

Do Higher Health Insurance Reimbursements Encourage Antibiotic Innovation?: Evidence from Medicare's 2007 DRG Restructuring

Venkatesh (Venki) Subramanian¹
For ASHEcon 2026, Minneapolis, MN.

¹Public Policy and Political Economy,
The University of Texas at Dallas
venkatesh.subramanian@utdallas.edu
<https://venkatsub.com>

June 8, 2026



Research question

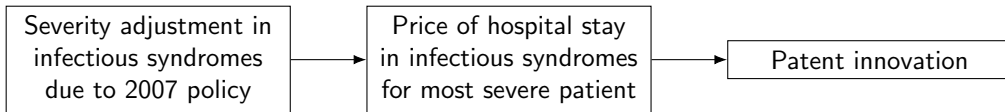
Did the 2007 Medicare Diagnostic-Related Groups (DRG) restructuring policy encourage patent innovation in antibiotics?

Research question

Did the 2007 Medicare Diagnostic-Related Groups (DRG) restructuring policy encourage patent innovation in antibiotics?

- This policy change was a part of Medicare Part A which reimburses eligible inpatients (i.e.) those older than 65 admitted to a hospital.

Empirical Strategy: Two-stage Difference-In-Differences



Results

- *No significant effect on patenting* detected in reduced form or second stage.

Results

- *No significant effect on patenting* detected in reduced form or second stage.
- But *first-stage effect observed*: \$8,584 increase in price of hospital stay per annum for treating the most severe patient with infectious syndromes for 4 years post-policy.

Results

- *No significant effect on patenting* detected in reduced form or second stage.
- But *first-stage effect observed*: \$8,584 increase in price of hospital stay per annum for treating the most severe patient with infectious syndromes for 4 years post-policy.
- Implications:

Results

- *No significant effect on patenting* detected in reduced form or second stage.
- But *first-stage effect observed*: \$8,584 increase in price of hospital stay per annum for treating the most severe patient with infectious syndromes for 4 years post-policy.
- Implications:
 - Is an \$8,584 increase inadequate to encourage antibiotic innovation? (Or)

Results

- *No significant effect on patenting* detected in reduced form or second stage.
- But *first-stage effect observed*: \$8,584 increase in price of hospital stay per annum for treating the most severe patient with infectious syndromes for 4 years post-policy.
- Implications:
 - Is an \$8,584 increase inadequate to encourage antibiotic innovation? (Or)
 - Is there inadequate pass through of hospital charges to the drug manufacturer?

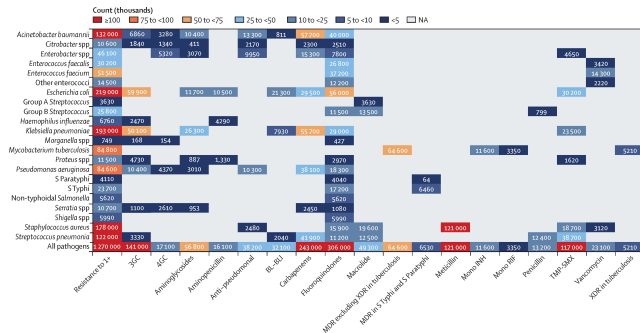
Contributions

- Contribute to the literature on Health Insurance → Health Innovation

Contributions

- Contribute to the literature on Health Insurance → Health Innovation
- Create a data attribution pipeline from insurance categories (DRGs) to patents

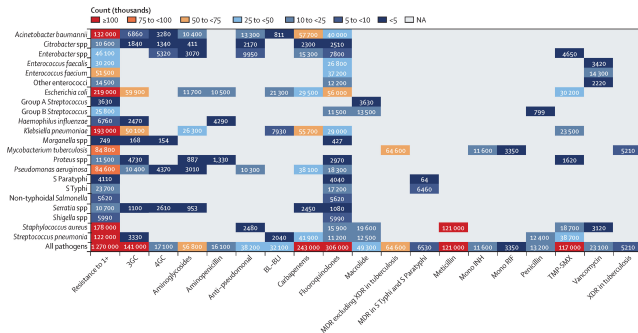
Antimicrobial resistance (AMR)



- Antibiotic usage has negative externalities $\Rightarrow$ Suppressed demand and profits

1.27 million worldwide deaths in 2019 attributed to
Bacterial AMR
(Murray et al. 2022)

