Short-term Fluctuations in Hospital Demand: Implications for Admission, Discharge, and Discriminatory Behavior

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Presentation for:
Applied Microeconomics Workshop
Yale University, April 6, 2006.

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Outline

I. Background and motivation.
II. Key results.
III. Elements of theoretical model.
IV. Results from the model.
V. Empirical Approach and related issues.
VI. Empirical evidence.
VII. Conclusion and directions for future research.

I. Background:

- Stochastic demand is a key feature of hospital operations.
- Implications for costs, capacity requirements.
- Examples: Cost of empty beds, impact of variance in demand/occupancy on hospital costs.
- Anti-trust Framework: Implications for hospital competition, mergers, acquisitions, closures, expansions.
- Forecasting hospital demand.

Motivation: Fluctuations in demand may have direct implications for hospital behavior.

- Hospital may have to be selective in which patients it will admit, and which current inpatients it will retain. A large OR literature examines strategies for optimal use of hospital capacity in the face of excess demand.
- Existing economic literature focuses on long-term issues.
- Focus on capacity constraints: Compare behavior when capacity constraints bind to behavior when hospital has ample capacity.

II. Key Results:

- Develops a new test for discrimination based on differences in hospital behavior on days with and without binding capacity constraints.
- Shows that regression or other analyses of differences in mean effects may be ill-suited to detect discrimination.
- Develops a simple proxy measure for the expected additional stay of current inpatients.
- Finds discharge behavior consistent with discrimination against OHP/Medicaid patients.

III. Elements of model: Patients

- Patients seeking care differ in expected resource requirements in treatment (LOS and intensity of treatment). E.g., Medicare's Diagnosis-Related Group (DRG) system. $t \in [t_{min}, t_{max}]$
- Current inpatients differ in the marginal benefit they will derive from an additional day in the hospital. $v \in [v_{min}, v_{max}]$
- Patients belong to two plans: Plan X pays more than plan Y, both plans pay prospectively (lumpsum; proportionate to expected resource requirement).

Elements of model: Hospital

- Hospital prefers to admit plan X patients, and patients with higher expected resource requirement. Prefers to retain plan X patients, and patients with higher marginal benefit of additional hospital day.
- Timing: At the beginning of each day, hospital learns the number and distribution of current inpatients, as well as of patients seeking care that day. Then, it simultaneously decides which patients it will admit, and which current inpatients it will discharge.

Elements of model: Discrimination

- Admission behavior discriminatory if there exists t such that hospital admits plan X patients with resource requirement t, but not plan Y patients with the same resource requirement.
- Discharge behavior discriminatory if there exists v such that the hospital discharges plan Y patients who derive marginal benefit v from an additional inpatient day, but retains plan X patients who derive the same marginal benefit.

Hospital's objective function:

$$\max_{t_{ix},t_{iy},v_{ix},v_{iy}} \; s_{ix}\int_{t_{ix}}^{t_{\max}}[\alpha(r_x-c)t+(1-\alpha)\beta_x B(t)]f_{ix}(t)dt+s_{iy}\int_{t_{iy}}^{t_{\max}}[\alpha(r_y-c)t+(1-\alpha)\beta_y B(t)]f_{iy}(t)dt$$

$$+n_{ix}\int_{v_{ix}}^{v_{\max}}(\beta_x v-\alpha c_v)h_{ix}(v)dv+n_{iy}\int_{v_{iy}}^{v_{\max}}(\beta_y v-\alpha c_v)h_{iy}(v)dv.$$

Capacity constraint:

$$C-(s_{ix}\int_{t_{ix}}^{t_{\max}}f_{ix}(t)dt+s_{iy}\int_{t_{iy}}^{t_{\max}}f_{iy}(t)dt+n_{ix}\int_{v_{ix}}^{v_{\max}}h_{ix}(v)dv+n_{iy}\int_{v_{iy}}^{v_{\max}}h_{iy}(v)dv)\geq 0$$

Lagrangian for hospital's problem:

$$\mathrm{L} = s_{ix}\int_{t_{ix}}^{t_{\max}}[\alpha(r_x - c)t + (1-\alpha)\beta_x B(t)]f_{ix}(t)dt + s_{iy}\int_{t_{iy}}^{t_{\max}}[\alpha(r_y - c)t + (1-\alpha)\beta_y B(t)]f_{iy}(t)dt$$

$$+ n_{ix}\int_{v_{ix}}^{v_{\max}}(\beta_x v - \alpha c_v)h_{ix}(v)dv + n_{iy}\int_{v_{iy}}^{v_{\max}}(\beta_y v - \alpha c_v)h_{iy}(v)dv$$

$$+ \lambda[C - (s_{ix}\int_{t_{ix}}^{t_{\max}} f_{ix}(t)dt + s_{iy}\int_{t_{iy}}^{t_{\max}} f_{iy}(t)dt + n_{ix}\int_{v_{ix}}^{v_{\max}} h_{ix}(v)dv + n_{iy}\int_{v_{iy}}^{v_{\max}} h_{iy}(v)dv)]$$

$$+ \mu_x(t_{ix} - t_{\min}) + \mu_y(t_{iy} - t_{\min}) + \gamma_x(v_{ix} - v_{\min}) + \gamma_y(v_{iy} - v_{\min}).$$

