Does Technology Substitute for Nurses?
--- Staffing Decisions in Nursing Homes

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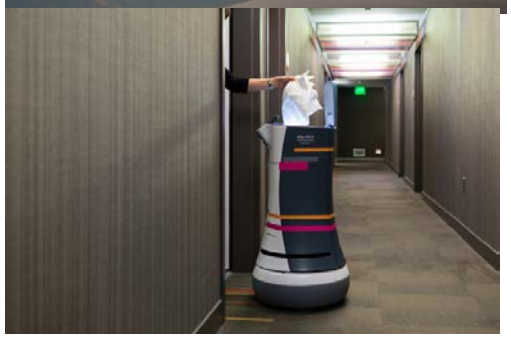
Agenda

- **Motivation**
- Theoretical Analysis
- Data and Identification
- Empirical Results
- Conclusions

Automation through Information Technology

Automation threatens all manner of workers, from drivers to waiters to nurses.” **Bill Gates, 2014**



software will eat the world
Marc Andreessen, 2012

Automation may be destroying jobs faster than it’s creating new ones.
Eric Brynjolfsson, 2013

Motivation

Advances in IT are changing healthcare delivery by bring digitization and automation into the industry.

Research Question (Broad)

How will IT-enabled automation affect healthcare employment?

Technology and Nurse Labor Markets

"the rollout of electronic health records systems is identified as one of the dangerous trends that nurses must know about."

"… if this sounds like the computer is taking over your independent nursing judgement and maybe ultimately your job, that's because it is.

--- **National Nurse**

Research Question

Does technology substitute for nurses?

Relatively simple structure of labor provision

Relatively homogeneous services: chronic care

Nursing Homes in the United States

- A nursing home is a place for people who do not need to be in a hospital but can no longer be cared for at home.
- 2011 spending on nursing home care: $111 billion
- Patient types
  - Short-term care patients (post-acute care)
  - Long-term care patients (chronic care)

Quality Mix

- 60% of patients are Medicaid (daily rate $140)
- 20% are Medicare patients for post-acute care (daily rate $500)
- 20% are private-paying patients (daily rate $300-400)

Vertical Differentiation

- The whole industry chases lucrative patients.
- The entire nursing home industry is competitive.
- Many studies find that there is a strong relationship between poor quality and a high percentage of Medicaid residents in nursing homes.

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Model Setup

- A nursing home's staffing problem:

$$\max_{s} V(s) = R(q,\theta) - w * s$$

Vertical Position

Wages ($)

Staffing Level

Revenue ($)/Pt

Quality Level

- Parameterization:

Care Quality

$$Q(r,k) = rk, \qquad R(q,\theta) = 1 - \theta e^{-A\theta q}. \quad \{\partial R/\partial q > 0,\ \partial^2 R/\partial q^2 < 0\}$$

Staff-to-patient ratio

Technology Level

$$0 < \underline{\theta} < \overline{\theta} < \sqrt{\frac{we^2}{Ak}}.$$

Model Analysis

Lemma:

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

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

Proposition 1:

The optimal staffing level s^*, the optimal quality level q^*, and the average revenue per patient $R(q^*, \theta)$ are increasing in θ.

Model Analysis

Proposition 2:

The optimal quality level q^* and the average revenue per patient $R(q^*, \theta)$ are increasing in the automation level k.

Proposition 3:

An increase in automation level leads to **an increase** of a nursing home's staffing level if $\theta < \sqrt{\frac{we}{Ak}}$, but it leads to **a decrease** of a nursing home's staffing level if $\theta > \sqrt{\frac{we}{Ak}}$.

Why?

- Automation -> More productive employees -> hire more!
- Demand is not infinite -> substitution effect -> hire less!

- Low vertical position: revenue expansion strategy
- High vertical position: cost reduction strategy

Hypotheses

- **Hypothesis 1**: An increase in automation level leads to a *decrease* in staff-to-patient ratio for a nursing home with a high vertical position.

