2017								0.423***	0.428***
								(0.0892)	(0.0896)
Skilled nursing home	0.0323	0.0926	0.0855	0.0965	0.0804	0.0735	0.0637	0.0232	0.0690
	(0.0628)	(0.0660)	(0.0667)	(0.0682)	(0.0698)	(0.0717)	(0.0747)	(0.0659)	(0.0706)
Log(number of residents)	0.0983***							0.0661*	
	(0.0306)							(0.0340)	
Log(care level 1~3 residents)		-0.00246	-0.00728	-0.0105	-0.00816	-0.0111	-0.0104		-0.0105
		(0.0249)	(0.0247)	(0.0247)	(0.0248)	(0.0262)	(0.0264)		(0.0262)
Log(care level 4 residents)		0.0320	0.0191	0.0133	0.0201	0.0222	0.0245		0.0400
		(0.0359)	(0.0357)	(0.0356)	(0.0354)	(0.0361)	(0.0363)		(0.0361)
Log(care level 5 residents)		0.0591**	0.0510*	0.0536*	0.0460	0.0344	0.0283		0.0278
		(0.0301)	(0.0308)	(0.0306)	(0.0308)	(0.0319)	(0.0327)		(0.0324)
Wheel chair lifts			0.0730**	0.0695**	0.0740**	0.0863***	0.0774**	0.0805**	0.0800**
			(0.0321)	(0.0317)	(0.0322)	(0.0333)	(0.0338)	(0.0341)	(0.0341)
Adjustable beds			-0.0785	-0.0856	-0.0970*	-0.122**	-0.138**	-0.147**	-0.153***
			(0.0573)	(0.0561)	(0.0537)	(0.0563)	(0.0566)	(0.0579)	(0.0575)
Seat lifting wheel chair			0.0190	-0.00227	-0.00380	0.0164	0.0176	0.0180	0.0167
			(0.0517)	(0.0516)	(0.0502)	(0.0532)	(0.0528)	(0.0519)	(0.0520)
Special bathtub			0.0141	0.0124	0.0204	0.00470	-0.0105	-0.0149	-0.0148
			(0.0390)	(0.0385)	(0.0394)	(0.0407)	(0.0426)	(0.0419)	(0.0419)
Stretcher			0.0557	0.0550	0.0599	0.0575	0.0770*	0.0846*	0.0809*
			(0.0445)	(0.0443)	(0.0444)	(0.0472)	(0.0463)	(0.0464)	(0.0464)
Wheel chair for showers			0.0245	0.0261	0.0296	0.0282	0.0263	0.0292	0.0285
			(0.0316)	(0.0318)	(0.0320)	(0.0331)	(0.0336)	(0.0331)	(0.0331)
Wheel chair scale			0.165***	0.154***	0.152***	0.145***	0.158***	0.153***	0.149***
			(0.0373)	(0.0371)	(0.0373)	(0.0383)	(0.0391)	(0.0406)	(0.0403)
Has employment regulation for non-regular workers				-0.0515	-0.0500	-0.0165	-0.0114	-0.0229	-0.0241
				(0.0551)	(0.0553)	(0.0604)	(0.0618)	(0.0616)	(0.0615)
Has a HR manager				0.0567*	0.0644**	0.0457	0.0634**	0.0739**	0.0737**
				(0.0297)	(0.0297)	(0.0311)	(0.0315)	(0.0312)	(0.0311)
Has a wage table				0.00704	0.0127	0.0265	0.0232	0.0248	0.0231
				(0.0504)	(0.0508)	(0.0537)	(0.0553)	(0.0538)	(0.0537)
Improve working conditions for retention				-0.0213	-0.0177	-0.0227	-0.0258	-0.0206	-0.0236
				(0.0293)	(0.0294)	(0.0304)	(0.0309)	(0.0304)	(0.0305)
Improve wages for retention				0.0919***	0.0903***	0.0830***	0.0836***	0.0891***	0.0901***
				(0.0291)	(0.0291)	(0.0303)	(0.0309)	(0.0305)	(0.0305)
Additional Provider Payment				-0.00409	-0.0141	-0.0253	-0.0135	-0.0253	-0.0296
				(0.0726)	(0.0723)	(0.0777)	(0.0776)	(0.0788)	(0.0787)
Log(per capita income)					0.172	0.116	0.131	0.636**	0.649**
					(0.266)	(0.276)	(0.282)	(0.287)	(0.288)
Unemployment rate					0.0731	0.0880	0.0412	-0.0134	-0.00871
					(0.0764)	(0.0798)	(0.0826)	(0.0820)	(0.0825)
Log(total population)					-1.557	-1.636	-0.531	-1.937	-1.949
					(1.413)	(1.465)	(1.485)	(1.494)	(1.488)
Log(population 70 or older)					-0.576	-0.642	-1.059	-0.331	-0.291
					(0.699)	(0.727)	(0.733)	(0.739)	(0.740)
Minimum wage					0.00143	0.00151	0.00201	0.00101	0.00101
					(0.00129)	(0.00134)	(0.00135)	(0.00136)	(0.00136)
Log(number of nursing homes)					0.0834	0.125	0.145	-0.250	-0.251
					(0.212)	(0.219)	(0.222)	(0.234)	(0.235)
Occupancy rate of nursing homes					-5.757***	-5.759***	-7.206***	-3.356	-3.386
					(1.995)	(2.116)	(2.236)	(2.368)	(2.384)

Jobs hired per opening					0.299	0.300	0.146	0.382	0.394
					(0.269)	(0.280)	(0.286)	(0.285)	(0.285)
NH job openings per applicants					0.0330	0.0509	0.0160	-0.0289	-0.0290
					(0.0364)	(0.0391)	(0.0404)	(0.0402)	(0.0404)