IV. Results from the model: Proposition 1.

Suppose $C-(s_{ix}\int_{t_{ix}^*}^{t_{\max}} f_{ix}(t)dt + s_{iy}\int_{t_{iy}^*}^{t_{\max}} f_{iy}(t)dt + n_{ix}\int_{v_{ix}}^{v_{\max}} h_{ix}(v)dv + n_{iy}\int_{v_{iy}}^{v_{\max}} h_{iy}(v)dv) < 0$

where $t_{ix}^* = t_{\min}$ and $t_{iy}^* \geq t_{\min}$. Then:

(i) if $0 < \lambda \leq \alpha(r_x - c)t_{\min} + (1-\alpha)\beta_x B(t_{\min})$, then $t_{iy}^c > t_{iy}^* \geq t_{\min}$ and $t_{ix}^c = t_{ix}^* = t_{\min}$;

(ii) if $\lambda > \alpha(r_x - c)t_{\min} + (1-\alpha)\beta_x B(t_{\min})$, then $t_{iy}^c > t_{iy}^* \geq t_{\min}$ and $t_{ix}^c > t_{ix}^* = t_{\min}$; and

(iii) $t_{iy}^c > t_{ix}^c$.

Predictions from the model:

- When admissions are affected by binding capacity constraint, hospital will restrict admissions to patients whose resource requirements exceed a certain threshold.
- When discharges are affected, the hospital will only retain current inpatients whose marginal benefit of additional stay exceeds a certain threshold.
- Discrimination=> thresholds higher & impact of constraints felt first for plan Y patients.
- Binding constraint=> admissions and discharges with higher t and v in the sense of FOSD.

Results from the model: Corollary 2 (part 1).

Let $D_{ij}(t) \equiv G_{ij}(t) - G_{ij}^{c}(t)$ for $j \in \{x, y\}$ and all $\mathrm{t} \in [\mathrm{t}_{\min}, \mathrm{t}_{\max}]$.

(i) If $0 < \lambda \leq \alpha(r_x - c)t_{\min} + (1-\alpha)\beta_x B(t_{\min})$, then

(i - a) $G_{ix}(t) = G_{ix}^{c}(t)$ for all $\mathrm{t} \in [\mathrm{t}_{\min}, \mathrm{t}_{\max}]$, $D_{ix}(t) = 0$ for all $\mathrm{t} \in [\mathrm{t}_{\min}, \mathrm{t}_{\max}]$, and

$$\int_{t_{\min}}^{t_{\max}} t g_{ix}(t)dt = \int_{t_{\min}}^{t_{\max}} t g_{ix}^{c}(t)dt. \text{ And,}$$

(i - b) $G_{iy}(t) > G_{iy}^{c}(t)$ for all $\mathrm{t} \in (\mathrm{t}_{\min}, \mathrm{t}_{\max})$, $D_{iy}(t) > 0$ for all $\mathrm{t} \in (\mathrm{t}_{\min}, \mathrm{t}_{\max})$, and

$$\int_{t_{\min}}^{t_{\max}} t g_{iy}(t)dt < \int_{t_{\min}}^{t_{\max}} t g_{iy}^{c}(t)dt.$$

Results from the model: Corollary 2 (part 2).

(ii) If $\lambda > \alpha(r_x - c)t_{\min} + (1-\alpha)\beta_x B(t_{\min})$, then

(ii-a) for $j \in \{x, y\}$, $G_{ij}(t) > G_{ij}^c(t)$ for all $t \in (t_{\min}, t_{\max})$, $D_{ij}(t)$ for all $t \in (t_{\min}, t_{\max})$,

and $\int_{t_{\min}}^{t_{\max}} t g_{ij}(t)dt < \int_{t_{\min}}^{t_{\max}} t g_{ij}^c(t)dt$. And,

(ii-b) $D_{ij}(t)$ is maximized when $t = t_{ij}^c$ for $j \in \{x, y\}$. If the hospital discriminates against patients from plan y in admissions, then the value of t that maximizes $D_{iy}(t)$ will be greater than the value of t that maximizes $D_{ix}(t)$.

Test of Discriminatory behavior:

- When marginal impact of capacity constraint is small, only plan Y patients are affected (higher *t* and *v* in the sense of FOSD).
- When marginal impact of capacity constraint is large, patients for both plans are affected (higher *t* and *v* in the sense of FOSD). Plan Y patients affected over larger range of *t* and *v*. => When distributions of admissions and discharges without and with capacity constraints are compared, maximum difference in CDFs will arise at higher *t* and *v* for plan Y patients than for plan X patients.

Key features of test:

- Basis of comparison: behavior without and with binding capacity constraint on otherwise similar days; no direct comparison of patients from different plans. =>no need to control for differences across patient groups.
- Difference observable in *admitted* patients.
- Because characteristics of days (day of week; month; holiday; beginning, end or middle of month) are much easier to observe than patient characteristics (health status, health seeking behavior), they are easier to account for in analysis.

Causes of daily variance in hospital demand:

- Patient/staff preferences in scheduling.
- Schedules of physicians’ offices/outpatient clinics.
- Variance in incidence/severity of disease.
- Variance in care seeking behavior.
- Beginning, middle, end of month also potential factors.
- Random variance.

