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Essays on The Economics of Helath Care Payment Reforms

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Abstract

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Both public and private health care sectors in the United States have been experimenting with many innovative payment methods with the aim of improving quality of care while containing the cost growth. For example, large employers and insurers in private sector innovated their insurance design to encourage patients to make better decisions regarding to treatments and health care providers. In public sector, Medicare recently implemented reforms on payments to physicians, hospitals and other health care facilities that incorporated quality-based bonuses. It also implemented policies such as "site-neutral payment" policies for different kinds of facilities that provide similar services in order to reduce unnecessary spending. In this thesis, I evaluate the impacts of some of such payment reforms on patients' choice, quality of care, and healthcare spending. I also examine the relative importance of different components of health care policies, e.g., financial incentives versus quality and cost information provision. Finally, combining data with theory I predict the effects of a Medicare's "site-neutral payment" policy and propose the optimal reimbursement and insurance policies for the outpatient care services.

Policy makers in the US are increasingly tying payments for health care providers to their quality measures, although there is mixed empirical evidence on the performance of the current program. In the first chapter, I evaluate the impact on hospital quality of Medicare's Hospital Value-Based Purchasing program, a large federal program which rewards hospital for quality of their service. I exploit the introduction of the incentive and the variations in incentives payment across hospitals to identify the program's effects on hospital quality. I find that, compared to non-participating hospitals, participating hospitals on average improve on more than half of the patient experience outcomes after the program started. However, the magnitude of the improvement is rather small. There is no significant improvement in mortality rates. I also find that there exists some convergence in quality of the participating hospitals. That is, hospitals that expect lower value-based incentive payment in the future improve quality more than hospitals that expect more payment in the future.

In the second chapter, I examine the relative importance of financial incentive and quality and cost information in changing healthcare consumer's facility choices. I do so by exploiting the Reference Pricing (RP) program implemented by the California Public Employee's Retirement

System, which increased cost-sharing at expensive health care providers and provided enrollees with a clear comparison of quality between high-cost and low-cost providers. I find that the program led to a 30.4% increase in the probability of a patient choosing low-cost ambulatory surgery centers (ASCs) when in need of a procedure covered by the RP. The program also led to a 22.6% increase in the probability of a patient choosing ASCs when in need of a procedure related to RP procedures but not directly impacted by the RP financially. The presence of the large spillover effect suggests the importance of the information the RP provided patients with. Furthermore, the demand estimation pre-RP and post-RP shows that patients with RP procedures are more sensitive to price and less sensitive to distance and their health risk after the RP. Their perception of HOPDs' quality drops significantly while that of ASCs' quality stays the same. I estimate that the financial incentive change in the RP program explains about 15% of the total demand change, while the change in patient's perception of facility quality explains about 70%.

In the final chapter, I study how Medicare can achieve greater efficiency by jointly optimizing its reimbursement structure and insurance design for the outpatient services performed in hospital outpatient departments and ambulatory surgery centers. Using large datasets on Medicare claims and providers' financials, I find that current Medicare reimbursement rates are significantly above marginal costs for both HOPDs and ASCs, and that ASCs offer equal or higher net value than HOPDs for common outpatient procedure groups. I develop a theoretical model to characterize the optimal reimbursement rates and coinsurance rates. I demonstrate that reimbursement rates should be set at providers' marginal costs, and that coinsurance rates should be higher for HOPDs than for ASCs. Counterfactual analyses show that moving from current practice to the proposed optimal policy would reduce Medicare spending by 15% to 23%, while simultaneously increasing the social surplus by 3.1% to 6.4%. In contrast, if coinsurance rates are constrained to be the same across provider types, as in the current Medicare insurance policy, more limited welfare improvements are still possible by increasing reimbursements rates for HOPDs to incentivize greater sorting into ASCs. Under such scenarios, I estimate an increase in social surplus of 3.1% to 6.1% and Medicare savings of 9% to 15% instead. Lastly, I show that Medicare's recent policy change, which decreased HOPDs' reimbursement rates to ASCs' rates while keeping the coinsurance rates the same, resulted in social surplus reduction.

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Chapter 1

Effects of Medicare's Hospital Value Based Purchasing on quality of hospitals in the United States

1.1 Introduction

Healthcare in the United States is extremely costly, and healthcare spending continues to rise in the recent years. Research on the correlation between costs and quality finds that the correlation between them is either nil or negative (Yasaitis et al., 2009; Jha et al., 2009; Hussey et al., 2013). Quality performance also varies widely across hospitals. For example, Jha et al. (2005) document that performance varies moderately among large hospital-referral regions, with the top-ranked regions scoring 12 percentage points (for acute myocardial infarction) to 23 percentage points (for pneumonia) higher than the bottom-ranked regions. The absence of positive correlation between quality and costs and the variation in quality suggests that there is large room for quality improvement.

Numerous public and private payer initiatives in the US have attempted to resolve this lack of positive return of healthcare spending through value-based purchasing programs. Indeed, the U.S Patient Protection and Affordable Care Act of 2010, also known as the "ACA," prioritizes improvements in the healthcare delivery infrastructure, healthcare quality, and containment of healthcare costs. Central to this Act is performance-based payment models and care delivery models that shift from a traditional fee-for-service model to a greater focus on increased quality and accountability with an emphasis on evaluating, reporting, rewarding excellence, and penalizing poor health care delivery.

Hospital Value-Based Purchasing program (HVBP) is a value-based payment program established by ACA for Medicare hospitals and Medicare patients. It is one of the largest and most comprehensive Medicare's pay-for-performance programs that affects more than 3000 hospitals in the US and targets a wide range of quality measures. Beginning in fiscal year (FY) 2013, HVBP makes Medicare payments to acute care hospitals - hospitals paid under the Inpatient Prospective Payment System (IPPS) - conditional on performance as assessed by a variety of metrics. Starting with clinical process and patient experience measures in fiscal year (FY) 2013, the program expands to include clinical outcome measures in FY 2014 and Medicare spending measures in FY 2015. HVBP is budget neutral, redistributing hospitals payment "withholds" from "losing" to "winning" hospitals that equals to 1% of hospital payments from the existing IPPS. The size of the program incentives also increases gradually from 1% of diagnosis-related group revenue in FY 2013 to 2% by FY 2017.

In this paper, I measure HVBP's impacts on a variety of hospitals' performance measures, including mortality rates and patient experience measures. First, I conduct a Difference-in-Differences analysis, comparing HVBP participating hospitals with HVBP non-participating hospitals before and after the program was launched in order to estimate the extensive margin of HVBP's effects on hospital quality. This kind of analysis for HVBP has been done before by Ryan et al. (2017) and Ryan et al. (2015). However, unlike their paper, I do not aggregate individual quality measures to a composite score for each quality domain. Instead, I use raw individual quality measures in order to examine if there is heterogeneity in responses of different quality measures to HVBP. By not aggregating measures within a domain of quality into a single composite index, I also preserve data variations that are needed to estimate the DID regression precisely. Moreover, although the performance score calculated by Medicare for HVBP payment is available during the post-HVBP implementation period for only HVBP participating hospitals, the raw quality measures are available for all hospitals participating and not participating in HVBP. Therefore, unlike Ryan et al. (2015), I do not have to impute quality performance for the non-participating hospitals.

I also conduct an instrumental variables (IV) analysis of the intensive margin of HVBP on participating hospitals. While the DID analysis mentioned above tells us whether the program works, the IV analysis will tell how much HVBP participating hospitals respond to the program payment generosity. The latter information is crucial to the design of the optimal HVBP program. The IV regression regresses a range of quality measures on the expected incentive payment that hospitals expect to receive in two periods time. This time lag of two years is due to the design of HVBP in which payment adjustment made in year $t + 2$ depends on how hospitals perform in year t. The challenge of this estimation is to construct the expected incentive payment. Under some assumptions, I construct an empirical analog of hospitals' expected incentive payment using hospital past year quality performance. Because of the mean reversion problem that is associated with the use of past year quality measures to predict the expected incentive payment, I propose to instrument for this variable by using predicted incentive generated from historical quality data. In the regression, the time period of the historical data is 2008 and the time period of the regression is 2012-2015. The idea of this instrument is that quality of a hospital is a stable process, so the predicted incentive generated using the raw quality measures in 2008 is correlated with quality and incentive payment in the years under HVBP. This correlation justifies the relevancy of the proposed instrument. Under the assumption that stochastic errors in quality process is serially uncorrelated, after controlling for hospital fixed effects and hospital observable characteristics, quality measures in 2008 should not be correlated with the stochastic errors in quality measures from 2012 onwards. This justifies the exogeneity assumption of the proposed instrument.