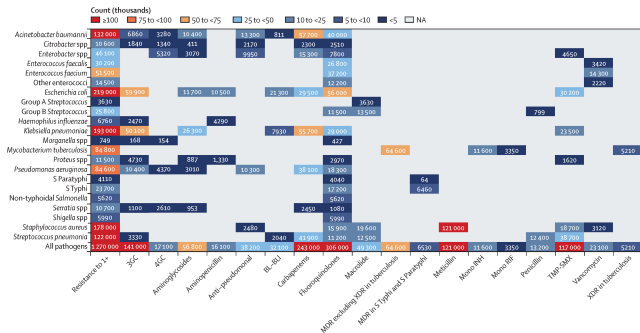
Antimicrobial resistance (AMR)



- Antibiotic usage has negative externalities $\Rightarrow$ Suppressed demand and profits
- Current policy proposals: Use 'pull' incentives to reward novel antibiotics entering the market

1.27 million worldwide deaths in 2019 attributed to
Bacterial AMR
(Murray et al. 2022)

Antimicrobial resistance (AMR)



1.27 million worldwide deaths in 2019 attributed to
Bacterial AMR
(Murray et al. 2022)

- Antibiotic usage has negative externalities $\Rightarrow$ Suppressed demand and profits
- Current policy proposals:* Use 'pull' incentives to reward novel antibiotics entering the market
- My question:* Can this 'pull' incentive reward come in the form of insurance reimbursements to hospitals for treating infectious syndromes?

The 2007 Medicare DRG restructuring policy: Adjusting for severity

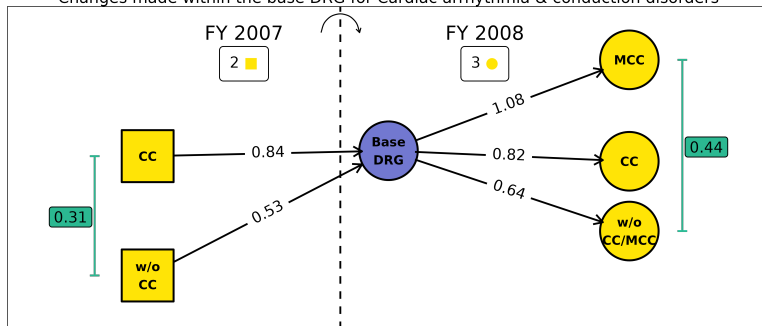
What did the policy do? Created a separate insurance category for inpatients with a severe condition.

The 2007 Medicare DRG restructuring policy: Adjusting for severity

What did the policy do? Created a separate insurance category for inpatients with a severe condition.

An illustration of the 2007 DRG restructuring policy in Medicare Part A

Changes made within the base DRG for Cardiac arrhythmia & conduction disorders



NOTE:
CC = Complication or Comorbidity
MCC = Major CC

SOURCE:

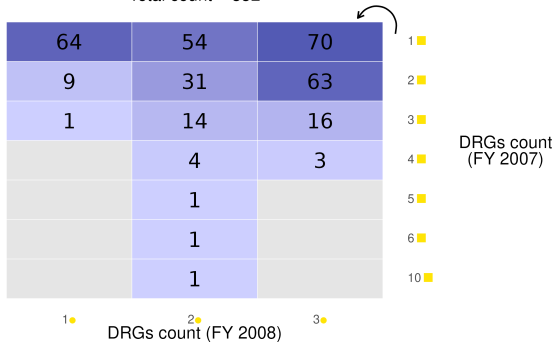
Final Rule for FY08 published in 72 Fed. Reg. 47130 (Aug. 22, 2007) by the Centers for Medicare & Medicaid Services