V. Empirical Approach:

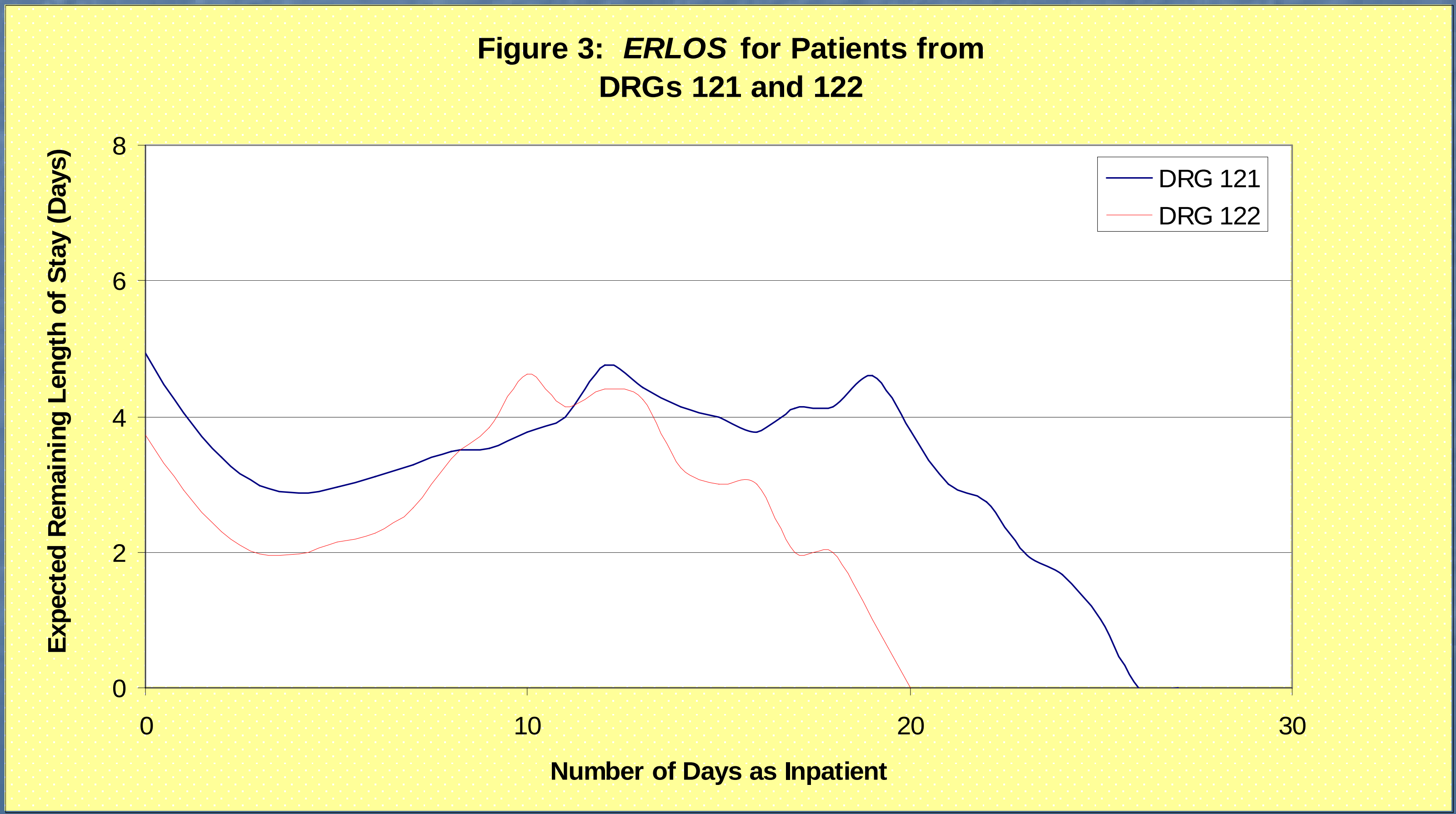
- Data on 381,499 patients discharged from Oregon hospitals between 12/1/97 and 11/30/98.
- Medicare DRG relative weight used as proxy for resource requirement in treatment.
- Expected remaining length of stay (*ERLOS*) used as proxy for marginal benefit of additional day in the hospital.
- Compare admissions and discharges of Medicaid patients to those of Medicare and privately insured patients.

Detour: Defining *ERLOS*

- Expected additional hospital stay will increase with the marginal benefit the patient derives from additional stay.
- Measure must account for type of illness necessitating hospitalization, and progression of illness and treatment since admission. We use DRG and number of days a patient has already been in the hospital.
- Measure based on state-wide experience (excluding transfers).

$$ERLOS_{DYk} = \sum_{l-k}^{n} (l-k)\left[\frac{NDY_{l-1} - NDY_{l}}{NDY_{k}}\right]$$

ERLOS for patients admitted for criculatory disorders with acute myocardial infarction with (121) and without (122) major complications.



