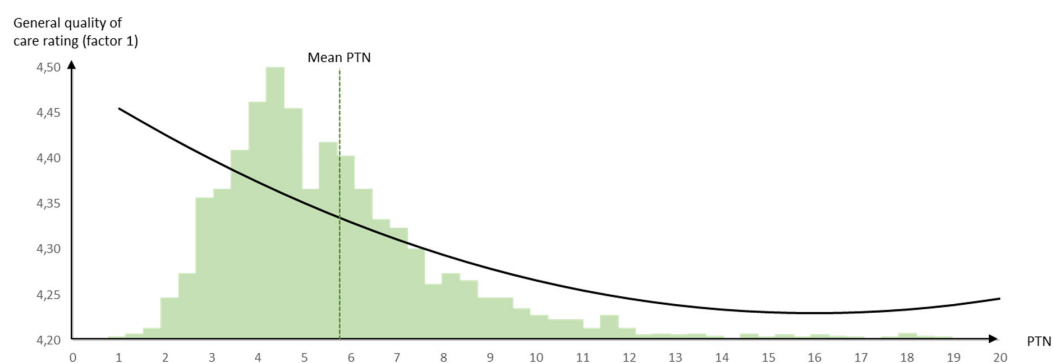


Appendix: Nurse staffing and patient-perceived quality of nursing care: A cross-sectional analysis of survey and administrative data in German hospitals

Appendix 1: Mean PTN ratio and skill mix ratio per unit type

unit type	patients	patient-to nurse ratio (mean)	skill mix ratio (mean)
internal medicine	6,260	5.92	7.54
geriatrics	106	8.75	11.91
cardiology	1,698	4.68	5.85
nephrology	61	4.78	4.70
hematology	181	5.31	5.56
endocrinology	22	8.41	13.59
gastroenterology	378	6.20	8.30
pneumology	200	4.91	7.68
rheumatology	121	9.75	9.71
pulmonary medicine	77	6.16	6.14
general surgery	7,512	5.87	6.59
trauma surgery	1,784	6.50	7.14
neurosurgery	582	5.90	5.64
vascular surgery	300	5.76	4.98
plastic surgery	186	5.01	4.30
thoracic surgery	81	5.25	6.44
heart surgery	319	3.77	5.08
urology	2,396	6.27	5.45
orthopedics	2,753	6.05	6.94
neurology	1,951	5.36	6.26
nuclear medicine	103	4.26	3.33
radiotherapy	53	5.32	5.27
dermatology	760	5.93	4.87
dentistry	252	4.85	4.41
total	28,136	5.84	6.61

Appendix 2 Illustration: Effect of an additional patient per nurse on QoNC factor 1 (ceteris paribus)



Note: the green area illustrates the distribution (histogram) of the PTN ratio and indicates the quantity of data points to substantiate the estimation depending on the PTN ratio.

Nurse staffing and patient-perceived quality of nursing care

Appendix 3: Regression results generalized random intercept model (odds ratios)

effect [†]	(1) general nursing care	(2) guidance	(3) loyalty
\overline{PTN}	0.951 [0.010] (0.915;0.988)	0.943 [0.010] (0.902;0.986)	0.929 [<0.001] (0.897;0.963)
\overline{PTN}^2	1.003 [0.035] (1.000;1.005)	1.003 [0.035] (1.001;1.006)	1.004 [0.001] (1.002;1.006)
\overline{skill}	0.995 [0.050] (0.991;1.000)	0.997 [0.050] (0.991;1.002)	0.991 [<0.001] (0.986;0.995)
<i>PCCL</i>	0.876 [<0.001] (0.851;0.900)	0.875 [<0.001] (0.846;0.906)	0.944 [<0.001] (0.922;0.967)
<i>age</i>	1.080 [<0.001] (1.066;1.094)	1.061 [<0.001] (1.045;1.077)	1.034 [<0.001] (1.024;1.045)
<i>age</i> ²	0.999 [<0.001] (0.999;1.000)	1.000 [<0.001] (0.999;1.000)	1.000 [<0.001] (1.000;1.000)
<i>gender</i> (= 1 if female)	0.903 [<0.001] (0.854;0.955)	0.934 [<0.001] (0.874;0.999)	0.822 [<0.001] (0.781;0.865)
<i>rurality</i>	1.060 [<0.001] (1.029;1.091)	1.025 [<0.001] (0.991;1.062)	1.010 [0.463] (0.984;1.037)
\overline{PTP}	0.997 [0.278] (0.992;1.002)	0.998 [0.278] (0.992;1.004)	0.997 [0.140] (0.993;1.001)
observations	28,136	28,136	28,136

P-values in square brackets, 95%-confidence intervals in parentheses

Abbreviations: \overline{PTN} : mean-centered patient-to-nurse ratio; \overline{skill} : mean-centered skill-mix ratio; *PCCL*: Patient Clinical Complexity Level index

[†]Fixed effects for the 24 unit types, months, bed categories and between-unit effects for PTN and skill mix included but not shown.