Log (Number of people certified for care level 3)					-0.232	-0.214	-0.229	-0.118	-0.122
					(0.296)	(0.310)	(0.313)	(0.306)	(0.309)
Log (Number of people certified for care level 4)					-0.0524	-0.137	0.279	0.858	0.835
					(0.506)	(0.524)	(0.560)	(0.552)	(0.554)
Log (Number of people certified for care level 5)					0.524	0.539	0.275	-0.268	-0.286
					(0.338)	(0.350)	(0.370)	(0.368)	(0.371)
Subsidies for securing workers					-0.0644***	-0.0647***	-0.0726***	-0.0780***	-0.0773***
					(0.0203)	(0.0209)	(0.0217)	(0.0216)	(0.0215)
Subsidies for improving facilities					0.00937**	0.00939**	0.0120**	0.0130***	0.0131***
					(0.00460)	(0.00472)	(0.00483)	(0.00475)	(0.00474)
Log (Estimated population in 2040)					0.413	0.390	-0.260	0.404	0.441
					(0.727)	(0.749)	(0.773)	(0.773)	(0.771)
Log (Estimated male over 70 in 2040)					-0.0884	-0.0137	-0.375	-0.507	-0.578
					(0.822)	(0.851)	(0.865)	(0.834)	(0.846)
Log (Estimated female over 70 in 2040)					1.356	1.436	1.648	2.073*	2.119*
					(1.026)	(1.066)	(1.086)	(1.078)	(1.082)
Training for regular care workers						0.101**	0.0991**	0.103**	0.105**
						(0.0492)	(0.0495)	(0.0490)	(0.0492)
Training for new regular care workers						-0.000503	0.00891	0.00912	0.00616
						(0.0444)	(0.0453)	(0.0445)	(0.0450)
Training for non-regular care workers						-0.0995**	-0.0999**	-0.102**	-0.102**
						(0.0451)	(0.0458)	(0.0456)	(0.0457)
Training for new non-regular care workers						0.0726	0.0646	0.0612	0.0623
						(0.0443)	(0.0457)	(0.0453)	(0.0454)
Perception on shortage of care workers							0.193	0.201	0.197
							(0.189)	(0.186)	(0.186)
Perception on shortage of nurses							0.317*	0.237	0.237
							(0.170)	(0.166)	(0.166)
Difficulty of hiring high-quality workers							-0.00360	-0.0944	-0.103
							(0.185)	(0.182)	(0.181)
Observations	938	938	938	934	934	884	857	857	857
R-squared	0.029	0.032	0.054	0.069	0.100	0.113	0.127	0.153	0.154

Notes: All regressions additionally control for years of operation, location (metropolis, urban, rural), corporation type (social council, social organization, medical facility, local government facility, and other), region fixed effects, and a dummy for skilled nursing homes. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 5. Robot adoption and staffing by type and time - OLS results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Log(number of care workers)			Log(number of nurses)			Log(total number of employees)
	All employees	Regular employees	Non-regular employees	All employees	Regular employees	Non-regular employees	
Panel A. Adoption by type of robot							
Aid robots	0.0146	-0.0134	0.0973	0.0598	0.000149	0.159**	0.0427
	(0.0554)	(0.0679)	(0.0913)	(0.0543)	(0.0634)	(0.0791)	(0.0575)
Mobility robots	-0.00669	0.0211	-0.0768	-0.0251	0.0168	0.00508	-0.0295
	(0.0599)	(0.0654)	(0.114)	(0.0658)	(0.0643)	(0.100)	(0.0608)
Communication robots	0.0351	0.0356	0.0437	0.0466	0.0814*	-0.0804	0.0403
	(0.0381)	(0.0452)	(0.0625)	(0.0344)	(0.0425)	(0.0616)	(0.0413)
Observations	857	857	857	857	857	857	857
R-squared	0.429	0.408	0.254	0.505	0.476	0.217	0.385
Panel B. Adoption by time							
Robot first adopted before 2017	0.0334	0.0123	0.0860	0.0573*	0.0619	0.0507	0.0430
	(0.0348)	(0.0428)	(0.0582)	(0.0330)	(0.0377)	(0.0546)	(0.0377)
Robot first adopted in 2017	0.103	0.150**	0.0216	0.137**	0.119	-0.0272	0.145**
	(0.0693)	(0.0675)	(0.132)	(0.0623)	(0.0861)	(0.123)	(0.0717)
Observations	857	857	857	857	857	857	857
R-squared	0.430	0.410	0.254	0.507	0.477	0.213	0.387