Third, the DID analysis and the IV analysis are complemented with the summary statistics that sheds light on the distributional effects of HVBP. This is an important aspect of the program to be evaluated because HVBP does not aim at only improving the average level of quality of hospitals across the U.S but also reducing the gaps in quality and costs across regions. It is also not sufficient to just examine the effects of HVBP on average hospital quality because for example, if hospitals do not improve quality significantly after HVBP, HVBP's effect might be purely re-distributional and the direction of this redistribution might or might not be desirable.

This article is related to a literature of small growing literature that studies pay-for-performance models in health care market. Ryan et al. (2015) and Ryan et al. (2017) are the first two papers that study this particular program, but as mentioned above they have some certain limitations with a way of implementing the Difference-in-Differences Analysis. Moreover, they and other papers that study other pay-for-performance programs focus mostly on the extensive margin of the program (see for example, Grossbart (2006), Lindenauer et al. (2007), Ryan (2009), Jha et al. (2012)). This paper extends the literature by analyzing the intensive margin of this particular program, and its distributional effects across the participating hospitals.

1.2 Institutional background

The Medicare's Hospital Valued-Based Purchasing Program [1] rewards acute care hospitals with incentive payments for the quality of care they give to people with Medicare. This program adjusts payment to hospitals under the Inpatient Prospective Payment System (IPPS) based on the quality of care they deliver. Under the IPPS before HVBP, Medicare payment is made to hospitals based on a predetermined, fixed amount. The payment amount for a particular service is derived based on the classification system of that service (for example, diagnosis-related groups for inpatient hospital services). The common critique of this Fee for Service (FFS) payment approach is that it induces over-utilization of medical treatments but does not encourage quality improvement. HVBP aims to fix that problem by tying payment to quality. Specifically, it aims to improve the quality and safety of acute inpatient care for Medicare beneficiaries and all patients by several ways, such as eliminating or reducing adverse events (healthcare errors resulting in patient harm), adopting evidence-based care standards and protocols that make the best outcomes for the most patients, changing hospital processes to make patients' care experiences better, etc.

Participating hospitals in HBVP are all U.S hospitals that are paid by Inpatient Prospective Payment System, i.e, Acute Care hospitals. Hospitals that are not paid prospectively - including Critical Access hospitals - are not eligible for HVBP. Exploiting this policy design, the DID analysis in subsection 1.3.2 take Acute Care hospitals as the treatment group and Critical Access hospitals as the control group.

HVBP withholds participating hospitals' Medicare payments by a percentage specified by law (1% when it was launched in 2013 and 2% since 2017) and uses the estimated total amount of those reductions to fund value-based incentive payments to hospitals based on their performance in the program. The program then applies the net result of the reduction and the incentive as a claim-by-claim Adjustment Factor to the base payment amount for Medicare FFS claims in the fiscal associated with the performance period. That is the net HVBP incentive payment for hospital h at time t is given by:

$$
\begin{aligned}
&Net\ incentive\ payment_{ht}\ \ (\$) \\
&= Adj\ Factor_{ht} \times FFS_{ht} \\
&= (1 + Incentive\ percentage_{ht} - Withhold\ percentage_t) \times FFS_{ht} \\
&= (1 + A_t \times Total\ Performance\ Score_{ht} - Withhold\ percentage_t) \times FFS_{ht}
\end{aligned}
$$

[1] http://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier2&cid=1228772039937

Domain	Measure Names	2013	2014	2015	2016
Patient Experience	Nurse Communication	x	x	x	x
	Doctor Communication	x	x	x	x
	Medicine Communication	x	x	x	x
	Discharge Information	x	x	x	x
	Staffs' Responsiveness	x	x	x	x
	Hospital Cleanliness	x	x	x	x
	Overall Rating of Hospital	x	x	x	x
Clinical Care Outcome	Heart Attack Mortality Rate	x	x	x	x
	Heart Failure Mortality Rate	x	x	x	x
	Pneumonia Mortality Rate	x	x	x	x

Table 1.1: List of quality measures included in HVBP program in 2013 - 2017

Incentive percentage is a linear exchange function of Total Performance Score, i.e., Medicare's aggregate score of hospital quality measures. The slope of this function A is common for all hospitals and can vary over time such that at each and every fiscal year the sum of incentive payment over all hospitals is equal to the sum of withhold amount of all hospitals.

Total Performance Score can be thought of as Medicare's aggregate measure of hopitals' many quality dimensions, such as mortality, patient safety, patient experience, spending, etc. Table 1 presents an example of a set of measures used to calculate hospital's Total Performance Score and their data availability for years after HVBP was launched. The full set of measures are included in the Appendix.

Total Performance Score for each hospital is essentially the weighted average of the hospital's scores of each quality domain. The weights for each domain change from year to year. For each domain, the domain score of a hospital is an unweighted average score of all measures within the domain. Score for each measure is in turn the higher of improvement point and achievement point. While improvement point tells how a hospital performs that quality measure relative to the past period, its achievement point tells how it performs relative to other hospitals of the same periods. The Total Performance score calculation method is detailed in the Appendix and will be utilized to construct an instrument as detailed in subsection 1.4.1.

1.3 Data and methodology

1.3.1 Data

The main data set is the quality measures downloaded from the publicly available Hospital Compare database [2]. The data set contains data on achievement point and improvement points of hospitals

[2] https://data.medicare.gov/data/hospital-compare

which participate in HVBP. It also contains the raw quality measures of those hospitals as well as nonparticipating hospitals. Note that achievement and improvement points capture not only how well a hospital performs relative to other hospitals in the same period but also how well it performs relative to its past. Using this measure in the Difference-in-Difference analysis will introduce undesirable serial correlation in quality measures, making the estimation imprecise. Therefore, I choose to use the raw data of quality measures for the empirical analysis.

There are four domains of care which HVBP rewards. They include clinical outcome domain, patient experience of care domain, process of care domain and safety domain. I exclude safety measures out of the empirical analysis because most of the measures are only recently included in the program (after 2016), therefore, the DID analysis might not have strong statistical power. I also exclude process of care measures because although they have been included in the program in 2013, most hospitals do not not report all measures, making the panel heavily imbalanced. Mortality rates and patient experience of care are the two domains that have relatively good data over the period of this study.

Patient experience measures are collected by the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey [3]. The survey asks adult patients about their experiences during their hospital stays, such as whether their nurses always communicated well, whether their doctors always communicated well, whether hospital staffs always responsive to their needs, whether the hospital environment was "Always" clean and quiet, etc. Mortality rates are the 30-day mortality rates for heart attack, heart failure and pneumonia, collected from medical Medicare's claim data. The mortality rates has been risk-adjusted for patient characteristics.

Tables 2 and 3 summarize raw quality measures for HVBP hospitals and non-HVBP hospitals. For clinical outcome measures, HVBP hospitals are generally better than non-HVBP hospitals. However, the difference is small in magnitude, around 1%, and not statistically insignificant. Interestingly, there is more variation in mortality rates among HVBP hospitals rather than non-HVBP hospitals.