Appendix 4: Regression results random effects model

effect [†]	(1) general nursing care	(2) guidance	(3) loyalty
\overline{PTN}	-0.006 [0.009] (-0.011;-0.002)	-0.007 [0.045] (-0.014;0.000)	-0.010 [<0.001] (-0.015;-0.005)
\overline{PTN}^2	0.001 [0.003] (0.000;0.002)	0.001 [0.037] (0.000;0.002)	0.001 [0.003] (0.000;0.002)
\overline{skill}	-0.003 [<0.001] (-0.004;-0.001)	-0.005 [<0.001] (-0.007;-0.003)	-0.003 [<0.001] (-0.005;-0.002)
<i>PCCL</i>	-0.048 [<0.001] (-0.057;-0.039)	-0.034 [<0.001] (-0.047;-0.022)	-0.027 [<0.001] (-0.036;-0.018)
<i>age</i>	0.022 [<0.001] (0.018;0.025)	0.018 [<0.001] (0.013;0.023)	0.018 [<0.001] (0.014;0.022)
<i>age</i> ²	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)
<i>gender</i> (= 1 if female)	-0.192 [<0.001] (-0.210;-0.174)	-0.276 [<0.001] (-0.303;-0.249)	-0.140 [<0.001] (-0.159;-0.121)
<i>rurality</i>	0.014 [0.004] (0.004;0.024)	0.028 [<0.001] (0.014;0.042)	0.004 [0.373] (-0.005;0.014)
\overline{PTP}	-0.002 [0.030] (-0.003;0.000)	-0.003 [0.026] (-0.005;0.000)	-0.002 [0.013] (-0.003;0.000)
observations	28,136	28,136	28,136

P-values in square brackets, 95%-confidence intervals in parentheses

Abbreviations: \overline{PTN} : mean-centered patient-to-nurse ratio; \overline{skill} : mean-centered skill-mix ratio; *PCCL*: Patient Clinical Complexity Level index

[†]Fixed effects for the 24 unit types, months, bed categories and between-unit effects for PTN and skill mix included but not shown.

Nurse staffing and patient-perceived quality of nursing care

Appendix 5: Regression results subgroup analysis case severity

effect [†]	(1) general nursing care		(2) guidance		(3) loyalty	
	low (PCCL=0)	high (PCCL>0) ^{††}	low (PCCL=0)	high (PCCL>0) ^{††}	low (PCCL=0)	high (PCCL>0) ^{††}
\overline{PTN}	-0.019 [0.009] (-0.033;-0.005)	-0.022 [0.121] (-0.051;-0.003)	-0.021 [0.051] (-0.043;0.000)	-0.024 [0.245] (-0.063;0.016)	-0.025 [0.001] (-0.040;-0.010)	-0.022 [0.142] (-0.050;-0.007)
\overline{PTN}^2	0.001 [0.009] (0.000;0.002)	0.001 [0.222] (-0.001;0.003)	0.001 [0.066] (0.0000;0.003)	0.001 [0.312] (-0.001;0.004)	0.001 [0.004] (0.000;0.002)	0.001 [0.375] (-0.001;0.003)
\overline{skill}	-0.003 [0.001] (-0.005;-0.001)	-0.003 [0.070] (-0.006;0.000)	-0.005 [<0.001] (-0.008;-0.003)	-0.004 [0.079] (-0.008;0.000)	-0.004 [<0.001] (-0.005;-0.002)	-0.003 [0.059] (-0.006;0.000)
PCCL	— —	-0.038 [<0.001] (-0.055;-0.021)	— —	-0.008 [0.505] (-0.032;0.016)	— —	-0.021 [0.017] (-0.038;-0.004)
age	0.018 [<0.001] (0.014;0.022)	0.030 [<0.001] (0.022;0.038)	0.015 [<0.001] (0.009;0.021)	0.022 [<0.001] (0.011;0.033)	0.015 [<0.001] (0.011;0.019)	0.022 [<0.001] (0.014;0.030)
age ²	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [0.024] (0.000;0.000)	0.000 [0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)
gender (= 1 if female)	-0.190 [<0.001] (-0.211;-0.169)	-0.193 [0.004] (-0.231;-0.154)	-0.283 [<0.001] (-0.315;-0.252)	-0.252 [<0.001] (-0.306;-0.198)	-0.142 [<0.001] (-0.164;-0.120)	-0.128 [<0.001] (-0.167;-0.089)
rurality	0.009 [0.125] (-0.002;0.020)	0.029 [0.004] (0.009;0.048)	0.021 [0.015] (0.004;0.037)	0.050 [<0.001] (0.023;0.077)	-0.001 [0.848] (-0.013;0.010)	0.020 [0.050] (0.000;0.039)
\overline{PTP}	-0.001 [0.175] (-0.003;0.001)	-0.003 [0.073] (-0.006;0.000)	-0.002 [0.226] (-0.004;0.001)	-0.005 [0.027] (-0.010;-0.001)	-0.001 [0.120] (-0.003;0.000)	-0.003 [0.039] (-0.007;0.000)
observations	20,624	7,512	20,624	7,512	20,624	7,512