Base facility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Resident case-mix	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other technology adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HR development practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor shortage perceptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Base facility characteristics control for years of operation, location (metropolis, urban, rural), corporation type, region fixed effects, and skilled nursing homes. Resident case-mix controls for the log number of residents with care levels 1-3, 4, and 5. Other technology adoption controls for each non-robot technology used in the nursing homes. Management practices control for human resource management practices. Prefecture characteristics controls for the demographic and economic conditions. HR development practices control for human resource development practices in a facility. Labor shortage perceptions control for labor shortage perceptions on careworkers, nurses, and laborers in general. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 6. Robot adoption and wage by type and time - OLS results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Care workers				Nurses				Managers
	All employees		Regular employees	Non-regular employees	All employees		Regular employees	Non-regular employees	
VARIABLES	Log(monthly wage)	Log(hourly wage)	Log(monthly wage)	Log(hourly wage)	Log(monthly wage)	Log(hourly wage)	Log(monthly wage)	Log(hourly wage)	Log(monthly wage)
Panel A. Adoption by type of robot									
Aid robots	0.00453	0.0204	0.00150	0.0203	-0.0363	-0.0109	-0.0334	-0.0136	0.0798*
	(0.0226)	(0.0148)	(0.0216)	(0.0147)	(0.0221)	(0.0435)	(0.0219)	(0.0446)	(0.0452)
Mobility robots	-0.0198	-0.00260	-0.0178	-0.00265	0.00681	0.0246	0.00568	0.0370	-0.0661
	(0.0210)	(0.0217)	(0.0210)	(0.0217)	(0.0164)	(0.0350)	(0.0159)	(0.0395)	(0.0579)
Communication robots	-0.00262	-0.0170	-0.00250	-0.0168	-0.00146	-0.095**	-0.00502	-0.11***	-0.0231
	(0.0133)	(0.0138)	(0.0125)	(0.0136)	(0.0121)	(0.0360)	(0.0122)	(0.0354)	(0.0282)
Observations	6,805	1,685	6,360	1,674	1,307	202	1,251	196	650
R-squared	0.590	0.316	0.569	0.316	0.508	0.798	0.467	0.799	0.429
Panel B. Adoption by time									
Robot first adopted before 2017	-0.00846	-0.0157	-0.00867	-0.0151	-0.0111	-0.065**	-0.0128	-0.068**	-0.00793
	(0.0141)	(0.0114)	(0.0138)	(0.0112)	(0.0150)	(0.0311)	(0.0143)	(0.0312)	(0.0360)
Robot first adopted in 2017	0.0154	-0.00167	0.0112	-0.00273	-0.00969	-0.0412	-0.0176	-0.0529	0.0391
	(0.0292)	(0.0187)	(0.0299)	(0.0189)	(0.0285)	(0.0500)	(0.0319)	(0.0553)	(0.0645)
Observations	6,805	1,685	6,360	1,674	1,307	202	1,251	196	650
R-squared	0.590	0.315	0.569	0.315	0.507	0.791	0.466	0.790	0.426
Worker characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Base facility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Resident case-mix	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other technology adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HR development practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor shortage perceptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Base facility characteristics control for years of operation, location (metropolis, urban, rural), corporation type, region fixed effects, and skilled nursing homes. Resident case-mix controls for the log number of residents with care levels 1-3, 4, and 5. Other technology adoption controls for each non-robot technology used in the nursing homes. Management practices control for human resource management practices. Prefecture characteristics controls for the demographic and economic conditions. HR development practices control for human resource development practices in a facility. Labor shortage perceptions control for labor shortage perceptions on careworkers, nurses, and laborers in general. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 7. Robot adoption and care worker turnover