Non-HVBP hospitals are in general better than HVBP hospitals in many of the patient experience measures, with the difference around 5 percentage. For example, 81.50 percent of patients in non-HVBP hospitals report that nurses always communicate well with them, as opposed to 76.56 percent of patient in HVBP hospitals report so. The difference is the largest for the Staff Responsiveness measure. Variations in patient experience of care measures for non-HVBP are slightly larger than

[3] http://www.hcahpsonline.org/globalassets/hcahps/survey-instruments/mail/july-1-2018-and-forward-discharges/2018_survey-instruments_english_mail.pdf

Table 1.2: Summary statistics of Clinical outcome measures

	HBVP Hospitals	Non-HVBP Hospitals
Heart Attack Mortality	15.30	16.08
	1.73	1.43
Heart Failure Mortality	11.51	12.17
	1.63	1.49
Pneumonia Mortality	12.26	12.74
	2.44	2.07

Note: All mortality rates are 30-day risk adjusted mortality rates. HVBP Hospitals are the Acute Care Hospitals which are exposed to the Hospital Value Based Purchasing program. Non-HVBP hospitals are the Critical Access Hospitals which are not exposed to the Hospital Value Based Purchasing program. Each cell has a column of two statistics: mean and standard deviation.

that for HVBP hospitals. This might be partially because there are much fewer non-HVBP hospitals (e.g., there are 1039 non-HVBP hospitals as opposed to 3314 HVBP hospitals in 2011). It might also because they are located in rural areas, where medicine practices might vary significantly.

I also supplement the main quality data set with information on hospital characteristics, such as ownership, teaching status, the number of beds, the number of registered nurses, percentage of Medicare days, the total number of hospital discharge, urban or rural location, percentage of a hospital's patient days attributable to low-income. The hospital characteristics data is available in Medicare Provider of Service Files [4], and Medicare Cost Reports [5]. Table 4 provides summary statistics of characteristics of HVBP hospitals and non-HVBP hospitals.

Many of HVBP hospitals are teaching hospitals, with more beds and more nurses. Non-HVBP hospitals have significantly less beds than HVBP hospitals. This is mainly due to the regulation for non-HVBP hospitals that Critical Access Hospitals have not more twenty six beds. HVBP hospitals and non-HVBP hospitals are similar in ownership status and proportion of low income patients. Although non_HVBP hospitals have significantly less number of hospital discharge, they treat the same percentage of low-income patients. In summary, HVBP hospitals tends to be teaching hospitals, bigger in size, treat more patients in general but not necessarily treat more Medicare patients than non-HVBP hospitals

[4]https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Provider-of-Services/

[5]https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Cost-Reports/

Table 1.3: Summary statistics of Patient Experience of Care measures

	HVBP hospitals	Non-HBVP hospitals
Communication with nurse	76.56	81.50
	5.89	4.95
Communication with doctor	80.09	84.47
	5.04	4.99
Communication about medicine	61.39	66.77
	6.31	7.47
Discharge information	83.62	85.84
	4.95	5.37
Responsiveness of staffs	63.94	74.06
	8.40	7.39
Pain management	69.42	72.69
	5.26	6.32
Hospital's cleaness	70.68	79.19
	7.07	7.08
Hospital Rating	68.04	73.22
	9.05	8.31

Note: Communication with nurse for each hospital is the percentage of patients at that hospital who report nurses always communicate well with them. Communication with doctor is the percentage of patients who report doctors always communicate well with them. Communication about medicine is the percentage of patients who report that staffs always usage of medicines well. Discharge information is the percentage of patients who report that they are given information at their discharge. Responsiveness of staffs is the percentage of patients who report that hospital staffs are always responsive to them. Pain management is the percentage of patients who report that pain management is performed well. Hospital cleanness is the percentage of patients who report that the hospital is always clean. Hospital rating is the percentage of patients who rates a hospital 9-10 out of scale from 0 to 10. Each cell in this table has a column of two statistics, mean and standard variation.

Table 1.4: Summary statistics of Hospital Characteristics

	HVBP hospitals	Non-HBVP hospitals
Ownership	0.4	0.4
	0.5	0.5
Teaching status	0.3	0.1
	0.5	0.2
Number of beds (100s)	2.6	0.3
	2.3	0.1
Number of nurses (100s)	3.3	0.3
	15.9	0.2
Share of Medicare days	0.4	0.6
	0.1	0.2
Total Hospital Discharges (1000s)	1.0	0.1
	1.0	0.0
Proportion of low income patients	0.2	0.2
	0.1	0.0

Note: Ownership is the indicator variable that takes value of 1 if a hospital is for profit hospital. Teaching status is the indicator variable that takes value 1 if a hospital has medical school affiliation. Share of Medicare days is the ratio betwen the number of days Medicare patients are treated in a hospital to the total number days all patients stay in the hospital. Each cell has a column of two statistics, mean and standard variation.

1.3.2 Methodology

The Difference in Differences Analysis for the extensive margin effects of HVBP

I first explore the extensive margin impact of HVBP on hospital quality by exploiting the introduction of this payment scheme to hospitals in 2013 over the period of 2008 to 2015. Acute Care hospitals in the US were exposed to the payment scheme in the years after HVBP but not in the years before it. Critical Access Hospitals are not exposed to HVBP before and after it was launched. Therefore Acute Care hospitals is the treatment group and Critical Access Hospitals is the control group. Although the first fiscal year when HVBP started to reward hospitals is 2013, the first payment depends on the performance period of 2011. Hospitals were also announced of the structure of the program earlier that year. Therefore, the Difference in Differences analysis chooses 2011 as the year of policy intervention.

The Difference in Differences regression takes the form:

$$Y_{hts} = d_s + d_h + d_t + \beta_0 HVBP_h + \beta_1 HVBP_h \times d_t + \beta_X X_{ht} + e_{ht} \tag{1.1}$$

where Y_{hts} is the quality outcome of hospital h at time t in state s, such as mortality rates or patient experience measures. d_s, d_h and d_t are state fixed effects, hospital specific effects and time effects, respectively. $HVBP_h$ is the indicator for whether the hospital h is exposed to HVBP. X_{ht} is the characteristics of the hospitals, including teaching status, ownership status, number of beds, number of nurses, number of discharges, shares of Medicare days.

The identification of the impact of HVBP replies on several assumptions of the DID. The first is that the allocation of the policy intervention was not determined by the outcome variable. This assumption is realistic because the reason why HVBP exclude Critical Access hospitals is not because that they perform better or worse than Acute Care hospitals. It is because Critical Access hospitals serve mostly residents in rural areas who would otherwise be a long distance from emergency care and Medicare does not want to expose them to too much financial uncertainty that might be associated with HVBP. The second assumption is that the treatment and control groups have parallel trends in outcome before the policy intervention. This assumption can be directly tested using graphical visualization and the placebo tests that randomly change the policy intervention year to some year before 2011.

The instrumental variable analysis for the intensive margin effects of HVBP

I proceed with estimating the intensive margin effects of HVBP by exploiting the variation in the expected incentive payment that Medicare pays for HVBP hospitals. The following regression is applied to a sample of HVBP hospital from 2012 to 2015.

$$Y_{ht} = d_h + d_s + d_t + \beta E_t \left[Net\ Incentive_{h,t+2} \right] + X'_{ht}\gamma + e_{ht} \tag{1.2}$$

where Y_{ht} is the quality outcome measures, $Net\ Incentive_{h,t+2}$ is the incentive the hospital h is going to get in $t+2$ for its performance in t. X_{it} is a vector of characteristics of hospital i at time t, e.g., teaching status, ownership, the number of beds, the number of nurses, the proportion of low-income patients, the share of Medicare patients, and the number of discharges. e_{ht} is the idiosyncratic error. d_h, d_t, d_s are hospital, time and state fixed effects. There is a time lag between the $Net\ Incentive_{h,t+2}$ and quality measures Y_{ht} because by the design of HVBP the incentive payment is paid out in two year times from the performance period when the hospitals choose its quality levels.

