Online Appendix

for

Does Technology Substitute for Nurses?

Staffing Decisions in Nursing Homes[1]

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Appendix 1: Proofs

Lemma: The optimal staffing level s^*, the optimal quality level q^*, and the resulting average revenue per resident for a nursing home with vertical position θ are given below:

$$s^* = \frac{1}{Ak\theta}\ln\frac{Akb\theta^2}{w}, \quad q^* = \frac{1}{A\theta}\ln\frac{Akb\theta^2}{w}, \quad R(q^*,\theta) = 1 - \frac{w}{Ak\theta}.$$

Proof:

The first-order condition for the nursing home's optimization problem yields

$$\frac{\partial R(q,\theta)}{\partial s} = w.$$

Using the functional form of $R(q,\theta)$, we have

$$b\theta e^{-Aks\theta}Ak\theta = w \Rightarrow s^* = \frac{1}{Ak\theta}\ln\frac{Akb\theta^2}{w}.$$

Therefore, $q^* = s^*k = \frac{1}{A\theta}\ln\frac{Akb\theta^2}{w}$ and $R(q^*,\theta) = 1 - b\theta e^{-Aks^*\theta} = 1 - \frac{w}{Ak\theta}$.

Proof of Proposition 1:

We evaluate the sign of the three derivatives. From the Lemma, we have

$$\frac{\partial s^*}{\partial \theta} = \frac{2 - \ln\frac{Akb\theta^2}{w}}{Ak\theta^2}, \quad \frac{\partial q^*}{\partial \theta} = \frac{2 - \ln\frac{Akb\theta^2}{w}}{A\theta^2}, \quad \frac{\partial R(q^*,\theta)}{\partial \theta} = \frac{w}{Ak\theta^2}.$$

[1] This paper is previously circulated as "Is Technology Eating Nurses? Staffing Decisions in Nursing Homes".

Clearly, we have

$$\frac{\partial R(q^*,\theta)}{\partial \theta} > 0.$$

By the technical assumption, we have

$$\theta \in \left(0, \sqrt{\frac{we^2}{Akb}}\right) \Rightarrow 2 - \ln\frac{Akb\theta^2}{w} > 0 \Rightarrow \frac{\partial s^*}{\partial \theta} > 0, \quad \frac{\partial q^*}{\partial \theta} > 0.$$

Proof of Proposition 2:

The claim follows directly from the fact that

$$\frac{\partial R(q^*,\theta)}{\partial \theta} = \frac{w}{A\theta k^2} > 0, \text{and } \frac{\partial q^*}{\partial \theta} = \frac{1}{A\theta k} > 0.$$

Proof of Proposition 3:

We only need to evaluate the sign of $\partial s^*/\partial k$. Using the Lemma, we have

$$\frac{\partial s^*}{\partial k} = \frac{1 - \ln\frac{Akb\theta^2}{w}}{A\theta k^2}.$$

Hence,

$$\frac{\partial s^*}{\partial k} > 0 \Leftrightarrow 1 - \ln\frac{Akb\theta^2}{w} > 0 \Leftrightarrow \theta < \sqrt{\frac{we}{Akb}},$$

$$\frac{\partial s^*}{\partial k} < 0 \Leftrightarrow 1 - \ln\frac{Akb\theta^2}{w} < 0 \Leftrightarrow \theta > \sqrt{\frac{we}{Akb}}.$$

Table A1: Summary Statistics on Variables Relating to Nurse Labor Markets

Variable	Obs	Mean	SD	Definition
State RN Supply	357	0.008	0.002	total RN full-time equivalents (FTEs) divided by state population
State LPN Supply	354	0.003	0.001	total state LPN FTEs divided by state population
State Hospital RN Supply	357	0.007	0.002	total state hospital RN FTEs divided by state population
State Hospital LPN Supply	354	0.002	0.001	total state hospital LPN FTEs divided by state population
RN Hourly Rate	356	2655	337	hourly rate for RN (cents)
LPN Hourly Rate	355	1849	342	hourly rate for LPN (cents)

Table A2: The Dynamic Effect of Nursing Home CPOE Adoption on Staffing

Dependent Variable:	OLS	2SLS
LN Hours per Resident Day	(1)	(2)
First 2 years of adoption	0.086***	0.081***
	(0.018)	(0.028)
Second 2 years of adoption	0.110***	0.097***
	(0.024)	(0.028)
More than 4 years of adoption	0.147***	0.160***
	(0.034)	(0.048)
First 2 years of adoption * High End	-0.164***	-0.150***
	(0.037)	(0.043)
Second 2 years of adoption * High End	-0.207***	-0.135**
	(0.048)	(0.068)
More than 4 years of adoption * High End	-0.271***	-0.250***
	(0.063)	(0.091)
Observations	12,313	12,250
Within R-squared	0.048	0.047