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All workers			Regular workers			Non-regular workers		
	Separation rate	Hiring rate	Turnover rate	Separation rate	Hiring rate	Turnover rate	Separation rate	Hiring rate	Turnover rate
Panel A. OLS estimates									
Adopt robots	-0.0153	-0.00667	-0.0219	-0.0129	-0.00780	-0.0207	0.00378	0.0259	0.0296
	(0.00985)	(0.0116)	(0.0192)	(0.00918)	(0.0115)	(0.0177)	(0.0212)	(0.0245)	(0.0402)
Observations	779	779	779	776	776	776	756	756	756
R-squared	0.095	0.132	0.120	0.147	0.136	0.158	0.074	0.100	0.097
Panel B. 2SLS estimates									
Adopt robots	-0.0433	-0.0458	-0.0890	0.00165	-0.0691*	-0.0674	0.0389	0.104	0.143
	(0.0787)	(0.0439)	(0.111)	(0.0453)	(0.0409)	(0.0747)	(0.100)	(0.0801)	(0.147)
Observations	779	779	779	776	776	776	756	756	756
First stage F-statistic	41.922	41.922	41.922	44.499	44.499	44.499	40.265	40.265	40.265
Base facility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Resident case-mix	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other technology adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HR development practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor shortage perceptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Base facility characteristics control for years of operation, location (metropolis, urban, rural), corporation type, region fixed effects, and skilled nursing homes. Resident case-mix controls for the log number of residents with care levels 1-3, 4, and 5. Other technology adoption controls for each non-robot technology used in the nursing homes. Management practices control for human resource management practices. Prefecture characteristics controls for the demographic and economic conditions. HR development practices control for human resource development practices in a facility. Labor shortage perceptions control for labor shortage perceptions on careworkers, nurses, and laborers in general. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 8. Robot adoption and staffing – IV Estimates using 2016 instrumental variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Log(number of care workers)	Log(number of nurses)	Log(total number of employees)	Log(monthly wage) - care workers	Log(hourly wage) - care workers	Log(monthly wage) - nurses	Log(hourly wage) - nurses	Log(monthly wage) - managers
Panel A. All employees								
Adopt robots	0.320***	0.427***	0.380***	0.0826	-0.0771	-0.181***	0.000763	0.00798
	(0.103)	(0.135)	(0.133)	(0.0638)	(0.0772)	(0.0566)	(0.137)	(0.143)
Observations	857	857	857	6,805	1,685	1,307	202	650
First stage F-statistic	51.556	51.556	51.556	32.019	34.574	37.158	2.974	38.073
Panel B. Regular employees								
Adopt robots	-0.0274	-0.0909	0.0472	0.0957		-0.153***		
	(0.148)	(0.135)	(0.167)	(0.0605)		(0.0504)		
Observations	857	857	857	6,360		1,251		
First stage F-statistic	51.556	51.556	51.556	37.069		39.032		
Panel C. Non-regular employees								
Adopt robots	1.005***	0.849***	0.879***		-0.0763		-0.00784	
	(0.220)	(0.281)	(0.185)		(0.0755)		(0.137)	
Observations	857	857	857		1,674		196	
First stage F-statistic	51.556	51.556	51.556		35.191		2.86	
Worker characteristics				Yes	Yes	Yes	Yes	Yes