Empirical Approach: Discrimination and analyses of differences in mean effects

Resource requirement	Scenario 1		Scenario 2	
	$f_x(t)$	$f_y(t)$	$f_x(t)$	$f_y(t)$
1	0.1	0.2	0.1	0.05
2	0.4	0.3	0.1	0.05
3	0.4	0.3	0.2	0.45
4	0.1	0.2	0.6	0.45

Scenario 1: Mean_x W/o const=2.5; Mean_y W/o const=2.5;

Mean_x W/const=2.67; Mean_y W/const=2.88;

Scenario 2: Mean_x W/o const=3.3; Mean_y W/o const=3.3;

Mean_x W/const=3.56; Mean_y W/const=3.5;

Accounting for differences between days

- Analyze Thursdays only.
- Adjust *ERLOS* at discharge for month of year and week of month.
- Drop Thanksgiving, Christmas, New Years Day.
- Shortcoming—No within DRG variance in DRG relative weights => Unable to account for seasonal, week of month effects in analysis of admissions.

Some other empirical issues:

- How do we detect times when hospitals have insufficient capacity?
- Capacity constraints apply whenever the quantity of any input necessary in treatment is insufficient for the patients the hospital would like to treat.
- Is capacity a hospital-wide, chain-wide, or market-wide phenomenon?

Our solution: Multiple approaches to identifying days when hospitals may have inadequate capacity.

We report results that arise when:

-Assume that each hospital serves a market comprising all hospitals within a 15 mile radius.

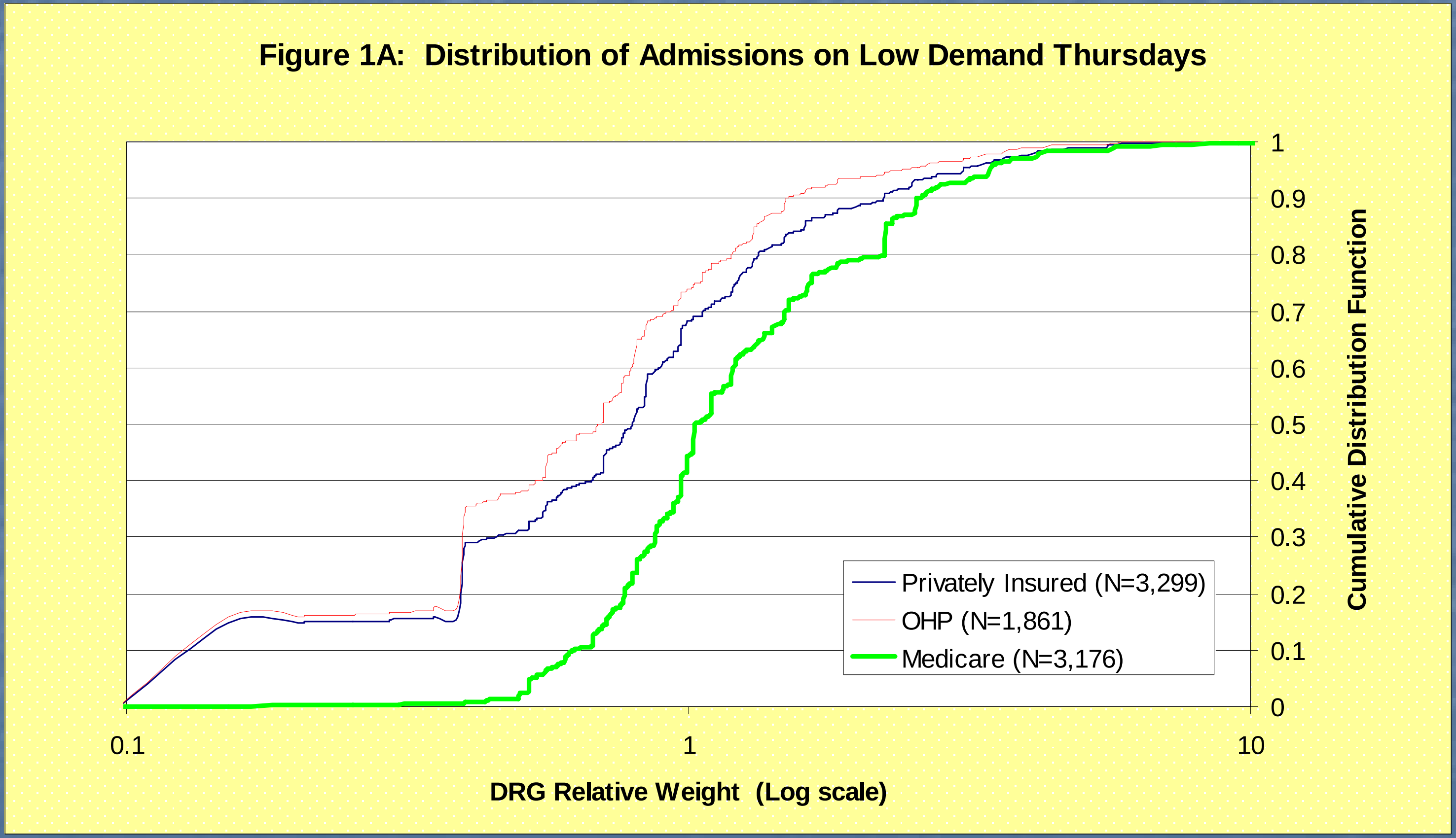
-Identify the 20% of Wednesdays with highest and lowest cumulative DRG relative weight counts in a hospital's market as, respectively, preceding high and low demand Thursdays for that hospital.

-Assume that hospital has sufficient capacity on low demand days, but may face capacity constraints on high demand days.