Summary of all changes from the policy

Summary of changes made in the 2007 DRG restructuring policy

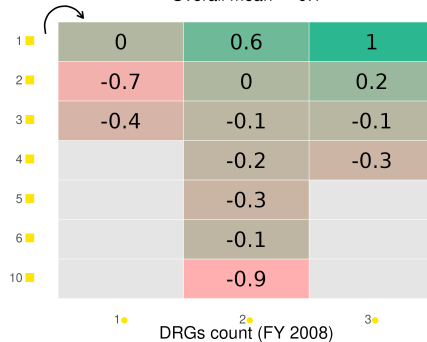
Base DRGs count

Total count = 332

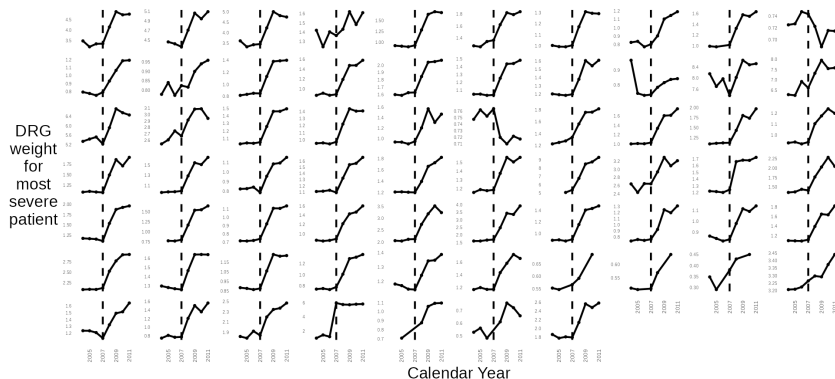


Mean expansion of weights in FY 2008

Overall mean = -0.1

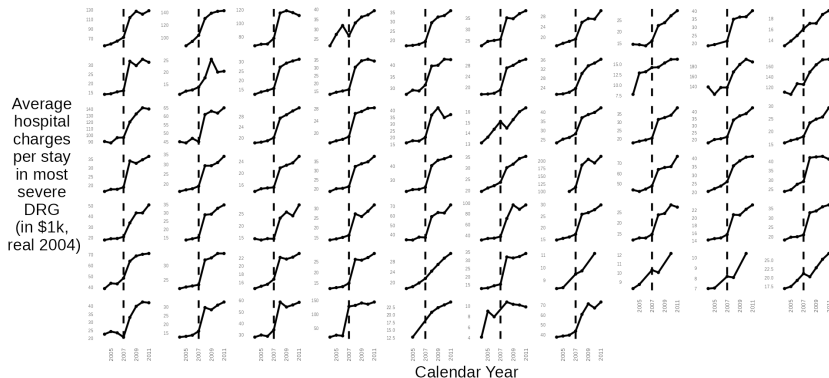


Variation in Encouragement variable: Weight of the DRG for the most severe patient



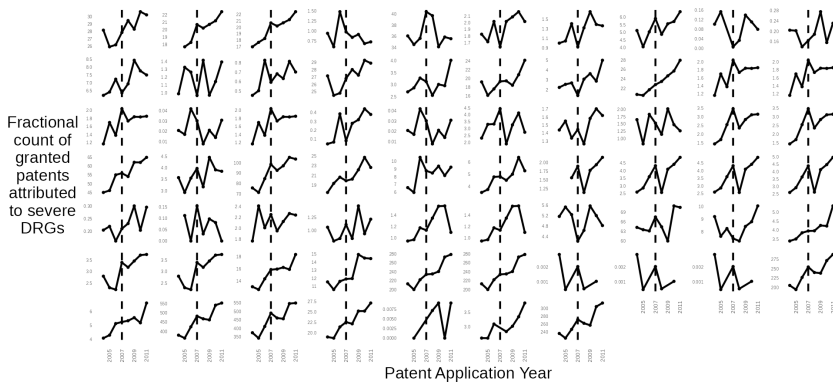
■ Data source:
Federal
Register
Final Rule
documents

Variation in Treatment variable: Average Hospital Charges per Stay (Price of Stay) for treating the most severe patient



- Real 2004, \$1k
- Data source: Nationwide Inpatient Sample (NIS) from AHRQ

Variation in Outcome variable: Granted Patents until 2021 indexed at application year



- But how are patents attributed to DRGs?

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes
 - Use **SureChEMBL** (Papadatos et al. 2016) to get the Medical Subject Headings (MeSH) annotations of patents.

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes
 - Use **SureChEMBL** (Papadatos et al. 2016) to get the Medical Subject Headings (MeSH) annotations of patents.
- **Step 2:** MeSH codes → ICD codes

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes
 - Use **SureChEMBL** (Papadatos et al. 2016) to get the Medical Subject Headings (MeSH) annotations of patents.
- **Step 2:** MeSH codes → ICD codes
 - Use the Unified Medical Language System (UMLS) (Bodenreider 2004).