- **Hypothesis 2**: An increase in automation level leads to an *increase* in staff-to-patient ratio for a nursing home with a low vertical position.

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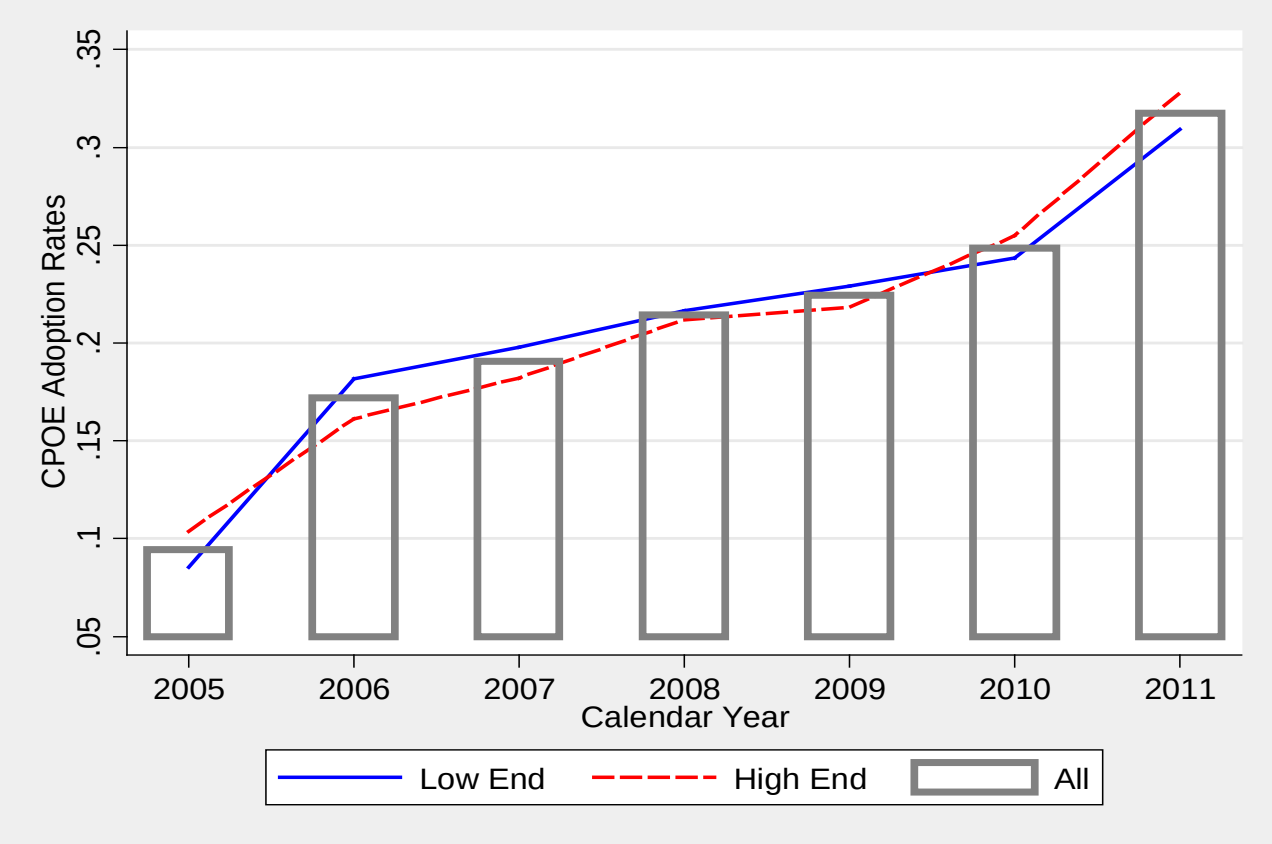
Data