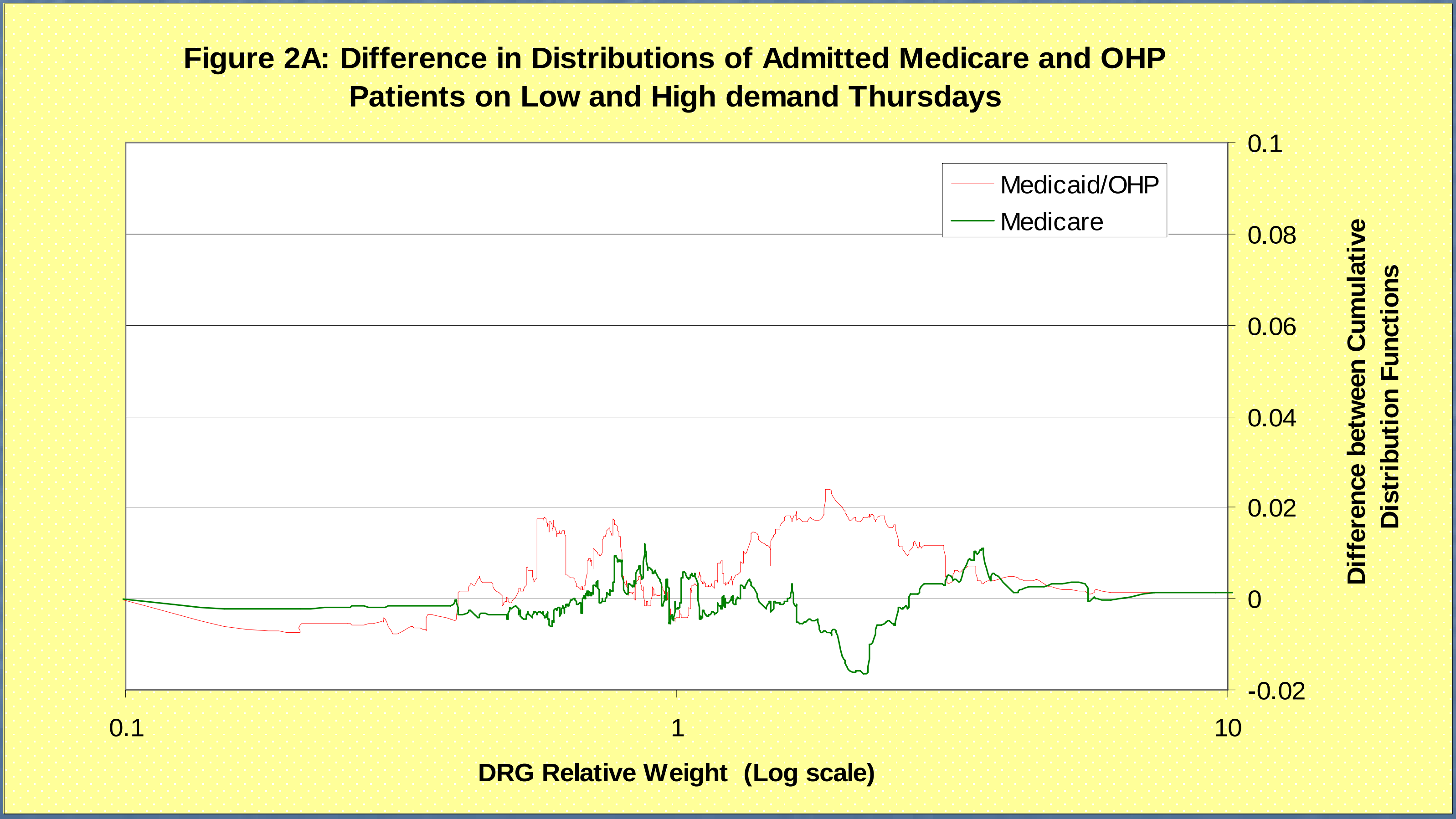
Statistical Analysis

- Since our test for discrimination implies changes in both means and CDFs, we conduct F-tests of differences in means and Kolmogorov-Smirnov (KS) tests of differences in distributions to compare the impact that high demand has on admissions and discharges of patients with different types of insurance.
- E.g., H_0:The mean and distribution over DRG relative weights (Adj *ERLOS* at discharge) of Medicare patients admitted (discharged) on high demand days is the same as on low demand days.