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes
 - Use **SureChEMBL** (Papadatos et al. 2016) to get the Medical Subject Headings (MeSH) annotations of patents.
- **Step 2:** MeSH codes → ICD codes
 - Use the Unified Medical Language System (UMLS) (Bodenreider 2004).
- **Step 3:** ICD codes → DRGs

Patent → DRG attribution pipeline

- **Step 1:** Patents → MeSH codes
 - Use **SureChEMBL** (Papadatos et al. 2016) to get the Medical Subject Headings (MeSH) annotations of patents.
- **Step 2:** MeSH codes → ICD codes
 - Use the Unified Medical Language System (UMLS) (Bodenreider 2004).
- **Step 3:** ICD codes → DRGs
 - CMS defines DRGs based on ICD codes

Data summary

Variable	Pre-policy percentiles					Post-policy percentiles				
	0%	25%	50%	75%	100%	0%	25%	50%	75%	100%
<i>Policy variable of interest</i>										
DRG weight of most severe patient	0.3	0.8	1.1	1.4	8.2	0.4	1.2	1.5	2.1	9.3
<i>Hospital Charges (real 2004 dollars) in most severe DRG</i>										
Avg. per stay (in \$1k)	4.1	14.9	19.0	26.4	139.1	8.1	27.0	33.4	43.2	214.4
<i>Patents attributed to most severe DRG</i>										
Fractionalized counts	0.0	1.2	3.2	18.2	489.3	0.0	1.5	3.7	20.7	553.5
Attributed via Claims/Abs./Title	0.0	0.1	0.4	2.5	114.1	0.0	0.1	0.4	2.3	98.0
Containing chemical compounds	0.0	1.1	3.2	16.6	464.8	0.0	1.4	3.7	16.4	559.3
Containing antibiotic compounds	0.0	0.1	0.2	1.1	30.7	0.0	0.1	0.3	1.5	41.4

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.
- Reduced form specification:

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times MaxWt_{gt} \right] + \epsilon_{gt}$$

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.
- Reduced form specification:

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times MaxWt_{gt} \right] + \epsilon_{gt}$$

- Base DRG g and calendar year t

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.
- Reduced form specification:

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times MaxWt_{gt} \right] + \epsilon_{gt}$$

- Base DRG g and calendar year t
- y_{gt} is the fractionalized count of granted patent counts

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.
- Reduced form specification:

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times MaxWt_{gt} \right] + \epsilon_{gt}$$

- Base DRG g and calendar year t
- y_{gt} is the fractionalized count of granted patent counts
- α_g, α_t are the base-DRG, and year specific fixed effects, respectively.

Empirical strategy

- **Assumption:** Parallel trends across base DRGs in hospital charges, and patent innovation absent the DRG restructuring policy.
- Reduced form specification:

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times MaxWt_{gt} \right] + \epsilon_{gt}$$

- Base DRG g and calendar year t
- y_{gt} is the fractionalized count of granted patent counts
- α_g, α_t are the base-DRG, and year specific fixed effects, respectively.
- $MaxWt_{gt}$ is the weight of the most severe DRG within base DRG g .

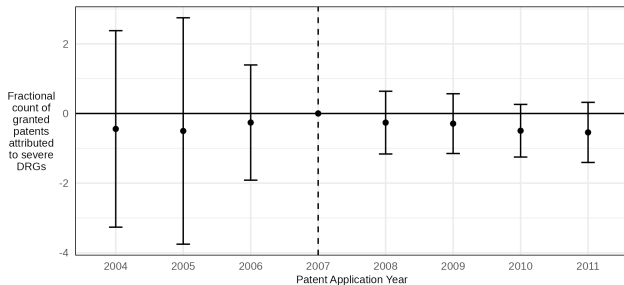
Two-stage DiD Design

To understand the mechanisms that drive the effect here, I also propose a two-stage DiD estimation process.

$$y_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times z_{gt} \right] + \epsilon_{gt}$$
$$z_{gt} = \alpha_g + \alpha_t + \left[\sum_{\substack{t=2004 \\ t \neq 2007}}^{2011} \beta_t \times I_t \times \text{MaxWt}_{gt} \right] + \epsilon_{gt}$$

where now z_{gt} is the average hospital charges per stay (price of stay).

