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Negative Externality on Service Level across Priority Classes: Evidence from a Radiology Workflow Platform

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Negative externality on service level across priority classes: Evidence from a radiology workflow platform

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Motivation

- Imbalanced compensation schemes (pay vs. workload) are common in different industries
  - We analyze data from a radiology workflow platform
- We study the impact of imbalanced compensation schemes on service level
  - Service level set by priority-specific turnaround time targets
  - Cherry picking profitable tasks may lead to neglecting high priority tasks

Radiology Workflow Platform

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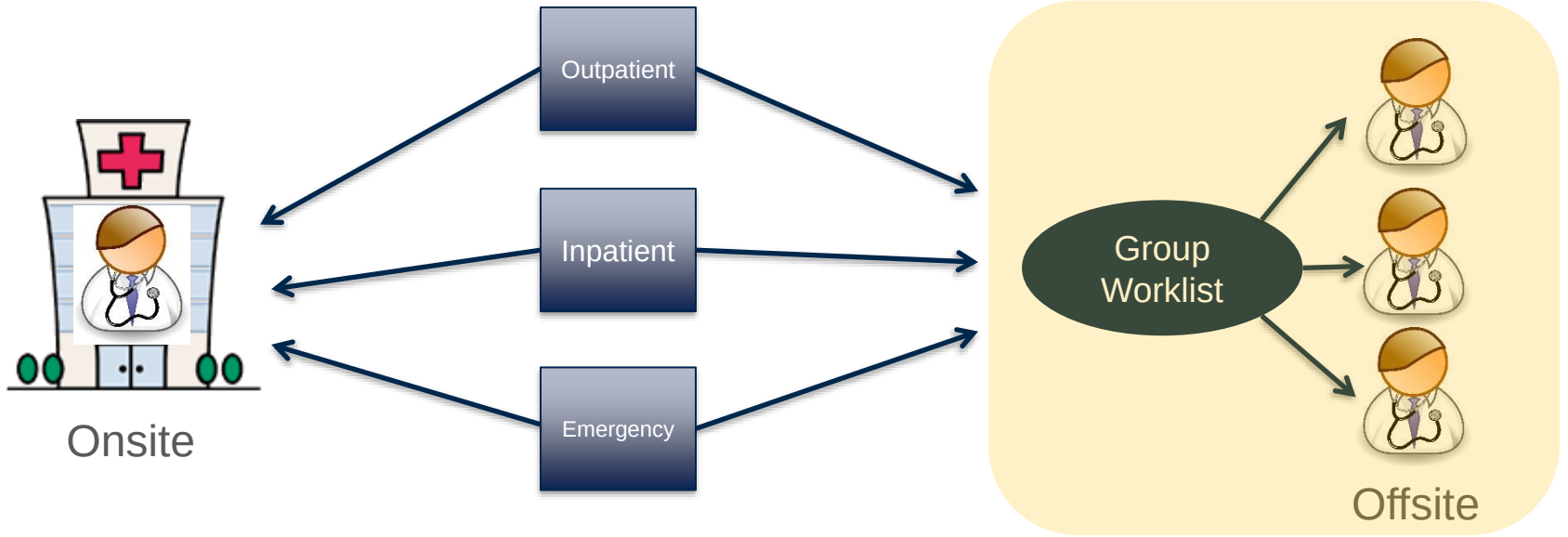
- *Onsite radiologists* work at employer hospital
  - Salaried, excluded from our analysis
- ***Offsite radiologists*** work from home
  - Compensated based on studies read, ≈ piece-rate compensation
  - Select studies from a common pool
- Each study has a ***priority level*** indicating its urgency
  - From Routine to Hyperacute. Defines **target turnaround time (TAT)**



Three Important Metrics

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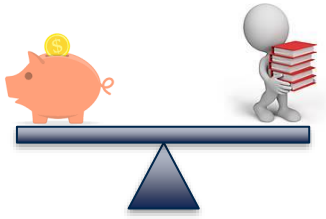
RVU

- Proxy for offsite radiologist **compensation** per study
- Stands for “Relative Value Unit”
- Set by CMS for all medical procedures
- In 2022, CMS reimburses $33.59 per RVU



- In principle, high RVU→ high workload (ERL). But is it perfectly aligned?
- Off-site radiologist may be in competition with each other for reading studies with high RVU and low ERL, i.e., high BFB

Research Questions

1) Do workers pick high pay-to-workload tasks when they have the freedom to select tasks with different pay-to-workload ratio from a common pool?