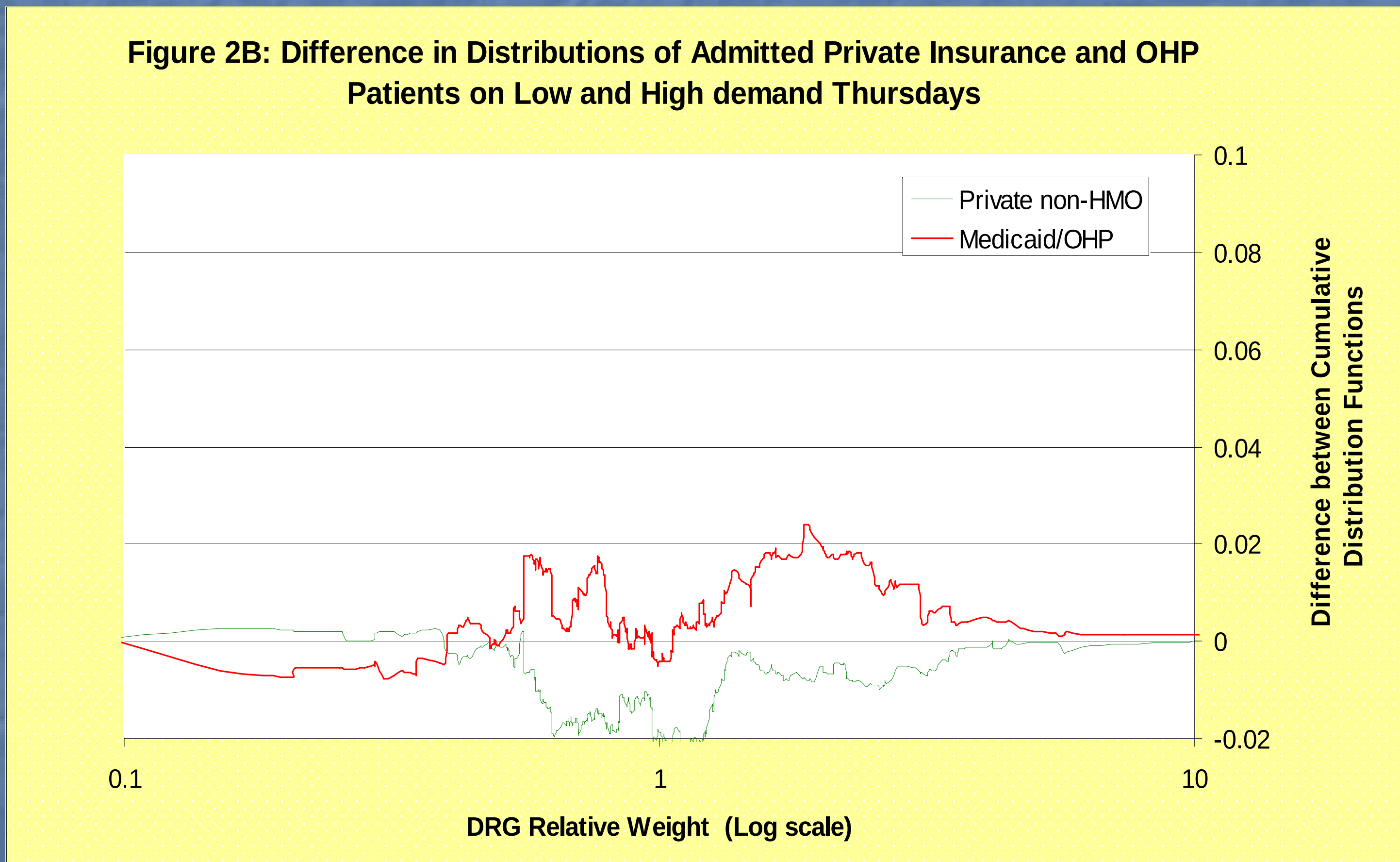
VI. Results: CDFs of admissions on low demand Thursdays.



Results: Difference between low and high demand Thursdays (Medicare and OHP).



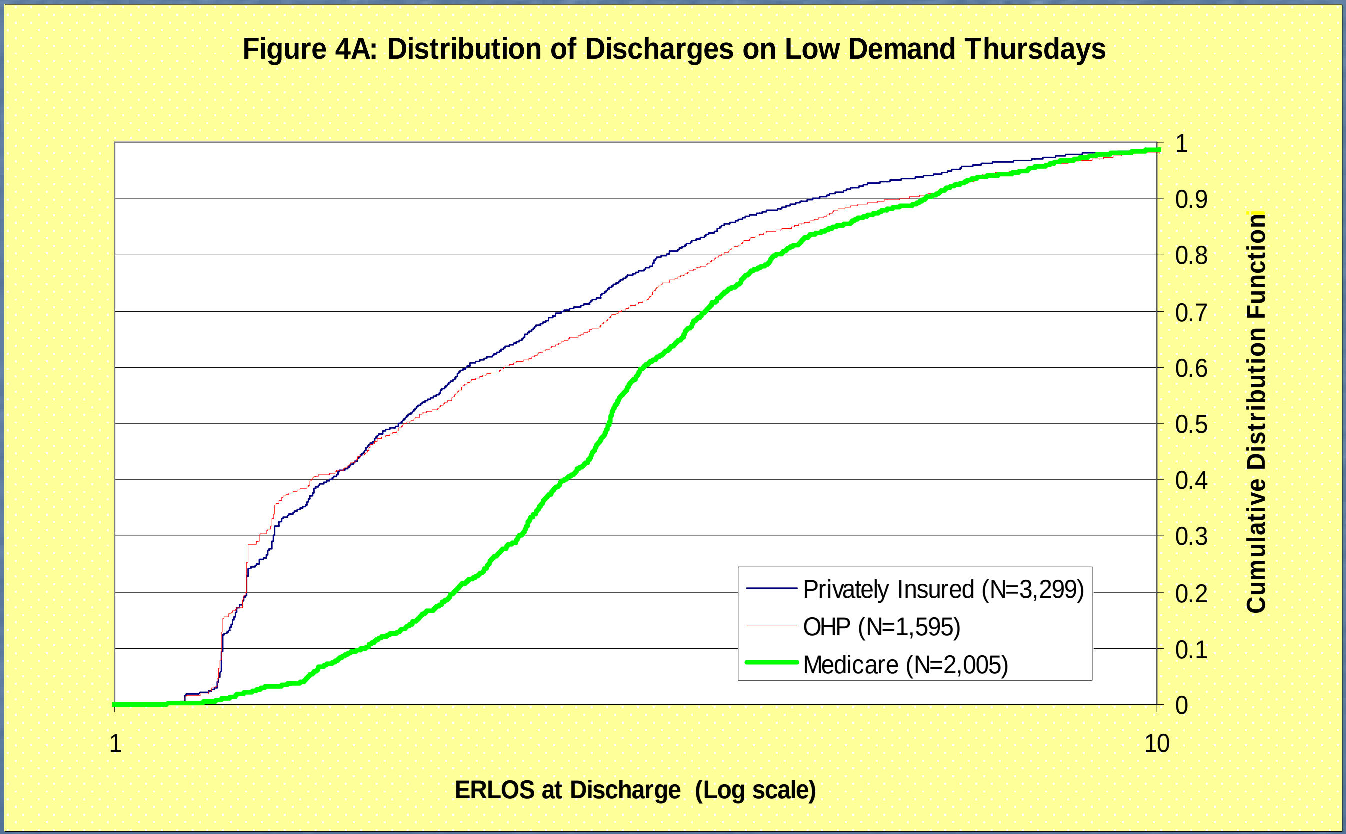
Results: Difference between low and high demand Thursdays (Private and OHP).