Recall that $Net\ Incentive_{h,t+2} = Adj\ Factor_{h,t+2} \times FFS_{h,t+2}$ where $FFS_{h,t+2}$ is the Fee for Service amount hospital h obtain from treating Medicare patients and $Adj\ Factor_{h,t+2}$ is the scalar that Medicare will adjust its FFS payment based quality of hospital h as well as all other hospitals. In the regression (1.3) I will use adjustment factor $Adj\ Factor_{h,t+2}$ for the incentive variable instead of $Net\ Incentive_{h,t+2}$. The main reason is that Medicare does not publish data on incentive payment for participating hospitals, only its summary statistics. I can calculate the incentive payment using data on Medicare Fee for Service payment for all medical condition groups, but this data is only available for 2014 and 2015.

[6] Using the short panel of 2014 and 2015 with just over two thousand hospitals might affect the precision of the estimate of parameters. Moreover, because $FFS_{h,t+2}$ captures the structural characteristics of hospitals, such as the number of beds, the number of interns, residents, etc., one can think of $Adj\ Factor_{h,t+2}$ as the normalized incentive payment by the size of the hospitals.

One challenge to estimating the above regression is to construct a measure of hospital beliefs $E_t\left[Adj\ Factor_{h,t+2}\right]$ which are unobserved. I will circumvent this issue by constructing an empirical analog using two assumptions. I assume that in year t hospitals base their expectation on knowledge of their past observed quality measures in year $t-1$ and the adjustment factor in year $t+1$, which depends on observed quality measures in year $t-1$ as well. This is a realistic assumption because hospitals are aware of their past quality measures in relation to other hospitals since Center of Medicare and Medicaid has been releasing raw quality rates on its Hospital Compare website for these conditions since 2007. Moreover, the adjustment factor in year $t+1$ is in the information set of hospital at time t, because CMS published proposed and final rule for adjustment factor for each year a year before that [7]. Second, I assume that hospitals are right on average, that is their expectations match the realized incentive payment in the future.

Accordingly I will construct a measure of expected payment paid in year $t+2$ as a linear fit of the raw percent rates in years $t-1$ for the period 2012 to 2015 [8].

$$E_t\left[Adj\ Factor_{h,t+2}\right] = \hat{\beta}_0 + \hat{\beta}_1 Adj\ Factor_{h,t+1} + \sum_k Y_{k,h,t-1}\hat{\beta}_{k2} + X_{ht}\hat{\beta}'_X \tag{1.3}$$

where $Y_{k,h,t-t}$ is one of all quality measures of Patient Experience Outcome domain and Mortality Rates indexed by k. $Adj\ Factor_{h,t+1}$ is hospital h 's adjustment factor. X_{ht} is hospital h's characteristics.

Estimating equation (1.2) via OLS using the empirical analog of adjustment factor as the key explanatory variable introduces endogeneity since it is based on a lagged value of raw quality measures. This endogeneity concern includes, but is not limited to mean reversion. For example,

[6] The same is used to calculate incentive payments and categorize hospitals into big and small winners (losers) in the summary statistics of hospital characteristics by HVBP hospitals' incentive payment - Table 1.4.1

[7] For example, CMS published in 2016 the proposed and final rule for 2017's hospital payment.

[8] All the quality measures and Adjustment Factor are available in year 2011, however the first period of data is lost due to the use of the one period lagged Adjustment Factor to predict for the current Adjustment Factor.

with the mortality rate over 2009 - 2011 was temporarily high for hospital h then hospital h could plausibly return to a lower long-run value in the later years, even in the absence of the (less) incentive payment. In the spirit of Gupta (2016)'s work, I propose an instrument for the expected adjustment factor using as the adjustment factor generated from historical data, i.e., the year 2008. This is a valid instrument under the assumption $E\left(\epsilon_{ht}\epsilon_{hs}\right) = 0$ for $t \neq s$, i.e., the unobserved time-varying error term of the quality process is serially uncorrelated.

I construct an instrumental variable Z_h as the scaled predicted $Adj\ factor_h$ using the quality measures in 2008 and the methodology of computing adjustment factor and incentive payment Services (2011). This time period is not included in the estimation of regressions (1.2) and (1.3). I detail this calculation step by step in the Appendix. Assuming that $E\left(e_{h2008}, e_{hs}\right) = 0$ for $s > 2011$, I construct a 4×4 matrix of instrument for each hospital:

$$Z_h = \begin{bmatrix} z'_{h,2012} \\ z'_{h,2013} \\ z'_{h,2014} \\ z'_{h,2015} \end{bmatrix} = \begin{bmatrix} Adj\ factor_{h,08} & 0 & 0 & 0 \\ 0 & Adj\ factor_{h,08} & 0 & 0 \\ 0 & 0 & Adj\ factor_{h,08} & 0 \\ 0 & 0 & 0 & Adj\ factor_{h,08} \end{bmatrix}$$

1.4 Empirical Results

1.4.1 Summary of distribution of HVBP payment

Before presenting the evidence of the intensive margin and extensive margin of HVBP's impact on hospital quality, I provide several statistics that shed light on the distributional effect of HVBP.

Table 5 summarizes and compares characteristics of hospitals that receive positive net-payment from HVBP with the hospitals that receive negative amounts. Losing hospitals tend to be teaching hospitals, for-profit, in the rural area, bigger in size, and serve higher percentage of low-income patients. They also treat significantly more patients than the winning hospitals.

Table 6 investigates characteristics of big winning hospitals versus small winning hospitals and big losing hospitals versus small losing hospitals. Columns 1 and 2 show that among the winners, the high earning hospitals tend to be teaching hospitals, non-profit, in rural area, bigger in size, and treat more Medicare patients. Columns 3 and 4 show that among the hospitals that lose money, the big loser tends to be teaching hospitals, non-profit, in rural area, bigger in size and treat more patients. These statistics reveal that hospitals that are teaching hospitals, non-profit, big in size, treat more Medicare patients, in rural area are most exposed to HVBP. This makes a good sense

Table 1.5: Summary of hospital characteristics by their performance in the HVBP program

	(1) Winners	(2) Losers	(1) - (2)
Teaching Status	0.294	0.412	-0.118
	(0.011)	(0.014)	(0.020)
For profit	0.342	0.396	-0.054
	(0.012)	(0.012)	(0.018)
Urban	0.309	0.188	0.120
	(0.010)	(0.011)	(0.016)
No. of beds (100s)	2.099	3.131	-1.031
	(0.061)	(0.069)	(0.094)
No. of nurses(1000s)	3.084	4.235	-1.151
	(0.400)	(0.483)	(0.678)
Share of low income patients	0.145	0.186	-0.041
	(0.003)	(0.005)	(0.007)
Share of Medicare days	0.388	0.361	0.027
	(0.003)	(0.003)	(0.004)
No. of discharges (1000s)	0.850	1.186	-0.336
	(0.028)	(0.029)	(0.044)

Note: The HVBP payment is calculated by author using the Medicare's Inpatient Payment for all diagnosis-related groups of medical conditions and the Hospital Compare's incentive percentage and withhold percentage. Winners are HVBP hospitals that receive positive HVBP payments. Losers are HVBP hospitals that receive negative payment.The statistics reported are for fiscal year 2015. Each cell contains of mean and standard error, which are calculated using bootstrap.

Table 1.6: Summary of hospital characteristics by the performance in the HVBP program

	(1) Big winners	(2) Small winners	(1)-(2)	(3) Big losers	(4) Small losers	(3) - (4)	(1) - (3)
Teaching Status	0.37	0.22	0.14	0.56	0.27	0.29	-0.26
	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
For profit	0.29	0.39	-0.10	0.33	0.46	-0.13	0.05
	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)	(0.03)
Urban	0.21	0.41	-0.20	0.06	0.32	-0.26	0.32
	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.03)
No. beds (100s)	2.80	1.40	1.40	4.46	1.81	2.65	-2.44
	(0.10)	(0.05)	(0.09)	(0.11)	(0.06)	(0.12)	(0.10)
No. nurses(100s)	4.72	1.45	3.27	6.67	1.80	4.86	-4.42
	(0.80)	(0.07)	(0.80)	(0.95)	(0.07)	(0.95)	(0.62)
Low income patients	0.15	0.14	0.01	0.19	0.18	0.00	-0.05
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Medicare days	0.39	0.39	0.01	0.35	0.37	-0.02	0.02
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
No. discharges(1000s)	1.24	0.46	0.77	1.78	0.59	1.19	-1.11
	(0.05)	(0.02)	(0.05)	(0.05)	(0.03)	(0.05)	(0.04)

Note: Big winners (losers) are defined as HVBP hospitals that earn (lose) higher than the fifty percentile of payment of the winning (losing) group. The third colum is the difference between column1 and column 2. Column 6 is the difference between column 3 and column 4. Column 7 is the difference between column 1 and column 4. Each cell has a column of two statistics, mean and standard variation.

because an incremental change in quality (measured in Total Performance Score) is multiplied with Medicare's Fee for Service payment to obtain the value-based incentive payment, and Medicare's Fee for Service payment is increasing in size of hospital, the proportion of low-income patients treated and whether the hospital is in rural area.