2) Does this behavior have a negative impact on the firm-level service provided to its customers?

Brief Literature Review

- Piece-rate Compensation Schemes:
  - Improved worker productivity & greater individual earnings: Paarsch and Shearer (1999, 2000), Guajardo et al. (2012), Chan et al. (2018), ...
  - Determining optimal pay rate can be very challenging: Edwards (1980), Clawson (1980), Freeman and Kleiner (2005), …
- Healthcare Management:
  - Performance as a function of workload: Powell et al. (2012), Kc (2013), Kuntz et al. (2014), Berry Jaeker and Tucker (2016), Freeman et al. (2016), …
  - Task ordering: Ibanez et al. (2017), KC et al. (2017), …
- Radiology:
  - Financial incentives on RVU per day: Monaghan et al. (2006), Ding et al.(2009), Boland et al (2010), Andriole et al (2010), Heller (2013), Swayne(2014), …
  - Relation between RVU and workload, potential for cherry-picking : Arenson et al. (2001), Duznak and Muroff (2010), Itri et al. (2019), …

Data

- **Final dataset: January 2014 to July 2017**
  - **2.168 M studies**
  - **251 procedures**
  - **115 radiologists**
  - **62 hospitals**

Data attributes

Attribute	Example values
study ID	1234567
Procedure	CT Head or Brain W Contrast
RVU	1.13
Priority	Routine
Date Arrived	01-01-2014 09:30:00 AM
Date Report Filed	01-01-2014 09:54:07 AM
Report Length	1137
Radiologist ID	123

Priorities and System Service Level

- ***Service level:*** characterized by meeting priority-dependent target turnaround times

Priority Name	Priority Type	Target Turnaround Time (TAT)	Percentage	Fraction of delays
Hyperacute	Emergency	0.5 hours	1.13%	5.94%
Stat	Urgent	1 hour	67.13%	6.23%
Expedited	Administrative	4 hours	6.67%	21.42%
Routine	Low	24 hours	25.07%	6.43%

Hypotheses Drivers of Turnaroundtime

- Kc et al. (2017): physicians preferred easier tasks when facing higher workload

- Ibanez et al. (2017) find that radiologists prioritize similar tasks and tasks with *shortest expected processing time*
  - Time-rate (salaried) setting
  - Studies are centrally assigned to individual queues
  - *Urgent studies only*

H1: TAT of a study is increasing in its ERL

Priority	Routine	Expedited	Stat
First Stage			
Z_{RVUi}	0.879 (0.136) [0.000]	0.904 (0.097) [0.000]	0.984 (0.145) [0.000]
Z_{L^Ri}	0.005 (0.004) [0.258]	0.005 (0.004) [0.276]	−0.002 (0.001) [0.102]
Z_{L^Ei}	0.014 (0.023) [0.550]	−0.182 (0.035) [0.000]	−0.021 (0.007) [0.003]
Z_{L^Si}	0.027 (0.021) [0.191]	0.064 (0.026) [0.012]	0.022 (0.013) [0.095]
Z_{L^Hi}	0.397 (0.211) [0.059]	0.045 (0.299) [0.874]	0.071 (0.114) [0.533]
Second Stage			
BFB	−0.143 (0.050) [0.004]	−0.085 (0.041) [0.038]	−0.035 (0.054) [0.512]
ERL	−0.447 (0.264) [*****]	0.180 (0.166) [*****]	0.981 (0.243) [*****]
L^R	0.113 (0.004) [0.000]	0.022 (0.003) [0.000]	0.003 (0.001) [0.002]
L^E	0.250 (0.014) [0.000]	0.448 (0.017) [0.000]	−0.019 (0.002) [0.000]
L^S	0.233 (0.012) [0.000]	0.515 (0.027) [0.000]	0.518 (0.016) [0.000]
L^H	−0.168 (0.105) [0.111]	0.761 (0.168) [0.000]	0.638 (0.032) [0.000]
Controls	✓	✓	✓
Pseudo R^2	0.114	0.113	0.21
Kleibergen-Paap p-value (Underidentification test)	0.011	0.004	0.008
Cragg-Donald Wald F statistic (Weak identification test)	$9.2 \times e^4$	$5.1 \times e^4$	$2.3 \times e^5$
Hansen J statistic p-value (Overidentification test of all instruments)	0.23	0.796	0.108
Anderson-Rubin Wald p-value (Weak-instrument-robust inference)	0.118	0.695	0.000

Robust standard errors are in parentheses. p-values are in brackets.

