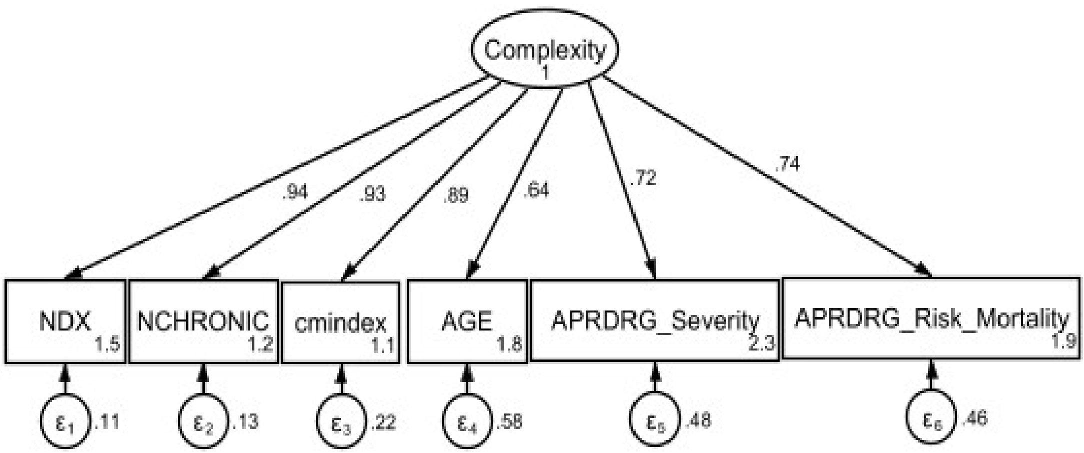
Uncertainty in Healthcare Operations: How Hospitals Weather the Perfect Storm

Appendix A

Figure A-1: Confirmatory Factor Analysis – Complexity of Care



Endogeneity Correction – Instruments, Control Function, and Estimation

As discussed in the manuscript, our empirical model specification includes a host of hospital-, category-, DRG-, time-, and patient-specific fixed intercepts to account for unobserved heterogeneity in the operational characteristics of hospital-departments that may motivate hospital decisions about their *related focus* capability. However, it is conceivable that our controls may not be exhaustive, giving rise to potential endogeneity. As part of a robust specification, we explore an instrumental-variables-based control-function approach for endogeneity correction. We build on prior work (e.g., Berry et al. 1995, Hausman 1996, Nevo 2000, Fan 2013, Berry and Haile 2014) that uses operating characteristics of competitors from other markets as instruments. The key identifying assumption (cf. Hausman 1996) is that hospital-departments in other healthcare markets are faced with supply-side constraints similar to that of the focal hospital-department but exogenous to healthcare outcomes in the focal hospital-department (cf. Nevo 2000), thereby satisfying the relevance and exclusion criteria for valid instruments.

Hospitals in our study sample are located in five states around the eastern region of the U.S. Hospitals from other geographic divisions similar to the hospitals in our sample constitute the 'other-market' hospitals. Similarity is defined using multiple criteria including hospital type (teaching vs. non-teaching, profit status, rural vs. urban, private control) and size, within the same MDC. We then use averaged values of care characteristics—including *focus* at the DRG and category levels, the number of *electives and clinical procedures* offered within the category, and the *mortality rate* in that category across these similar 'other-market' hospitals—as instruments.

For model estimation, we follow a Control Function (CF) approach, which is inherently an instrumental variables method (Petrin and Train 2010, Wooldridge 2015, Papies et al. 2017). In this approach, the exogenous variation induced by the instrumental variables provides separate variation in the residuals, which then serve as the control functions. While the CF approach is similar to a 2SLS estimator, the CF perspective has a couple of attractive features. First, the CF approach produces a simple Hausman (1978) test that compares OLS and 2SLS, testing for endogeneity. Second, the CF approach parsimoniously handles nonlinearity in endogenous explanatory variables such as higher-order and interaction terms. The significant F-statistics in the first-stage regressions are indicative of instrument strength. Additionally, the Anderson Canonical Correlation LM statistic: (1.2e+04, p = 0.000) is further suggestive of the instrument relevance and validity.

Table A-1: MDC – Department Definitions

MDC #	**Definition**
1	Nervous System
2	Eye
3	Ear, Nose, Mouth, And Throat
4	Respiratory System
5	Circulatory System
6	Digestive System
7	Hepatobiliary System and Pancreas
8	Musculoskeletal System and Connective Tissue
9	Skin, Subcutaneous Tissue, and Breast
10	Endocrine, Nutritional, and Metabolic System
11	Kidney and Urinary Tract
12	Male Reproductive System
13	Female Reproductive System
14	Pregnancy, Childbirth, and Puerperium
15	Newborn and Other Neonates (Perinatal Period)
16	Blood and Blood Forming Organs and Immunological Disorders
17	Myeloproliferative Diseases and Disorders (Poorly Differentiated Neoplasms)
18	Infectious and Parasitic Diseases and Disorders
19	Mental Diseases and Disorders
20	Alcohol/Drug Use or Induced Mental Disorders
21	Injuries, Poison, and Toxic Effect of Drugs
22	Burns
23	Factors Influencing Health Status
24	Multiple Significant Trauma
25	Human Immunodeficiency Virus (HIV) Infection

Source: Center for Medicare and Medicaid Services

Table A-2: Comparing DRG-level vs. MDC-level: Effects of Mix- & Volume- Uncertainty

Dependent Variable	NPR		LOS	
Model:	(1)	(2)	(3)	(4)
	DRG-level	MDC-level	DRG-level	MDC-level
Variables				
MU	0.0000146	**0.000459*****	**0.000026****	-0.0000452
	(0.0000213)	(0.000171)	(0.0000115)	(0.0000556)
Rel_Focus	0.120	**-0.806*****	**-0.2793*****	**-0.246*****
	(0.0991)	(0.0993)	(0.0464)	(0.0499)
MU#Rel_Focus	-0.0000286	**-0.000673****	**-0.0000504****	0.0000996
	(0.0000414)	(0.000315)	(0.0000223)	(0.000111)
VU	**-0.0639****	**-0.170*****	-0.0005891	**0.117*****
	(0.0311)	(0.0474)	(0.0157)	(0.0261)
Util	**0.1891*****	0.0240	0.0353	**0.0928*****
	(0.0470)	(0.0498)	(0.0221)	(0.0279)
Util#Util	**-0.1504*****	**-0.0698****	**-0.0249***	**-0.0543*****
	(0.0309)	(0.0282)	(0.0147)	(0.0156)
VU#Util	**0.0958****	**0.246*****	**0.0387****	-0.00427
	(0.0377)	(0.0555)	(0.0192)	(0.0304)
Fixed Effects:				
FE: Comorbidities	✓	✓	✓	✓
FE: Primary DRG	✓	✓	✓	✓
FE: MDC	✓	✓	✓	✓
FE: Hospital	✓	✓	✓	✓
Controls:				
Patient Complexity, Task/Department Focus, Patient Gender, Patient Race, Elective Admission Emergency Admission, Transfer_In, Transfer_Out, Payor, Admission Month, Weekend Admission, Hospital Birth, Disposition at Discharge, Endogeneity Correction				

Standard errors in parentheses

Coefficient estimates of fixed effects and control variables not included for brevity of exposition.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$