Comparing columns 1 and 3 reveals how the distributional effects of HVBP. Big losers, in comparison with big winners, tend to be teaching hospitals, in rural areas, have a significantly higher number of beds and nurses, serve a higher percentage of low-income patients, treat more Medicare patients and non-medicare patients. So from the distribution point of view, HVBP redistributes Medicare's funding from hospitals from big rural hospitals who serve more Medicare, low-income patients to smaller sized hospitals in the urban areas with less Medicare, low-income patients.

Note that HVBP value-based incentive payment depends on hospital performances as well as hospital's Fee for Services payment. Therefore variances in the volume of hospital discharges and the total amount of Medicare payment will affect incentive payment range. In the Appendix, I report the summary statistics for the same hospital characteristics and big versus small winners and losers is defined not by HVBP value-based incentive dollar payment but by their percentage change of Medicare payment. I find the same pattern described above even with this measure of incentive payment.

1.4.2 Extensive margin of HVBP's impacts on quality measure: Difference in Difference Analysis

Difference in Difference Analysis for Patient Experience Outcomes

This section provides evidence of the impact of HVBP on the Patient Experience Outcomes. Figures 4.1 and 4.2 show the average trends of patient experience outcome measures of HVBP hospitals and non-HVBP hospitals. I normalize the average trends of the two hospital groups by subtracting from both their associated means in the year 2008. For most of the measures such as Nurse Communication, Discharge Communication, Responsiveness, Pain Management, Cleanness, Hospital Rating, I find an increase in the difference between the two hospital groups after 2011. However, for some measures such as Nurse Communication, Cleanness, and Hospital Rating, it seems that HVBP hospitals started to change their behavior before 2011 in anticipation of HVBP.

Table 7 presents results from DID regressions (1.1) which regresses the raw patient experience measures on the program fixed effect, $HVBP_h$, time fixed effect, $Post11_t$, the interaction terms, $HVBP_h \times Post11_t$, state fixed effects, hospital fixed effects and hospital characteristics.

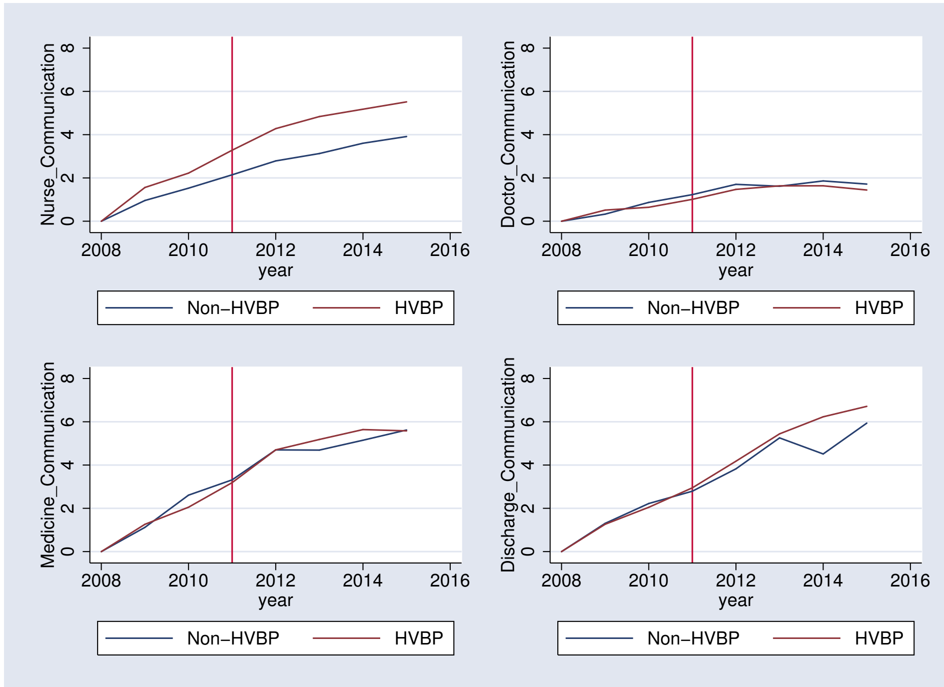

Figure 1.1: Average trends in patient experience communication measures of HVBP hospitals and non-HVBP hospitals in 2008 - 2015

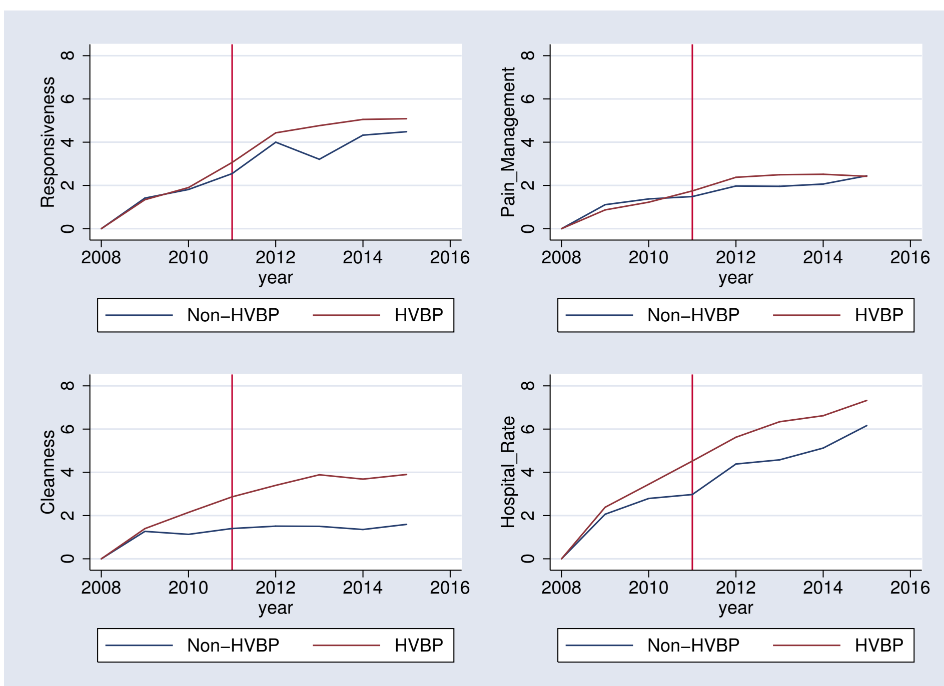

Figure 1.2: Average trends in other patient experience measures of HVBP hospitals and non-HVBP hospitals in 2008 - 2015

The regression results in Table 7 show that for some measures of patient experience domain, four out of seven measures experience small but statistically significant improvements in HVBP hospitals compared to the non-HVBP hospitals after HVBP. For example, the percentage of patients in HVBP reporting that nurses always communicate well in HVBP hospitals is on average nearly 1% higher than that in the non-HVBP hospitals relative their difference before HVBP. This is nearly 20% of the standard variation of 5.89 reported in Table 3. Similarly, after HVBP the rate at which HVBP hospitals are reported to always be clean is 1.6%, i.e., 20 % of its standard deviation, higher than the rate of non-HVBP hospitals, relative to before HVBP. The coefficients of the controls also reveal that on average non-profit hospitals with a high share of Medicare days tend to perform worse in patient experience domain than for-profit hospitals with a low share of Medicare days.