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No support for Routine and Expedited studies

Supported for Stat studies

Hypotheses Drivers of Turnaroundtime

- Financial incentives for *salaried* radiologist are effective in reducing TAT (Andriole et al. 2010, Boland et al. 2010)

- Financial incentives in radiology are based on meeting RVU targets over a period of time (Heller 2013, Itri et al. 2019)

H2: TAT of a study is decreasing in its BFB

Priority	Routine	Expedited	Stat
First Stage			
Z_{RVU_i}	0.879 (0.136) [0.000]	0.904 (0.097) [0.000]	0.984 (0.145) [0.000]
$Z_{L^R{}_i}$	0.005 (0.004) [0.258]	0.005 (0.004) [0.276]	−0.002 (0.001) [0.102]
$Z_{L^E{}_i}$	0.014 (0.023) [0.550]	−0.182 (0.035) [0.000]	−0.021 (0.007) [0.003]
$Z_{L^S{}_i}$	0.027 (0.021) [0.191]	0.064 (0.026) [0.012]	0.022 (0.013) [0.095]
$Z_{L^H{}_i}$	0.397 (0.211) [0.059]	0.045 (0.299) [0.874]	0.071 (0.114) [0.533]
Second Stage			
BFB	−0.143 (0.050) [0.004]	−0.085 (0.041) [0.038]	−0.035 (0.054) [0.512]
ERL	−0.447 (0.264) [*****]	0.180 (0.166) [*****]	0.981 (0.243) [*****]
L^R	0.113 (0.004) [0.000]	0.022 (0.003) [0.000]	0.003 (0.001) [0.002]
L^E	0.250 (0.014) [0.000]	0.448 (0.017) [0.000]	−0.019 (0.002) [0.000]
L^S	0.233 (0.012) [0.000]	0.515 (0.027) [0.000]	0.518 (0.016) [0.000]
L^H	−0.168 (0.105) [0.111]	0.761 (0.168) [0.000]	0.638 (0.032) [0.000]
Controls	✓	✓	✓
Pseudo R^2	0.114	0.113	0.21
Kleibergen-Paap p-value (Underidentification test)	0.011	0.004	0.008
Cragg-Donald Wald F statistic (Weak identification test)	$9.2 \times e^4$	$5.1 \times e^4$	$2.3 \times e^5$
Hansen J statistic p-value (Overidentification test of all instruments)	0.23	0.796	0.108
Anderson-Rubin Wald p-value (Weak-instrument-robust inference)	0.118	0.695	0.000

Robust standard errors are in parentheses. p-values are in brackets.

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Supported for Routine and Expedited studies

No Support for Stat studies

Hypotheses on Externality Effect

- In Healthcare, myopic focus on attractive tasks can have a negative externality
  - Stan and Vermaulen (2013), Freeman et al (2016), …

H3: The TAT of Stat and Expedited studies increases with the load per capita of Routine studies with high BFB*

H4: The pbb of delay of Stat and Expedited studies increases with the load per capita of Routine studies with high BFB*

*Routine studies with high BFB = Routine studies with higher BFB than 90th Routine BFB percentile

Summary of Results on Spillover Effect

Effect of	On: Expedited (Administrative)	On: Stat (Medical)
Routine – Low BFB	Small	Small
Routine – High BFB	Longer TAT Higher pbb of delay	Small