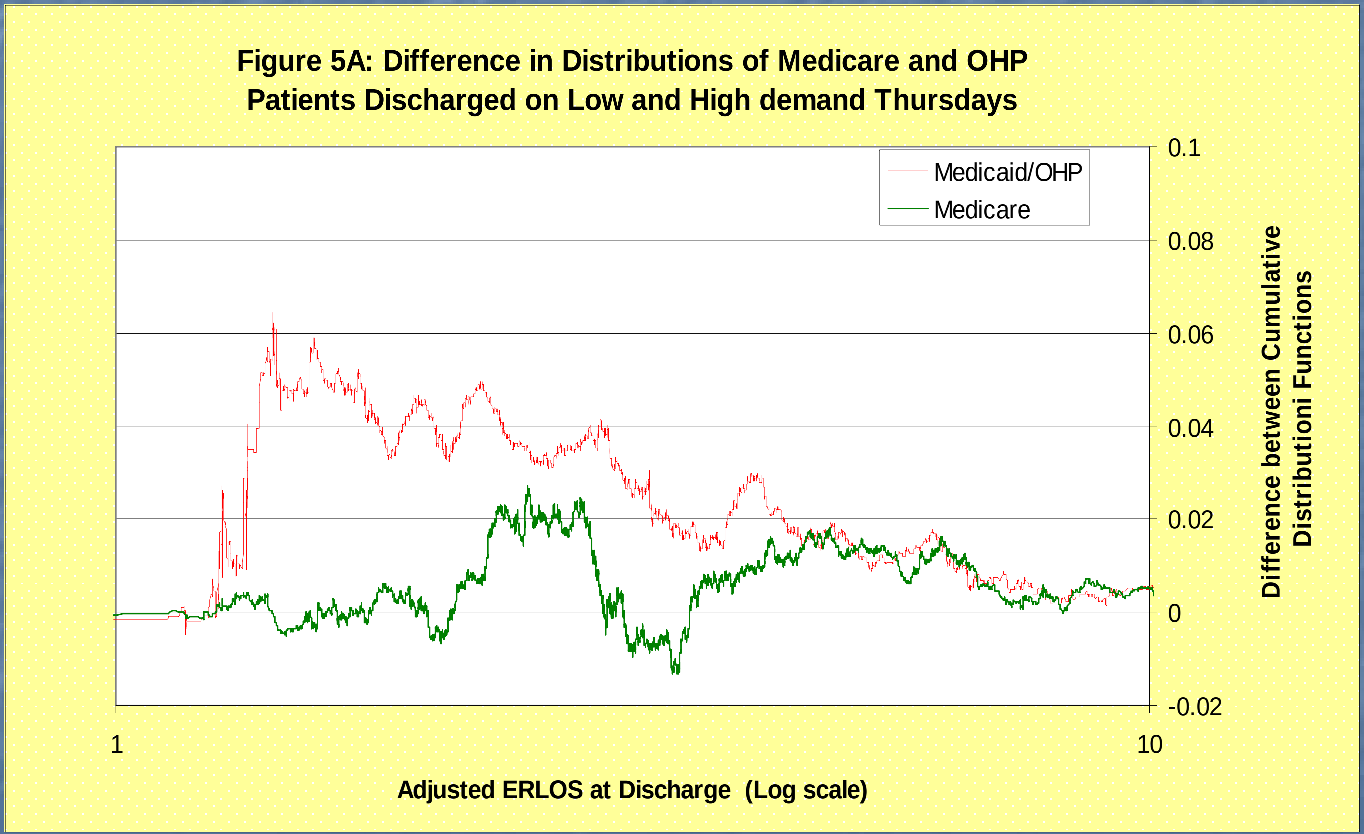
Results: DRG relative weights of patients admitted on high and low demand Thursdays.