- Data Sources
  - The Online Survey Certificate and Reporting Database (OSCAR) from 2006 to 2012
  - The Health Information Systems Society (HIMSS) from 2005 to 2011

- Key Variables:
  - Staff-to-Patient Ratio: staff hours per patient day (HPRD) for licensed nurses (LNs)
  - Vertical Position

Adoption Rates over Years



Econometrics and Identification

- Average Effect:

$$S_{it} = \alpha_0 + \alpha_1 IT_{i,t-1} + \alpha_2 X_{it} + \alpha_3 Z_{ct} + \alpha_4 State_s * Year_t + \alpha_i + \alpha_t + \varepsilon_{it} \quad (1)$$

- Heterogeneous Effect:

$$S_{it} = \beta_0 + \beta_1 IT_{i,t-1} + \beta_2 IT_{i,t-1} * High\ End_i + \beta_3 X_{it} + \beta_4 Z_{ct} + \beta_5 State_s * Year_t + \beta_i + \beta_t + \varepsilon_{it} \quad (2)$$

- Endogeneity Issues
  - The adoption of CPOE is not randomly assigned.

Instrumental Variable (IV)

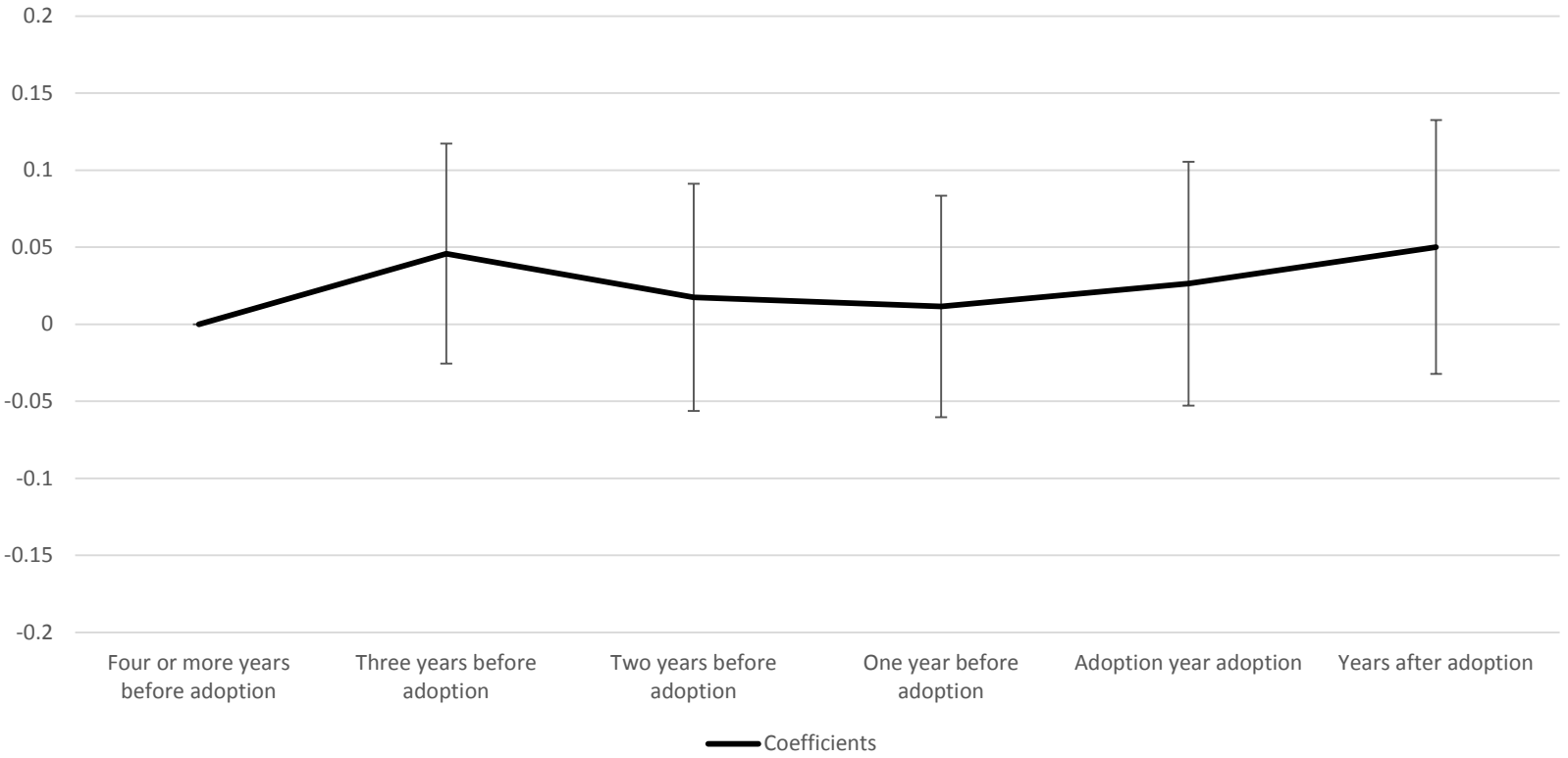
- We construct an instrumental variable, *hospital_CPOE*, describing the yearly hospital CPOE adoption rates in the local market where we define a county as a market.
  - Inclusion criteria
    - First stage: 0.552 (p-value <0.001)
    - Weak IV problem:
      - The Kleibergen-Paap rk Wald F statistics is 622.17, allowing us to easily reject the null hypothesis.
  - Exclusion criteria
    - nurse labor market
    - nursing home staffing