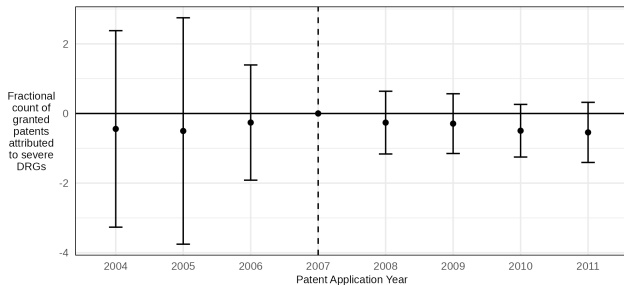
Reduced-form effect of DRG Weight of the most severe patient on patenting



- Patents counts fractionalized to avoid double counting

I do not find a statistically significant effect.

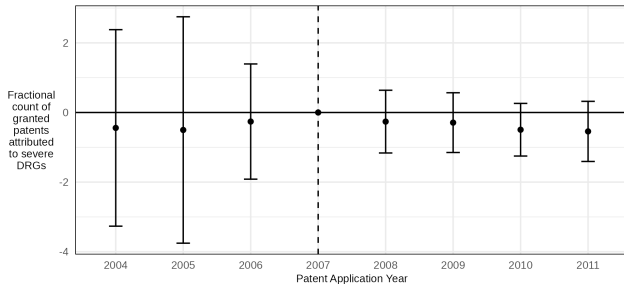
Reduced-form effect of DRG Weight of the most severe patient on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.

I do not find a statistically significant effect.

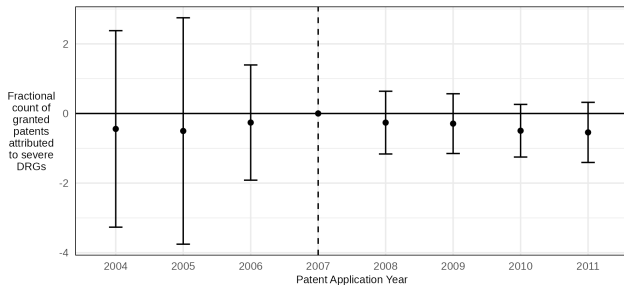
Reduced-form effect of DRG Weight of the most severe patient on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.

I do not find a statistically significant effect.

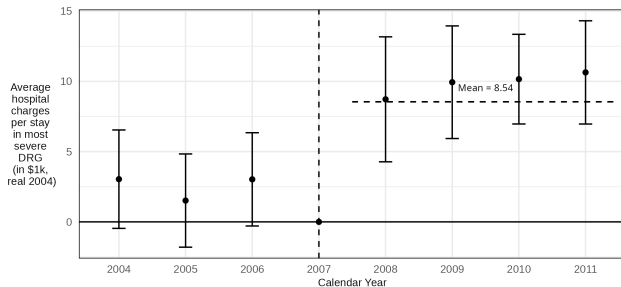
Reduced-form effect of DRG Weight of the most severe patient on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.
- 95% confidence intervals with base-DRG-clustered SE.

I do not find a statistically significant effect.

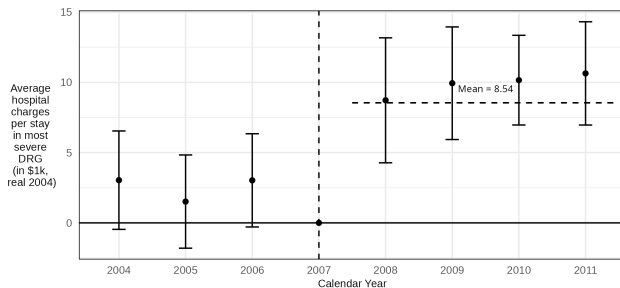
First-stage effect of DRG Weight of the most severe patient on price of stay



- Dashed line indicates the reference year 2007.

I observed an average increase in the average hospital charges per stay by \$8,584 per annum for the most-severe patient across antibiotic base DRGs, 4 years post-policy.