Table 1.7: Effect of the HVBP on Patient Experience measures: DID analysis

	Nurse Comn	Doctor Comn	Respon siveness	Pain Mngn	Medicine Comn	Clean- ness	Discharge Info	Hospital Rating
After HVBP	2.6***	1.5***	2.6***	1.4***	4.2***	1.0***	4.3***	4.0***
	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)	(0.3)
HVBP * After HVBP	0.9***	-0.4*	0.8**	0.3	-0.3	1.6***	-0.3	0.3
	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.2)	(0.3)
Ownership	-0.4*	-0.3	-0.8***	-0.3	-0.5*	-0.2	-0.3	-0.7**
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Teaching status	0.3	0.1	0.6**	0.1	0.2	0.1	0.2	0.6**
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)	(0.2)
Number of beds (100s)	0.2*	0.1	0.2	0.2	0.1	0.0	0.2*	0.2
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Number of nurses (100s)	0.0	0.0	0.0	0.0	0.0	0.0*	0.0*	0.0***
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of Medicare days	-6.6***	-0.7	-8.4***	-4.1***	-6.8***	-3.2**	-9.6***	-8.8***
	(0.9)	(0.8)	(1.2)	(1.1)	(1.1)	(1.1)	(0.9)	(1.2)
Number of discharges (10,000s)	-0.1	-0.0	-0.0	-0.0	-0.1	-0.2	-0.9**	0.3
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)
R^2	0.80	0.81	0.84	0.68	0.71	0.79	0.74	0.84
Observations	24083	24083	24082	24079	24069	24083	24080	24083

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

In order to examine potential heterogeneity in the effects of HVBP on patient experience measures, I include in the baseline regression equation (1.1) interaction terms between $HVBP_h$, $Post11_t$

Table 1.8: Heterogeneity effect of the HVBP program in Patient Experience measures: DID Analysis with interaction terms

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
After HVBP	2.7***	1.5***	2.6***	1.4***	4.2***	1.1***	4.3***	4.0***
	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)	(0.3)
HVBP * After HVBP	1.8***	-0.3	1.0*	0.6	-0.4	2.3***	-0.2	0.3
	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)	(0.4)	(0.3)	(0.5)
Ownership	-0.3	-0.1	-0.7**	-0.1	-0.4	0.1	-0.2	-0.6*
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)
Teaching status	0.3	0.0	0.6*	0.2	0.3	0.2	0.2	0.5*
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)
Number of beds (100s)	0.0	0.0	-0.0	-0.0	-0.0	-0.3*	0.1	-0.0
	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Number of nurses (100s)	0.1**	0.0	0.1**	0.0	0.1*	0.0	0.1*	0.1**
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of Medicare days	-5.2***	-0.4	-7.8***	-3.5**	-6.6***	-2.0	-9.3***	-8.3***
	(0.9)	(0.8)	(1.2)	(1.1)	(1.2)	(1.2)	(0.9)	(1.3)
Number of discharges (10,000s)	-0.3	-0.3	-0.3	-0.1	-0.2	-0.4	-0.8**	0.1
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.3)	(0.3)
HVBP*Post11 *Ownership	-0.2	-0.3*	-0.1	-0.2	-0.1	-0.3	-0.2	-0.1
	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)
HVBP*Post11 *Teaching	0.0	0.1	0.1	-0.0	-0.1	-0.2	0.0	0.1
	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)
HVBP*Post11 *No. of Beds	0.1	0.0	0.1	0.1*	0.1*	0.2	0.1**	0.2*
	(0.1)	(0.0)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)	(0.1)
HVBP*Post11 *No. of Nurses	-0.1**	-0.0	-0.1**	-0.0	-0.1*	-0.0	-0.0*	-0.1*
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
HVBP*Post11 *Share of Medicare days	-3.2***	-0.8*	-1.5*	-1.3*	-0.4	-2.8***	-0.4	-1.3
	(0.5)	(0.4)	(0.7)	(0.5)	(0.6)	(0.7)	(0.5)	(0.7)
HVBP*Post11 *No.of discharges	0.3*	0.3**	0.4*	0.1	0.1	0.3	-0.1	0.3
	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)
R^2	0.81	0.81	0.84	0.68	0.71	0.79	0.74	0.84
Observations	24083	24083	24082	24079	24069	24083	24080	24083

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Standard errors in parentheses. All regressions include state fixed effects and hospital fixed effects, and use robust variance - covariance structure.

and hospital characteristics. Table 8 reveals that there are significant variations in the ways that hospitals of different characteristics respond to HVBP. For example, from before to after HVBP, for-profit, big sized HVBP hospitals with many nurses and high proportion of Medicare patients improve patient experience less than non-profit hospitals, small sized HVBP hospitals with less nurses and high proportion of Medicare patients. This might be at first counter intuitive because for big sized hospitals with high proportion of Medicare patients, their marginal rewards to incremental increase in quality are higher than that of small hospitals with low proportion of Medicare patients. However, their negative responses can be rationalized by considering the cost of complying with the program and improving quality. . Estimating the cost of improving each of the quality measures or quality domains is a difficult task and outside the scope of this paper because of the lack of reliable cost data and the tight correlation between quality measures within same quality domain.

The most critical DID assumption is the parallel trend assumption, which requires that in the absence of treatment, the treatment and the control groups have common trends in outcome variables. Figures 1 and 2 have shown clearly that some HBVP hospitals already responded to the anticipation of the policy before the policy actually started. To test this common trend assumption, I run two placebo tests, one of which assumes HVBP starts in 2009 and the other assumes HVBP starts in 2010. If the common trend assumptions are warranted, the estimated coefficient β_1 of the interaction term between time and policy fixed effect should be statistically insignificant. Table 9 shows the results of the regression which assumes that the time of policy intervention was 2009. The result of the placebo test which assumes the time of policy intervention was 2010 is reported in the Appendix.

The regression in Table 9 shows that for the most of measures, except Nurse Communication and Hospital Cleanness measures, there is no significant difference in the difference between the two groups of hospitals before and after 2009. However, the other placebo test in Table 19 in the Appendix shows that for Doctor Communication, Medicine Communication and Hospital Cleanness, there is a significant change in the difference between the groups of hospitals before and after 2009. In order to take into account possible changes in hospitals quality prior to the program starting year, I re-estimate the DID regression with the time of policy intervention being 2009. The results are presented in Table 10. There is no evidence that the estimated coefficient β_1 changes by a statistically significant magnitude. For example, the estimated effect on Nurse Communication measure was 0.9 % with a confidence interval of [0.5%, 1.3%] while the updated estimated effect is 1.1%. Therefore the conclusion that HVBP has a small but statistically significant impact on some of the measure of patient experience outcome holds true.

Table 1.9: Placebo Test for DID Analysis of HCAHPS measures - Placebo time of intervention: 2009

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
Post09	1.2***	0.6**	1.5***	1.2***	1.9***	1.2***	1.7***	2.5***
	(0.2)	(0.2)	(0.3)	(0.3)	(0.3)	(0.2)	(0.2)	(0.3)
HVBP*Post09	0.6**	0.0	0.0	-0.2	-0.3	0.6*	-0.0	0.4
	(0.2)	(0.2)	(0.3)	(0.3)	(0.3)	(0.2)	(0.2)	(0.3)
Ownership	0.0	-0.2	-0.2	0.3	0.1	0.4	-0.4	-0.3
	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)	(0.4)	(0.2)	(0.4)
Teaching status	0.5	0.2	0.1	0.3	0.1	-0.2	0.0	0.0
	(0.3)	(0.2)	(0.4)	(0.3)	(0.4)	(0.3)	(0.2)	(0.3)
No. of beds	0.2	0.2	0.3*	0.2	-0.1	0.2	0.3*	0.5**
(100s)	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)
No. of nurses	0.0	0.0	0.1*	0.0	0.0	0.0	-0.0	0.0
(100s)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of	-0.6	0.8	-1.5	0.2	0.9	0.3	-0.4	-0.2
Medicare days	(1.8)	(1.7)	(2.5)	(2.3)	(2.6)	(1.8)	(1.6)	(2.4)
R^2	0.89	0.88	0.91	0.81	0.81	0.89	0.86	0.91
Observations	10255	10255	10255	10255	10255	10255	10255	10255