P-values in square brackets, 95%-confidence intervals in parentheses

Abbreviations: \overline{PTN} : mean-centered patient-to-nurse ratio; \overline{skill} : mean-centered skill-mix ratio; PCCL: Patient Clinical Complexity Level index

[†]Fixed effects for the 24 unit types, months, bed categories and between-unit effects for PTN and skill mix included but not shown.

^{††} Subgroup "high" comprises patients with a PCCL from 1 to 6.

Appendix 6: Regression results subgroup analysis hospital size^{††}

effect [†]	(1) general nursing care		(2) guidance		(3) loyalty	
	small	large	small	large	small	large
\overline{PTN}	-0.018 [0.024] (-0.034;-0.002)	-0.015 [0.186] (-0.037;0.007)	-0.009 [0.447] (-0.033;-0.015)	-0.031 [0.058] (-0.063;0.001)	-0.024 [0.005] (-0.040;-0.007)	-0.014 [0.216] (-0.037;0.008)
\overline{PTN}^2	0.001 [0.048] (0.000;0.002)	0.001 [0.155] (0.000;0.002)	0.000 [0.660] (-0.001;0.002)	0.002 [0.041] (0.000;0.004)	0.001 [0.035] (0.000;0.002)	0.001 [0.245] (-0.001;0.002)
\overline{skill}	-0.004 [<0.001] (-0.006;-0.002)	-0.002 [0.183] (-0.004;0.001)	-0.005 [0.002] (-0.008;-0.002)	-0.004 [0.009] (-0.008;-0.001)	-0.005 [<0.001] (-0.007;-0.003)	-0.001 [0.369] (-0.003;0.001)
PCCL	-0.050 [<0.001] (-0.062;-0.037)	-0.046 [<0.001] (-0.058;-0.035)	-0.043 [<0.001] (-0.062;-0.024)	-0.028 [0.002] (-0.045;-0.011)	-0.034 [<0.001] (-0.047;-0.021)	-0.022 [<0.001] (-0.035;-0.010)
age	0.026 [<0.001] (0.021;0.030)	0.017 [<0.001] (0.012;0.022)	0.023 [<0.001] (0.016;0.030)	0.012 [0.002] (0.004;0.019)	0.022 [<0.001] (0.017;0.027)	0.013 [<0.001] (0.008;0.018)
age ²	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [0.097] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [0.002] (0.000;0.000)
gender (= 1 if female)	-0.165 [<0.001] (-0.189;-0.140)	-0.223 [<0.001] (-0.251;-0.195)	-0.245 [<0.001] (-0.282;-0.208)	-0.311 [<0.001] (-0.351;-0.271)	-0.116 [<0.001] (-0.141;-0.090)	-0.166 [<0.001] (-0.195;-0.138)
rurality	0.010 [0.148] (0.003;0.023)	0.020 [0.006] (0.006;0.034)	0.033 [0.001] (0.013;0.053)	0.024 [0.020] (0.004;0.044)	-0.007 [0.337] (-0.020;0.007)	0.017 [0.020] (0.003;0.032)
\overline{PTP}	0.000 [0.885] (-0.002;0.002)	-0.004 [0.006] (-0.006;-0.034)	-0.001 [0.711] (-0.003;0.002)	-0.006 [0.007] (-0.009;-0.002)	0.000 [0.884] (-0.002;0.002)	-0.005 [<0.001] (-0.008;-0.002)
observations	14,387	13,749	14,387	13,749	14,387	13,749