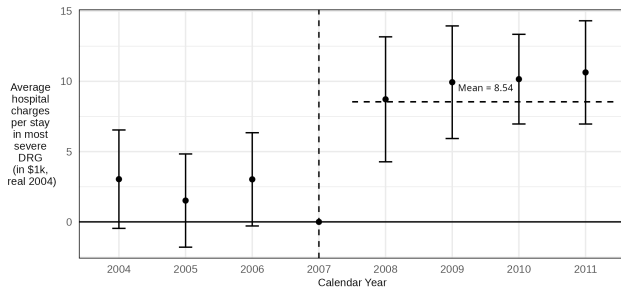
First-stage effect of DRG Weight of the most severe patient on price of stay



- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.

I observed an average increase in the average hospital charges per stay by \$8,584 per annum for the most-severe patient across antibiotic base DRGs, 4 years post-policy.

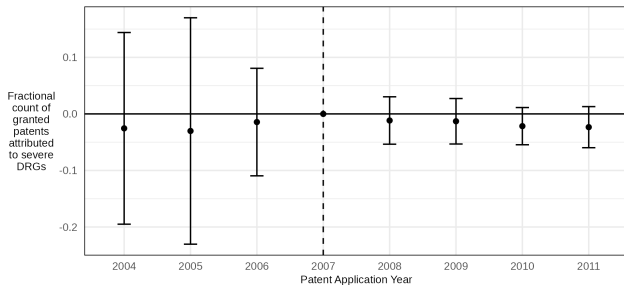
First-stage effect of DRG Weight of the most severe patient on price of stay



- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.
- 95% confidence intervals with base-DRG-clustered SE.

I observed an average increase in the average hospital charges per stay by \$8,584 per annum for the most-severe patient across antibiotic base DRGs, 4 years post-policy.

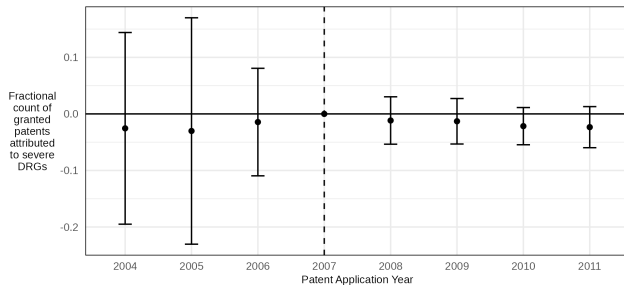
Second-stage effect of price of stay on patenting



- Patents counts fractionalized to avoid double counting

I still do not find a statistically significant effect.

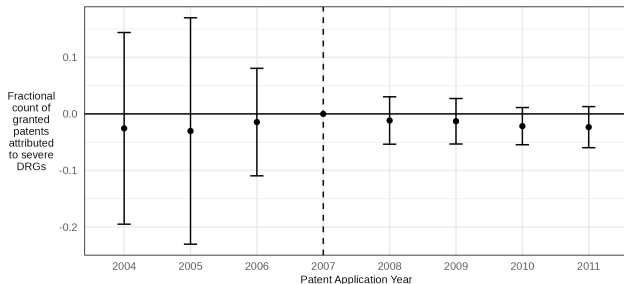
Second-stage effect of price of stay on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.

I still do not find a statistically significant effect.

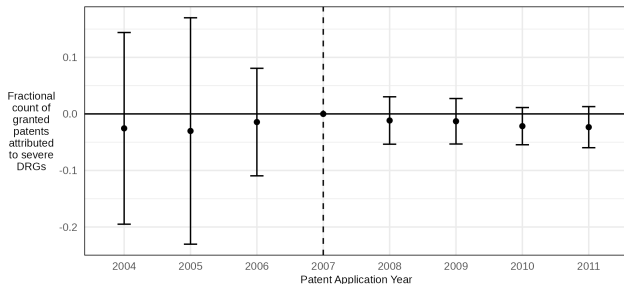
Second-stage effect of price of stay on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.

I still do not find a statistically significant effect.

Second-stage effect of price of stay on patenting



- Patents counts fractionalized to avoid double counting
- Dashed line indicates the reference year 2007.
- Base DRG and Year Fixed effects included.
- 95% confidence intervals with base-DRG-clustered SE.

I still do not find a statistically significant effect.

Effect on alternative measures of patenting

Dep: Fractional count of granted patents attributed to severe DRGs containing. . .

...MeSH codes of antibiotic DRGs in claims or abstract or title only ...a chemical compound ...an antibiotic drug compound

- Independent variable is instrumented.