The Impact of Hospital CPOE on Nurse Labor Market

Dependent Variable	State Nurse Supply		State Hospital Nurse Supply		Wage: Hourly Rate (cent)	
Nurse Type	RNs	LPNs	RNs	LPNs	RNs	LPNs
	(1)	(2)	(3)	(4)	(5)	(6)
Hosp_CPOE	-0.001	-0.0002	-0.002	-0.00001	-200.881	-531.14
	(0.001)	(0.001)	(0.001)	(0.001)	(141.867)	(381.591)
State Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Observations	357	354	357	354	356	355
R-squared	0.089	0.026	0.095	0.028	0.279	0.082

The adoption of hospital CPOE has no effect on nurse labor market.

The Impact of Hospital CPOE Adoption on Nursing Home Staffing



The adoption of hospital CPOE has no effect on nurse home staffing.

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Average Effect on Staffing

Dependent Variable:	Average Effect		
LN HPRD	OLS	First Stage	2SLS
	(1)	(2)	(3)
CPOE	0.006		-0.001
	(0.019)		(0.039)
IV: Hospital_CPOE		0.552***	
		(0.022)	
Nursing Home Dummies	Y	Y	Y
Year Dummies	Y	Y	Y
Individual State Linear Trends	Y	Y	Y
Time-varying Controls	Y	Y	Y
Weak Identification Test	Kleibergen-Paap rk Wald F statistic: 622.17***		
Observations	12313	12313	12250
Within R-squared	0.044	0.272	0.044
Number of provider	2119	2119	2056

The adoption of CPOE has no effect on nursing home staffing on average.

Heterogeneous Effect by Vertical Position

Dependent Variable: Hours per patient Day	Licensed Nurses			Registered Nurses	
	Minimum LNs			Minimum RNs	
	OLS	2SLS	2SLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)
CPOE	0.106***	0.282***	0.145***	0.154***	0.073**
	(0.036)	(0.062)	(0.046)	(0.040)	(0.029)
CPOE * Position	-0.065**	-0.172***		-0.145***	
	(0.029)	(0.042)		(0.044)	
CPOE * High End			-0.255***		-0.109**
			(0.071)		(0.047)
Nursing Home Dummies	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y	Y
F test: CPOE+CPOE* High End			-0.110**		-0.036*
Observations	12,313	12,250	12,250	12,250	12,250
Within R-squared	0.046	0.040	0.041	0.057	0.058
Number of provider	2,119	2,056	2,056	2,056	2,056

Robust standard errors in parentheses clustered by nursing home

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

The adoption of CPOE has opposite effects on staffing decisions.