Insurance type	Mean		P-Values	
	High	Low	F	KS
Medicare	1.452	1.438	0.63	0.008
OHP/Medicaid	0.907	0.854	0.087	0.012
Private	1.002	1.033	0.216	0.012
All patients	1.129	1.128	0.923	0.005

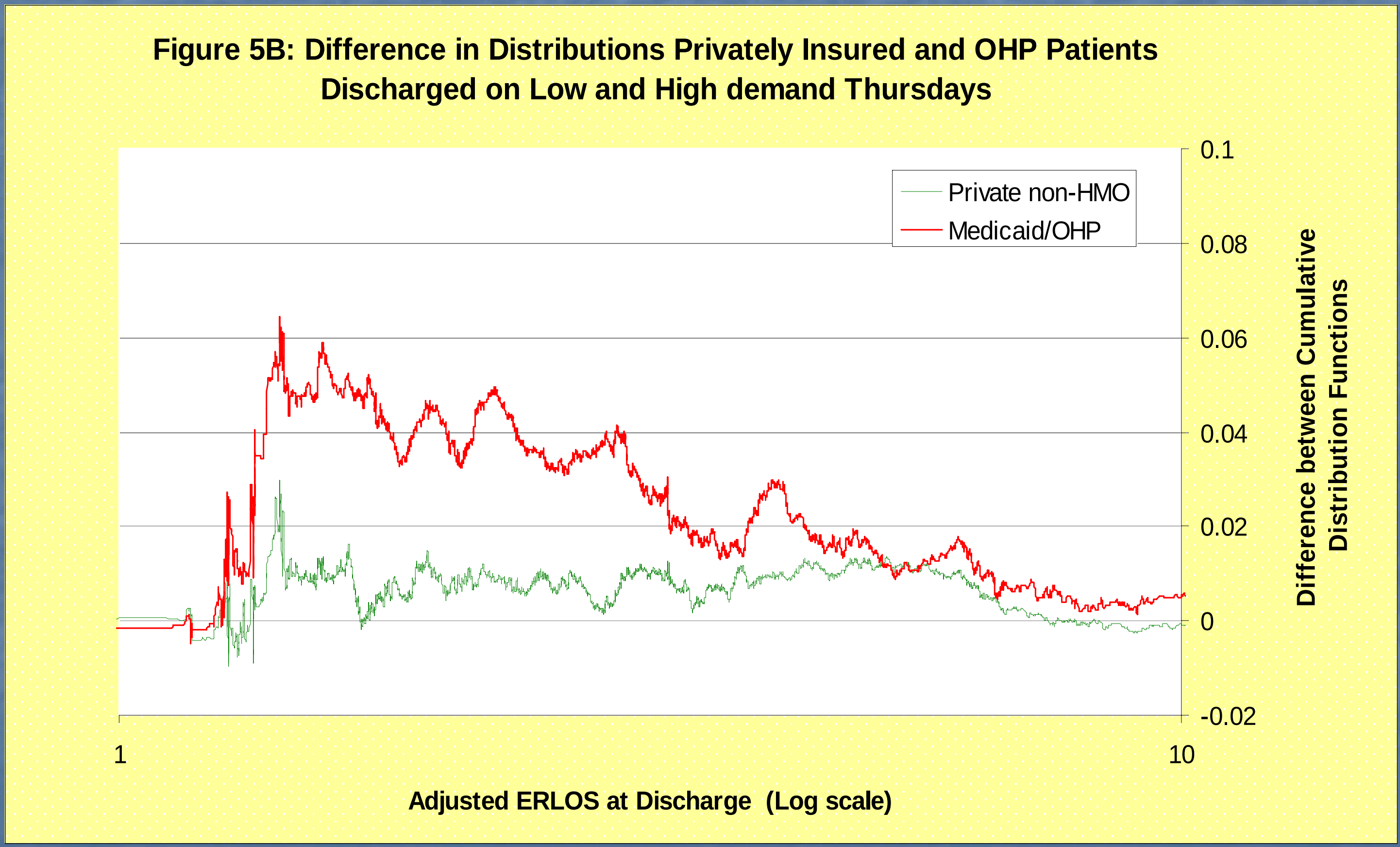
Results: CDFs of discharges on low demand Thursdays.



Results: Difference between low and high demand Thursdays (Medicare and OHP).



Results: Difference between low and high demand Thursdays (Private and OHP).



Results: Adj *ERLOS* of patients discharged on high and low demand Thursdays.

Insurance type	Mean		P-Values	
	High	Low	F	KS
Medicare	3.563	3.473	0.138	0.013
OHP/Medicaid	3.047	2.853	0.032	0.032
Private	2.637	2.602	0.501	0.015
All patients	3.046	2.964	0.013	0.017

VII. Conclusion:

- Examine impact of fluctuations in demand on hospital admission and discharge behavior.
- Reduction in health and treatment disparities is a policy priority. New test for discriminatory behavior using widely available data. Problems with analyses of differences in mean effects.
- New measure of remaining treatment: *ERLOS.*
- Patients discharged on high demand days are discharged earlier relative to expectations than those discharged on low demand days.
- Differences in discharges of OHP patients that are consistent with discriminatory behavior.

Areas for further research:

- Adjust for seasonal, time of month factors in admissions analysis.
- Refine methods for identifying capacity constraints: department level; different time frames. Refine payment analysis.
- Our methods may be useful in identifying discrimination in other health care settings, and potentially, outside the health field in areas such as police or fire services.