Average hospital chargers per stay X 2008 (in real 2004, \$1k)	-0.002 (0.006)	-0.011 (0.021)	-0.000 (0.001)
Average hospital chargers per stay X 2009 (in real 2004, \$1k)	-0.001 (0.005)	-0.019 (0.021)	-0.002 (0.001)
Average hospital chargers per stay X 2010 (in real 2004, \$1k)	0.001 (0.004)	-0.029 (0.022)	-0.001 (0.002)
Average hospital chargers per stay X 2011 (in real 2004, \$1k)	-0.001 (0.003)	-0.038 (0.029)	-0.002 (0.005)
Observations	518	518	518
R2	0.99	0.98	0.97
Outcome Mean (SDev)	6.5 (17.3)	39.9 (98.5)	2.6 (6.5)

No statistically significant effect in alternative measures either.

Effect on alternative measures of patenting

Dep: Fractional count of granted patents attributed to severe DRGs containing. . .

...MeSH codes of antibiotic DRGs in claims or abstract or title only

...a chemical compound

...an antibiotic drug compound

Average hospital chargers per stay X 2008 (in real 2004, \$1k)	-0.002 (0.006)	-0.011 (0.021)	-0.000 (0.001)
Average hospital chargers per stay X 2009 (in real 2004, \$1k)	-0.001 (0.005)	-0.019 (0.021)	-0.002 (0.001)
Average hospital chargers per stay X 2010 (in real 2004, \$1k)	0.001 (0.004)	-0.029 (0.022)	-0.001 (0.002)
Average hospital chargers per stay X 2011 (in real 2004, \$1k)	-0.001 (0.003)	-0.038 (0.029)	-0.002 (0.005)
Observations	518	518	518
R2	0.99	0.98	0.97
Outcome Mean (SDev)	6.5 (17.3)	39.9 (98.5)	2.6 (6.5)

- Independent variable is instrumented.
- Chemical compounds data from SureChEMBL, and antibiotic drug compounds data from AntibioticDB.

No statistically significant effect in alternative measures either.

Effect on alternative measures of patenting

Dep: Fractional count of granted patents attributed to severe DRGs containing. . .

...MeSH codes of antibiotic DRGs in claims or abstract or title only

...a chemical compound

...an antibiotic drug compound

Average hospital chargers per stay X 2008 (in real 2004, \$1k)	-0.002 (0.006)	-0.011 (0.021)	-0.000 (0.001)
Average hospital chargers per stay X 2009 (in real 2004, \$1k)	-0.001 (0.005)	-0.019 (0.021)	-0.002 (0.001)
Average hospital chargers per stay X 2010 (in real 2004, \$1k)	0.001 (0.004)	-0.029 (0.022)	-0.001 (0.002)
Average hospital chargers per stay X 2011 (in real 2004, \$1k)	-0.001 (0.003)	-0.038 (0.029)	-0.002 (0.005)
Observations	518	518	518
R2	0.99	0.98	0.97
Outcome Mean (SDev)	6.5 (17.3)	39.9 (98.5)	2.6 (6.5)

- Independent variable is instrumented.
- Chemical compounds data from SureChEMBL, and antibiotic drug compounds data from AntibioticDB.
- Base DRG and Year Fixed effects included.

No statistically significant effect in alternative measures either.

Effect on alternative measures of patenting

Dep: Fractional count of granted patents attributed to severe DRGs containing. . .

...MeSH codes of antibiotic DRGs in claims or abstract or title only

...a chemical compound

...an antibiotic drug compound

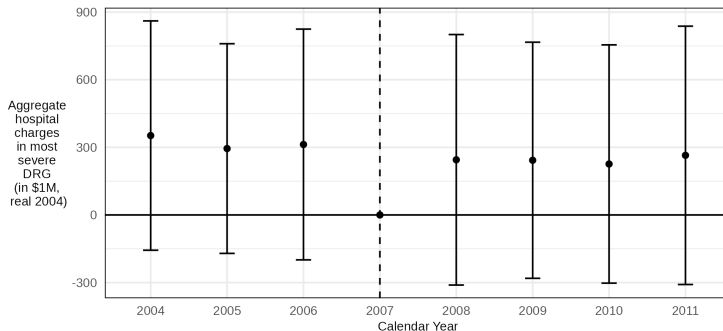
Average hospital chargers per stay X 2008 (in real 2004, \$1k)	-0.002 (0.006)	-0.011 (0.021)	-0.000 (0.001)
Average hospital chargers per stay X 2009 (in real 2004, \$1k)	-0.001 (0.005)	-0.019 (0.021)	-0.002 (0.001)
Average hospital chargers per stay X 2010 (in real 2004, \$1k)	0.001 (0.004)	-0.029 (0.022)	-0.001 (0.002)
Average hospital chargers per stay X 2011 (in real 2004, \$1k)	-0.001 (0.003)	-0.038 (0.029)	-0.002 (0.005)
Observations	518	518	518
R2	0.99	0.98	0.97
Outcome Mean (SDev)	6.5 (17.3)	39.9 (98.5)	2.6 (6.5)