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Table 1.10: Updated DID Analysis of HCAHPS measures - Policy intervention in 2009

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
Post09	2.5***	1.3***	2.7***	1.7***	3.8***	1.4***	4.0***	4.1***
	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.2)	(0.3)
HVBP*Post09	1.1***	-0.1	0.7*	0.1	-0.1	1.5***	-0.2	0.5
	(0.2)	(0.2)	(0.3)	(0.3)	(0.3)	(0.3)	(0.2)	(0.3)
Ownership	-0.4*	-0.2	-0.7**	-0.2	-0.4*	-0.1	-0.2	-0.6*
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)
Teaching status	0.4*	0.1	0.7**	0.2	0.4	0.2	0.3*	0.7**
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
No. of beds	0.4***	0.2*	0.4**	0.2**	0.3**	0.1	0.4***	0.4**
(100s)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
No.of nurses	0.0*	0.0	0.0**	0.0	0.0**	0.0**	0.0***	0.0***
(100s)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of	-10.0***	-1.8*	-11.9***	-5.5***	-11.2***	-5.4***	-14.1***	-12.2***
Medicare days	(1.0)	(0.8)	(1.2)	(1.1)	(1.2)	(1.1)	(1.0)	(1.3)
No.of	-0.7*	-0.2	-0.6	-0.3	-0.9*	-0.6	-1.6**	-0.4
discharges (10,000s)	(0.3)	(0.2)	(0.3)	(0.2)	(0.4)	(0.3)	(0.5)	(0.3)
R^2	0.98	0.81	0.83	0.67	0.68	0.79	0.69	0.84
Observations	24083	24083	24082	24079	24069	24083	24080	24083

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

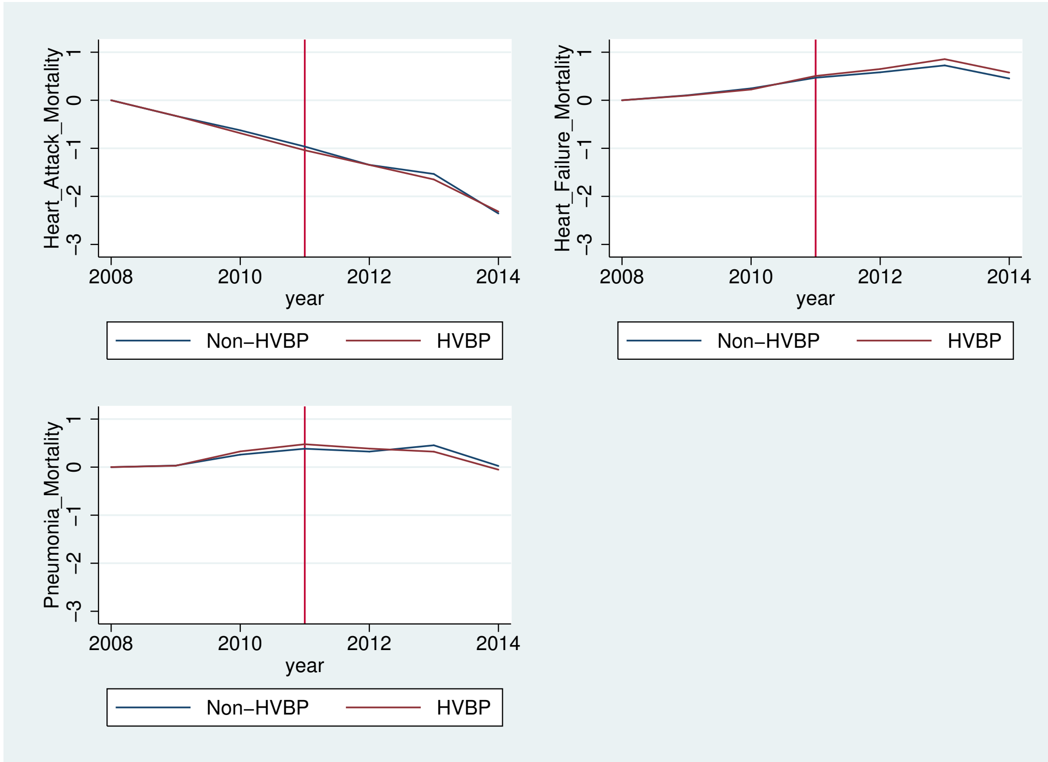

Figure 1.3: Differences in other Clinical outcome measures in 2008 - 2015

DID results for Mortality measures

This section presents evidence of the impacts of HVBPs on mortality measures. Figure 4.3 shows the normalized average trends of mortality rates in HVBP hospitals and non-HVBP hospitals. While heart attack mortality rate trends down significantly by more than 2% over the study period, heart failure mortality trends up by nearly 1%. Interestingly, before HVBP, pneumonia mortality rate increases by 0.4%; however, this trend subsides and reverses in the years after HVBP.

As predictable from the average trends in Figure 4.3, the DID regressions reported in Table 11 indicate that HVBP has resulted in no significant change in heart attack mortality, heart failure mortality and pneumonia mortality rates.

I proceed by investigating whether HVBP hospitals of different characteristics respond to HVBP differently and whether the heterogeneity might be averaged out in regressions reported in Table 11. I regress again the DID regression 1.1 including the interaction terms of $HVBP_h$, $Post11_t$ and hospital characteristics such as ownership, teaching status, number of nurses, number of beds, number of discharges and share of Medicare days. The regression results in Table 20 in the Appendix show that mortality measures do not experience significant change before and after HVBP, and the lack of response in mortality measures holds true for all HVBP hospitals of different characteristics.

Table 1.11: Impact of HVBP on Mortality measures - DID Analysis

	Heart Attack Mortality	Heart Failure Mortality	Pneumonia Mortality
After HVBP	-0.6	0.9***	-0.6
	(0.6)	(0.2)	(0.6)
HVBP * After HVBP	-0.8	0.1	-0.8
	(0.7)	(0.3)	(0.7)
Ownership	-0.3	0.6	-0.3
	(0.6)	(0.3)	(0.6)
Teaching status	-0.9*	0.2	-0.9*
	(0.4)	(0.5)	(0.4)
Number of beds	1.4*	-1.3**	1.4*
(100s)	(0.7)	(0.4)	(0.7)
Number of nurses	0.3	0.4	0.3
(100s)	(0.4)	(0.2)	(0.4)
Share of	2.9	0.7	2.9
Medicare days	(2.2)	(1.2)	(2.2)
Number of discharges	-0.9	0.2	-0.9
(10,000s)	(1.4)	(1.1)	(1.4)
R^2	0.682826	0.577170	0.682826
Observations	215	547	215

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Similar to the DID analysis for patient experience measures, I also run the same placebo tests for the mortality measures in order to test for the common trend assumption. Table 12 indicates that in the placebo regressions that assume 2009 as a year of policy intervention, from before to after HVBP, HVBP hospitals do not change their mortality rates significantly compare to non-HVBP hospitals. Table 20 in the Appendix present the same results for the placebo test that assumes that the policy started in 2010. In summary, the DID analysis for the mortality rates has shown consistently that HVBP has no significant effects on hospitals' clinical outcomes.