- H3 and H4 supported for Expedited studies
- Weaker support for Stat studies

Econometric Specifications: H3

- TATs T_i are continuous, nonnegative, and right skewed
- We fit a two-stage least squares (2SLS) regression, with ERL as the endogenous variable, to explain the TATs
- The instruments are Heteroscedasticity Based Instrumental Variables we construct
- The variables of interest are a partition of the load per capita (LPC) according to priorities

$$ERL_i = \gamma_{0j} + \boldsymbol{\gamma_{1j}^T} X_i + \psi_{1j} L_i^{LR} + \psi_{2j} L_i^{HR} + \gamma_{2j} L_i^E + \gamma_{3j} L_i^S + \gamma_{4j} L_i^H + \gamma_{5j} BFB_i + + \boldsymbol{\eta_j'} \boldsymbol{Z_i} + \nu_i,$$

$$\log T_i = \beta_{0j} + \boldsymbol{\beta_{1j}^T} X_i + \phi_{1j} L_i^{LR} + \phi_{2j} L_i^{HR} + \beta_{2j} L_i^E + \beta_{3j} L_i^S + \beta_{4j} L_i^H + \beta_{5j} BFB_i + \alpha_j \hat{ERL}_i + \epsilon_i.$$

Controls: hour, day of week, calendar month, radiologist, ERL and BFB of arriving study with interactions.

$P_{ij} = 1$ if study i has priority j, Expedited is the base priority. Not Routine: Expedited + Stat + Hyperacute

Econometric Specifications: H4

- Let $D_i = 1$ if study is delayed, i.e. its turnaround time is longer than the target according to its priority, and $D_i = 0$ otherwise
- We fit a linear probability model to the delay of the studies
- The controls and variables of interest are the same as before

$$ERL_i = \gamma_{0j} + \boldsymbol{\gamma}_{\mathbf{1j}}^{\boldsymbol{T}} X_i + \psi_{1j} L_i^{LR} + \psi_{2j} L_i^{HR} + \gamma_{2j} L_i^{E} + \gamma_{3j} L_i^{S} + \gamma_{4j} L_i^{H} + \gamma_{5j} BFB_i + + \boldsymbol{\eta}_{\boldsymbol{j}}' \boldsymbol{Z}_{\boldsymbol{i}} + \nu_i,$$

$$D_i = \beta_{0j} + \boldsymbol{\beta}_{\mathbf{1j}}^{\boldsymbol{T}} X_i + \phi_{1j} L_i^{LR} + \phi_{2j} L_i^{HR} + \beta_{2j} L_i^{E} + \beta_{3j} L_i^{S} + \beta_{4j} L_i^{H} + \beta_{5j} BFB_i + \alpha_j \hat{ERL}_i + \epsilon_i.$$

Priority	Routine	Expedited	Stat
First Stage			
$Z_{RVU\,i}$	0.879 (0.136) [0.000]	0.904 (0.097) [0.000]	0.984 (0.145) [0.000]
$Z_{L^R\,i}$	0.005 (0.004) [0.244]	0.004 (0.004) [0.301]	−0.002 (0.001) [0.100]
$Z_{L^E\,i}$	0.012 (0.023) [0.59]	−0.173 (0.036) [0.000]	−0.021 (0.007) [0.003]
$Z_{L^S\,i}$	0.026 (0.021) [0.206]	0.062 (0.026) [0.015]	0.022 (0.013) [0.088]
$Z_{L^H\,i}$	0.398 (0.209) [0.057]	0.045 (0.299) [0.88]	0.07 (0.113) [0.536]
Second Stage			
BFB	−0.15 (0.05) [0.003]	−0.086 (0.041) [0.036]	−0.034 (0.054) [0.525]
ERL	−0.421 (0.262) [*****]	0.185 (0.169) [*****]	0.976 (0.244) [*****]
L^{LR}	0.097 (0.006) [0.000]	0.015 (0.006) [0.012]	−0.007 (0.001) [0.000]
L^{HR}	0.296 (0.034) [0.000]	0.1 (0.033) [0.003]	0.12 (0.003) [0.000]
L^E	0.241 (0.015) [0.000]	0.445 (0.018) [0.000]	−0.021 (0.002) [0.000]
L^S	0.233 (0.012) [0.000]	0.517 (0.027) [0.000]	0.519 (0.016) [0.000]
L^H	−0.194 (0.105) [0.064]	0.758 (0.168) [0.000]	0.652 (0.032) [0.000]
Controls	✓	✓	✓
Pseudo R^2	0.1145	0.1135	0.211
Kleibergen-Paap p-value (Underidentification test)	0.010	0.004	0.008
Cragg-Donald Wald F statistic (Weak identification test)	$9.3 \times e^4$	$5.1 \times e^4$	$2.3 \times e^5$
Hansen J statistic p-value (Overidentification test of all instruments)	0.201	0.607	0.08
Anderson-Rubin Wald p-value (Weak-instrument-robust inference)	0.099	0.399	0.000

Robust standard errors are in parentheses. p-values are in brackets.