- Independent variable is instrumented.
- Chemical compounds data from SureChEMBL, and antibiotic drug compounds data from AntibioticDB.
- Base DRG and Year Fixed effects included.
- SE clustered at base DRG level.

No statistically significant effect in alternative measures either.

Implication 1: Was the first stage effect big enough incentive?

Maybe not. I can't detect an increase in aggregate charges!



But how much is a big enough incentive? This requires data on cost of innovation at DRG-level to answer.

Implication 2: Pass through was not enough

Harder to argue for/against this implication.

- Data on DRG-level disambiguated cost centers (drugs, beds etc.) not available.
- HCRIS disambiguates cost-centres only by provider and not DRG!

I discuss my contribution by comparing against two existing works...

Contrasting my work against Azoulay, Heggeness, and Kao (2025)

The Medicare Part A reimbursement mechanism (Azoulay, Heggeness, and Kao 2025)

The payment from the Prospective Payment System (*PPS*) received by a hospital h for providing the product bundle represented by DRG d for a discharge completed in fiscal year t can be denoted as the function:

$$PPS_{h,d,t} = f(\text{Base rate}_t, \text{DRG weight}_{d,t}, \text{Wage index}_{h,t}, \text{Adjustments}_{h,t})$$

► Specific example

Azoulay, Heggeness, and Kao (2025)

- IV: $g(\text{Adjustments}_{h,t})$ due to Balanced budget Act of 1997
- DV: NIH grants of Academic Medical Centers

Me

- IV: $h(\text{Base rate}_t, \text{DRG weight}_{d,t})$ due to DRG restructuring of 2007
- DV: Patent innovation relevant to the DRG

Contrasting against Cook and Averett (2020)

- Cook and Averett (2020) study the impact of the 2007 DRG restructuring as I do here.
- Their outcome is upcoding by hospitals (provider behavior) while I study patent innovation (innovator behavior).

Summary

Research question

Did the 2007 Medicare Diagnostic-Related Groups (DRG) restructuring policy encourage patent innovation in antibiotics?

Empirical Strategy: Two-stage Difference-In-Differences

Severity adjustment in infectious syndromes due to 2007 policy



Price of hospital stay in infectious syndromes for most severe patient



Patent innovation

Results

- *No significant effect on patenting* detected in reduced form or second stage.
- But *first-stage effect* of \$8,584 increase in price of hospital stay per annum for treating the most severe infectious syndrome patient for 4 years post-policy.

Thank You!

Venkatesh (Venki) Subramanian¹

For ASHEcon 2026, Minneapolis, MN.

¹Public Policy and Political Economy,

The University of Texas at Dallas

`venkatesh.subramanian@utdallas.edu`

`https://venkatsub.com`

Appendix: Example of reimbursement calculation

The Office of Evaluation and Inspections (2001)

Hypothetical patient at Generic Hospital in San Francisco, CA, DRG 482, HIP & FEMUR PROCEDURES EXCEPT MAJOR JOINT W/O CC/MCC (2001) ^{[19]:8}	
Description	Value
Average length of stay	3.8 ^[20]
Large urban labor-related rate	\$2,809.18
Large urban non-labor-related	\$1,141.85
Wage index	1.4193
Standard Federal Rate: labor * wage index + non-labor rate	\$5,128.92
DRG relative weight (RW) factor	1.8128
Weighted payment: Standard Federal Rate * DRG RW	\$9,297.71
Disproportionate Share Payment (DSH)	0.1413
Indirect medical education (IME)	0.0744
Total cost outlier reimbursement	\$0
Total operating payment: Weighted payment * (1 + IME + DSH)	\$11,303.23