Base facility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Resident case-mix	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other technology adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HR development practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor shortage perceptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Worker characteristics control for gender, age, age squared, experience, experience squared, and qualification level of the worker. Base facility characteristics control for years of operation, location (metropolis, urban, rural), corporation type, region fixed effects, and skilled nursing homes. Resident case-mix controls for the log number of residents with care levels 1-3, 4, and 5. Other technology adoption controls for each non-robot technology used in the nursing homes. Management practices control for human resource management practices. Prefecture characteristics controls for the demographic and economic conditions. HR development practices control for human resource development practices in a facility. Labor shortage perceptions control for labor shortage perceptions on careworkers, nurses, and laborers in general. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 9. Robot adoption and staffing – IV Estimates (Custodial nursing homes only)

VARIABLES	(1) Log(number of care workers)	(2) Log(number of nurses)	(3) Log(total number of employees)	(4) Log(monthly wage) - care workers	(5) Log(hourly wage) - care workers	(6) Log(monthly wage) - nurses	(7) Log(hourly wage) - nurses	(8) Log(monthly wage) - managers
Panel A. All employees								
Adopt robots	0.328***	0.590***	0.230	-0.00638	-0.0843	-0.267***	-0.0872	0.216
	(0.120)	(0.166)	(0.146)	(0.0583)	(0.0679)	(0.0715)	(0.488)	(0.135)
Observations	684	684	684	5,684	1,405	988	59	540
First stage F-statistic	26.499	26.499	26.499	30.991	46.116	27.242	0.157	25.211
Panel B. Regular employees								
Adopt robots	-0.127	0.0262	-0.134	-0.00228		-0.223***		
	(0.150)	(0.155)	(0.176)	(0.0611)		(0.0696)		
Observations	684	684	684	5,308		968		
First stage F-statistic	26.499	26.499	26.499	36.358		29.902		
Panel C. Non-regular employees								
Adopt robots	1.210***	1.033***	0.734***		-0.0839		0.652	
	(0.203)	(0.381)	(0.198)		(0.0671)		(1.126)	
Observations	684	684	684		1,396		57	
First stage F-statistic	26.499	26.499	26.499		46.854		0.301	
Worker characteristics				Yes	Yes	Yes	Yes	Yes
Base facility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Resident case-mix	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Other technology adoption	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Management practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HR development practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor shortage perceptions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Worker characteristics control for gender, age, age squared, experience, experience squared, and qualification level of the worker. Base facility characteristics control for years of operation, location (metropolis, urban, rural), corporation type, region fixed effects, and skilled nursing homes. Resident case-mix controls for the log number of residents with care levels 1-3, 4, and 5. Other technology adoption controls for each non-robot technology used in the nursing homes. Management practices control for human resource management practices. Prefecture characteristics controls for the demographic and economic conditions. HR development practices control for human resource development practices in a facility. Labor shortage perceptions control for labor shortage perceptions on careworkers, nurses, and laborers in general. Standard errors clustered by prefecture are in parentheses. *** p<0.01, ** p<0.05, * p<0.1