Standard errors are clustered by nursing home
*** p<0.01, ** p<0.05, * p<0.1

This table investigates the dynamic effects of CPOE adoption in the post adoption periods. The unit of observation is a nursing home-year. Samples includes annual data from 2006 to 2012. Regressions include time-varying nursing home characteristics, state linear trends, nursing home fixed effects and year effects. The base period is all years before nursing home adoption. The dummy variable *First 2 years of adoption* is 1 if the year is either the adoption year or the year after the adoption. Other dummy variables are similarly defined.

Results in this table show that the CPOE effect on labor demand appears immediately after adoption and continues afterward. To see if the effects grow over time, we also conducted a series of F tests across different periods. The tests show insignificant changes over time for both types of nursing homes.

Table A3: Subsample Analysis for Ownership Type and Facility Size

Dependent Variable:	Ownership and Size			
LN Hours per Resident Day	FP	NP	Large Size	Small Size
	(1)	(2)	(3)	(4)
CPOE	0.463*	0.092*	0.103*	0.149**
	(0.276)	(0.050)	(0.061)	(0.068)
CPOE * High End	-0.805*	-0.175**	-0.247**	-0.252***
	(0.459)	(0.082)	(0.116)	(0.094)
Nursing Home Dummies	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y
Time Varying Controls	Y	Y	Y	Y
Observations	4,130	6,329	6,166	6,062
Centered R-squared	0.046	0.044	0.098	0.036
Number of provider	749	1,181	1,013	1,092

Robust standard errors in parentheses clustered by nursing home

*** p<0.01, ** p<0.05, * p<0.1

This table investigates whether ownership and facility size matters by using different subsamples. It seems that for-profit nursing homes are more likely to follow the optimal staffing strategy in response to CPOE adoption than their non-profit counterparts. And it seems there is little differences in the differential CPOE effects on labor across facility sizes. Overall, our results remain robust regardless of a nursing home's ownership type and size.

Figure A1: Quality Mix and Occupancy Rates

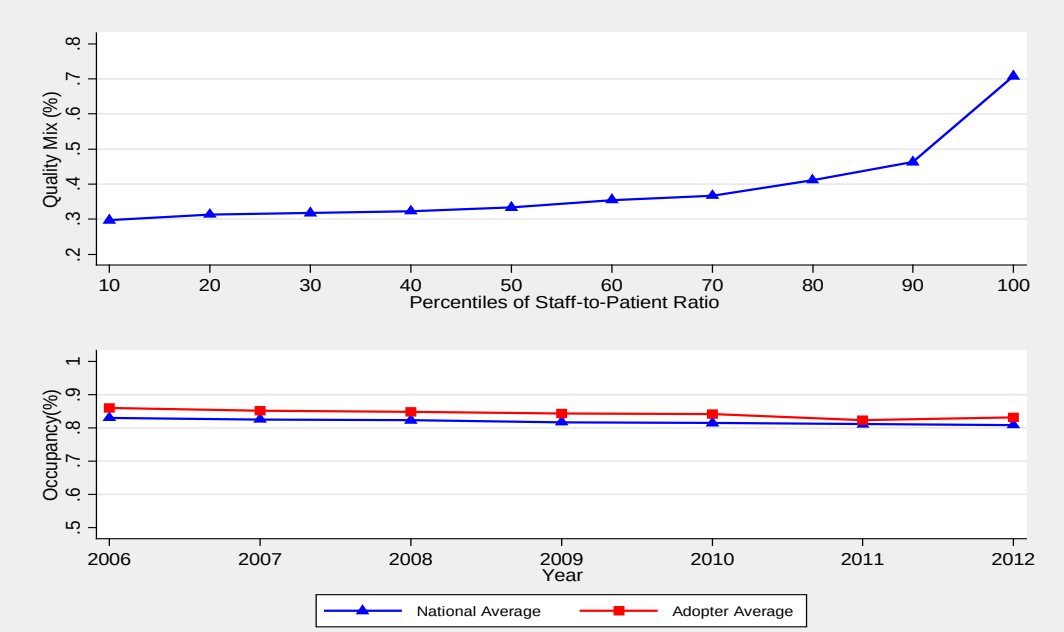

Figure A2: Trends in CPOE Adoption from 2005 to 2011