- TAT of Expedited studies is
  - ≈ unaffected by platform's load per capita of Routine studies with low BFB (L^{LR}) → 2 min (**significant**)
  - increasing in platform's load per capita of Routine studies with high BFB (L^{HR}) → 18 min (**significant**)

- *Externality from Routine studies degrades the service level provided to Expedited studies*
  - Supports H3 and H4 for Expedited studies

Priority	Routine	Expedited	Stat
First Stage			
Z_{RVU_i}	0.879 (0.136) [0.000]	0.904 (0.097) [0.000]	0.984 (0.145) [0.000]
$Z_{L^R{}_i}$	0.005 (0.004) [0.244]	0.004 (0.004) [0.301]	−0.002 (0.001) [0.100]
$Z_{L^E{}_i}$	0.012 (0.023) [0.59]	−0.173 (0.036) [0.000]	−0.021 (0.007) [0.003]
$Z_{L^S{}_i}$	0.026 (0.021) [0.206]	0.062 (0.026) [0.015]	0.022 (0.013) [0.088]
$Z_{L^H{}_i}$	0.398 (0.209) [0.057]	0.045 (0.299) [0.88]	0.07 (0.113) [0.536]
Second Stage			
BFB	−0.006 (0.005) [0.264]	−0.03 (0.001) [0.001]	−0.019 (0.005) [0.000]
ERL	0.011 (0.27) [*****]	0.08 (0.03) [*****]	0.177 (0.034) [*****]
L^{LR}	0.006 (0.0004) [0.000]	0.005 (0.001) [0.000]	−0.002 (0.0002) [0.000]
L^{HR}	0.061 (0.004) [0.000]	0.036 (0.004) [0.000]	0.012 (0.002) [0.000]
L^E	0.021 (0.001) [0.000]	0.111 (0.005) [0.000]	−0.018 (0.0005) [0.000]
L^S	0.018 (0.002) [0.000]	0.126 (0.003) [0.000]	0.126 (0.004) [0.000]
L^H	0.028 (0.03) [0.362]	0.152 (0.05) [0.002]	0.104 (0.01) [0.000]
Controls	✓	✓	✓
Pseudo R^2	0.061	0.096	0.104
Kleibergen-Paap p-value (Underidentification test)	0.010	0.004	0.008
Cragg-Donald Wald F statistic (Weak identification test)	$9.3 \times e^4$	$5.1 \times e^4$	$2.3 \times e^5$
Hansen J statistic p-value (Overidentification test of all instruments)	0.463	0.975	0.405
Anderson-Rubin Wald p-value (Weak-instrument-robust inference)	0.052	0.198	0.000

Robust standard errors are in parentheses. p-values are in brackets.

- TAT of Expedited studies is
  - ≈ unaffected by platform's load per capita of Routine studies with low BFB (L^{LR}) → 2 min (**significant**)
  - increasing in platform's load per capita of Routine studies with high BFB (L^{HR}) → 18 min (**significant**)
- Stronger results for Probability of Delay
- *Externality from Routine studies degrades the service level provided to Expedited studies*
  - Supports H3 and H4 for Expedited studies

Conclusions

- Imbalanced compensation schemes (pay vs. workload) are common in different industries
  - We analyze data from a radiology workflow platform
- We study the impact of imbalanced compensation schemes on service level
  - Service level set by priority-specific turnaround time targets
  - Cherry picking profitable tasks may lead to neglecting high priority tasks
- We show turnaround (service level) time is:
  - decreasing in pay-to-workload for lower priority tasks
  - increasing in workload for high-priority tasks
- Negative externality:
  - $\uparrow$ economically attractive low priority tasks $\Rightarrow$ $\uparrow$ turnaround times & delays for administrative priority

Robustness and impact

- Our results are robust to Kinky Regression, joint estimation with interactions, etc.
- Counterfactual: Negative externality responsible for an annual **bed blocking** cost of $1.5M USD
- Unbalanced piece-rates can have significant operational consequences for organizations with common task pool
  - E.g. Radiology, Amazon Mechanical Turk, Clickworker, etc.
  - Opportunity to mitigate negative effects through data analytics and operations management tools