Robustness Checks

Dependent Variable:	Alternative Measures, Controls and Specifications							
LN HPRD	Relative Position	IV NH	IV HSA	IV HRR	Control supply/wage	Control other IT Apps	GMM	Diff-in-Diff (OLS)
(2SLS)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CPOE	0.221***	0.127*	0.103**	0.216**	0.146***	0.147***	0.146***	0.049***
	(0.070)	(0.072)	(0.044)	(0.110)	(0.046)	(0.050)	(0.046)	(0.017)
CPOE * High End	-0.258***	-0.393***	-0.183***	-0.443***	-0.257***	-0.251***	-0.255***	-0.082**
	(0.078)	(0.116)	(0.063)	(0.149)	(0.071)	(0.071)	(0.072)	(0.037)
Time-Varying Controls	Y	Y	Y	Y	Y	Y	Y	Y
Nursing Home Dummies	Y	Y	Y	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y	Y	Y	Y	Y
Observations	12,250	12,408	10,448	10,459	12,237	12,237	12,067	12,313
Within R-squared	0.041	0.032	0.04	0.026	0.041	0.042	0.041	0.044
Number of Providers	2,056	2,061	1,995	1,997	2,056	2,056	2,041	2,119

Effect on Clinical Quality

Dependent Variable: Clinical Quality	Five Star Ratings		
	Ratings on Quality Measures		
	OLS	First Stage	2SLS
	(1)	(2)	(3)
CPOE	0.008		0.198*
	(0.046)		(0.102)
IV: Hospital_CPOE		0.540***	
		(0.025)	
Nursing Home Dummies	Y	Y	Y
Year Dummies	Y	Y	Y
Individual State Linear Trends	Y	Y	Y
Time Varying Controls	Y	Y	Y
Weak Identification Test	Kleibergen-Paap rk Wald F statistic: 241.20***		
Observations	8,634	8,632	8,489
Within R-squared	0.057	0.28	0.054
Number of provider	2,004	2002	1,859

The adoption of CPOE improves patient clinical outcomes as well.

Effects on Patient Composition

Dependent Variable: Log of Daily Admissions	Patient Types			
	Total Admission		Medicaid Admission	
	(1)	(2)	(3)	(4)
CPOE	0.006	0.138	-0.147**	-0.201*
	(0.086)	(0.147)	(0.072)	(0.112)
CPOE * Position		-0.079		0.038
		(0.057)		(0.052)
Nursing Home Dummies	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y
Observations	11,017	11,017	9,548	9,548
Centered R-squared	0.282	0.282	0.055	0.054
Number of provider	1,880	1,880	1,630	1,630

Robust standard errors in parentheses clustered by nursing home
*** p<0.01, ** p<0.05, * p<0.1

The adoption of CPOE decreases the admissions of Medicaid patients by 14.7%.

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Key Findings

- When adopting CPOE:
  - LN staffing level:
    - decreases by 5.8% in high-end nursing homes
    - increases by 7.6% in low-end homes
- Driving Force:
  - Interplay of two competing effects of automation on LN:
    - substitution of technology for labor
    - leveraging of complementarity between technology and labor
- Other IT Outcomes:
  - Improves the ratings on clinical quality by 6.9%
  - Decreases admissions of less profitable residents by 14.7%

Strategic Take Away

- Managers
  - Will your new IT be focusing on revenue expanding or on cost saving?
- Individual Nurses
  - Jobs will constantly shift
  - The vertical position of the nursing home determines the IT impact on employment prospects now
- Policy makers
  - Provide subsidies to encourage proper technology adoption!

Thank You!

Q&A