P-values in square brackets, 95%-confidence intervals in parentheses

Abbreviations: \overline{PTN} : mean-centered patient-to-nurse ratio; \overline{skill} : mean-centered skill-mix ratio; PCCL: Patient Clinical Complexity Level index

[†]Fixed effects for the 24 unit types, months, bed categories and between-unit effects for PTN and skill mix included but not shown.

^{††} subgroup small comprises hospitals with less than 500 bed; subgroup large comprises hospitals with 500 beds and more

Nurse staffing and patient-perceived quality of nursing care

Appendix 7: Regression results subgroup analysis medical vs. surgical patients

effect [†]	(1) general nursing care		(2) guidance		(3) loyalty	
	medical	surgical	medical	surgical	medical	surgical
\overline{PTN}	-0.014 [0.216] (-0.037;0.008)	-0.012 [0.159] (-0.029;-0.005)	-0.042 [0.015] (-0.075;-0.008)	-0.008 [0.510] (-0.032;-0.016)	-0.058 [<0.001] (-0.081;-0.034)	-0.005 [0.594] (-0.022;-0.013)
\overline{PTN}^2	0.001 [0.245] (-0.001;0.002)	0.000 [0.412] (-0.001;0.002)	0.003 [0.003] (0.001;0.005)	0.000 [0.965] (-0.002;0.002)	0.004 [<0.001] (0.002;0.005)	0.000 [0.831] (-0.001;0.001)
\overline{skill}	-0.001 [0.369] (-0.003;0.001)	-0.003 [0.006] (-0.005;-0.001)	-0.004 [0.039] (-0.007;0.000)	-0.005 [0.001] (-0.008;-0.002)	-0.003 [0.025] (-0.005;0.000)	-0.003 [0.002] (-0.006;-0.001)
PCCL	-0.022 [<0.001] (-0.035;-0.010)	-0.060 [<0.001] (-0.072;-0.047)	-0.021 [0.035] (0.004;-0.022)	-0.051 [<0.001] (-0.069;-0.033)	-0.019 [0.006] (-0.033;-0.006)	-0.040 [<0.001] (-0.053;-0.027)
age	0.013 [<0.001] (0.008;0.018)	0.023 [<0.001] (0.018;0.028)	0.013 [0.003] (0.004;0.022)	0.021 [<0.001] (0.014;0.028)	0.016 [<0.001] (0.010;0.022)	0.021 [<0.001] (0.016;0.026)
age ²	0.000 [0.002] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [0.085] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)	0.000 [<0.001] (0.000;0.000)
gender (= 1 if female)	-0.166 [<0.001] (-0.195;-0.138)	-0.183 [<0.001] (-0.208;-0.159)	-0.294 [<0.001] (-0.338;-0.250)	-0.255 [<0.001] (-0.291;-0.219)	-0.165 [<0.001] (-0.195;-0.134)	-0.122 [<0.001] (-0.141;-0.097)
rurality	0.017 [0.020] (0.003;0.032)	0.017 [0.015] (0.003;0.030)	0.018 [0.118] (-0.005;0.041)	0.038 [<0.001] (0.019;0.057)	0.001 [0.886] (-0.017;0.015)	0.007 [0.293] (-0.006;-0.021)
\overline{PTP}	-0.005 [0.020] (-0.008;-0.002)	0.001 [0.490] (-0.002;0.004)	-0.004 [0.024] (-0.008;-0.001)	0.000 [0.819] (-0.004;0.005)	-0.004 [0.005] (-0.006;-0.001)	0.000 [0.764] (-0.003;0.003)
observations	11,868	13,769	11,868	13,769	11,868	13,769

P-values in square brackets, 95%-confidence intervals in parentheses

Abbreviations: \overline{PTN} : mean-centered patient-to-nurse ratio; \overline{skill} : mean-centered skill-mix ratio; PCCL: Patient Clinical Complexity Level index

[†]Fixed effects for the 24 unit types, months, bed categories and between-unit effects for PTN and skill mix included but not shown.