1.4.3 Intensive margin of HVBP's impacts on hospital quality

This section presents results of the intensive margin analysis of HVBP's impacts on hospital quality. The analysis exploits variations in incentive payment HVBP hospitals expect to be paid. Recall that the regression will not use the incentive payment in dollars but will instead use the adjustment factor that is used to adjust Fee for Service baseline payment. Expected adjustment factor is proxied by a

Table 1.12: Placebo Test for DID Analysis for Clinical outcome measures: Placebo policy in 2009

	Heart Attack Mortality	Heart Failure Mortality	Pneumonia Mortality
Post09	-0.4***	0.2***	-0.4***
	(0.1)	(0.0)	(0.1)
HVBP* Post09	-0.1	-0.0	-0.1
	(0.1)	(0.0)	(0.1)
Ownership	0.0	-0.0	0.0
	(0.1)	(0.1)	(0.1)
Teaching status	0.2	0.1	0.2
	(0.1)	(0.1)	(0.1)
Number of beds	-0.1	0.0	-0.1
(100s)	(0.0)	(0.0)	(0.0)
Number of nurses	-0.0	-0.0	-0.0
(100s)	(0.0)	(0.0)	(0.0)
Share of	0.3	-1.0**	0.3
Medicare days	(0.6)	(0.3)	(0.6)
R^2	0.82	0.84	0.82
Observations	7810	10982	7810

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

linear function of quality measure and the associated adjust factor in the previous period. The graph that shows fitness of the predicted adjustment factor is provided in the Appendix. The predicted adjustment factor explains about 44% of variations in the realized adjustment factor.

By the construction of the expected adjustment factor constructed by previous quality measures might be endogenous due to mean reversion. To address this issue I construct an instrument which is the adjustment factor generated by quality measures in the year 2008.

Table 13 summarizes the regression results for patient experience measures. The coefficients of expected Adjustment Factor is consistently negative for all the Patient Experience measures. This would mean that hospitals that expect to receive higher payments in the two periods time would actually do worse than hospitals that expect to receive less payments. In other words, there is evidence of lower quality hospitals, measured by the expected incentive payment based on their past performance, catching up with higher quality hospitals. To put dollars into the estimated coefficients, consider a hospital which expects to move from the 50th percentile to the 75th percentile of the Adjustment Factor distribution or the Total Performance Score distribution in 2015 [9]. This movement is equivalent to almost USD 50,000 of incentive payment, a third of the net incentive payment standard deviation. [10]. The coefficient for the nurse communication regression implies that expecting to receive USD 50,000 more, the hospital will decrease its performance by 0.187%, i.e., three times of standard deviation. The patient experience that responds most significantly is medicine communication, by a magnitude of 0.024%. Consistent with the extensive margin analysis, for-profit and big size (measured by the number of beds) hospitals is negatively correlated with the quality. The lower panel of Table 14 provides some test statistics and p-value for under-identification test, over-identification and weak-identification test. Overall, they imply that the model is identified and that I can cautiously conclude that the proposed instruments are not weak. The over-identification test shows that there are three instances where the exclusion restrictions assumptions are rejected. However, given the estimated

coefficients of the predicted adjustment factor are consistently negative over all measures within patient experience domain, the magnitude or at least the sign of the estimated coefficients are reliable.

I proceed the same estimation for the Clinical quality measures. Consistent and complementary with the extensive margin analysis, Table 14 shows that even within HVBP program, heart attack

[9]The distribution of the two variable are the same because Adjustment Factor is a linear function of Total Performance Score and the slope of that function is endogenously determined by the total funding available for the program.

[10]The average Medicare Fee for Service payment is 19,014,427. The 50th and 75th percentiles of Adjustment Factor distribution are 1.003229 and 1.000601 correspondingly. Standard derivation of the net incentive payment is $165252.

Table 1.13: Intensive margin of the effects of HVBP Payment on Patient Experience measures

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
Predicted Adjustment Factor	-7.127***	-4.482***	-7.780***	-2.545**	-9.419***	-5.172***	-4.670**	-6.668***
	(1.418)	(1.068)	(1.722)	(0.952)	(1.981)	(1.432)	(1.683)	(1.824)
Teaching status	-0.003	-0.002	-0.004	0.002	0.001	-0.004	-0.001	-0.001
	(0.003)	(0.002)	(0.004)	(0.002)	(0.004)	(0.003)	(0.004)	(0.004)
Ownership	-0.010*	-0.007*	-0.011	0.001	-0.012*	-0.006	-0.012**	-0.013*
	(0.004)	(0.003)	(0.006)	(0.003)	(0.006)	(0.004)	(0.004)	(0.005)
No. of beds (100s)	-0.002	-0.003*	-0.002	-0.001	-0.004	-0.002	-0.003	-0.003
	(0.002)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)
No. of nurses (100s)	0.000***	0.000***	0.000***	0.000***	0.000***	0.000**	0.000***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Low income Patient Share	0.011	0.007	0.002	0.005	0.003	-0.009	-0.003	-0.005
	(0.021)	(0.015)	(0.025)	(0.014)	(0.029)	(0.020)	(0.025)	(0.026)
No. discharges (10,000s)	0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share of Medicare days	0.031	0.038*	0.035	0.019	0.022	-0.007	0.030	0.027
	(0.021)	(0.017)	(0.028)	(0.015)	(0.029)	(0.021)	(0.025)	(0.027)
No. Obs	7084	7084	7084	7084	7084	7084	7084	7084
Under identification	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Over identification	0.035	0.189	0.062	0.079	0.001	0.172	0.183	0.001
Weak identification	38.233	38.233	38.233	38.233	38.233	38.233	38.233	38.233

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. The underidentification test has the null hypothesis that the excluded variables are relevant, meaning correlated with the predicted Adjustment Factor. The overidentifcation test has the null hypothesis that the exclusion restriction holds. p-value > 0.05 means there is no evidence against the exclusion assumption of the proposed IVs. The statistics for weak identification test is the Kleibergen-Paap rk Wald F statistic statistic, with the critical values being 19.93 and the higher statistics means rejection of the null that the instruments are weak.

mortality and pneumonia mortality do not decrease significantly for hospitals that expect higher incentive payment. It also provides a relatively weak evidence that heart failure mortality actually increases for hospitals that expect to receive a high incentive payment.

Table 1.14: Intensive margin of the effects of HVBP Payment on Clinical outcome measures

	Heart Attack Mortality	Heart Failure Mortality	Pneumonia Mortality
Predicted	-0.054	1.109*	-0.960
Adjustment Factor	(0.493)	(0.488)	(0.637)
Teaching status	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)
Ownership	0.001	0.000	-0.001
	(0.001)	(0.002)	(0.002)
Number of beds	0.000	0.001	0.000
(100s)	(0.000)	(0.001)	(0.001)
Number of nurses	0.000*	-0.000***	0.000***
(100s)	(0.000)	(0.000)	(0.000)
Low income	0.003	-0.000	-0.013
Patient Share	(0.007)	(0.006)	(0.009)
Number of	-0.000	0.000	0.000
discharges (10,000s)	(0.000)	(0.000)	(0.000)
Share of	0.013	0.003	0.018
Medicare days	(0.007)	(0.007)	(0.009)
Observations	6943	7085	7084
p-value of underidentification test	0.000	0.000	0.000
p-value of overidentification test	0.628	0.536	0.680
Statistics weak identificantion test	34.380	38.337	38.349

Note: Standard errors in parentheses. The underidentification test has the null hypothesis that the excluded variables are relevant, meaning correlated with the predicted Adjustment Factor. The overidentifcation test has the null hypothesis that the exclusion restriction holds. p-value $>$ 0.05 means there is no evidence against the exclusion assumption of the proposed IVs. The statistics for weak identification test is the Kleibergen-Paap rk Wald F statistic, with the critical value being 19.93 and the higher statistics means rejection of the null that the instruments are weak.

1.5 Concluding remarks

This paper examines both intensive margin and extensive margin of the impact on hospital quality of Medicare's Hospital Value-Based Purchasing, one of the largest value-based payment that the US government implements

Exploiting the exogenous introduction of this payment scheme to Acute Care hospitals and not to Critical Access hospitals, Difference-in-Differences analysis shows that HVBP only has limited extensive margin effects on hospital quality measures. Comparing the hospitals which participate in HVBP with the ones which do not, I find that relative to non-HVBP hospitals, HVBP hospitals improve significantly in only half of the patient experience measures from before to after HVBP. The magnitude of the improvement is around 20% of those measures' standard deviation. Other patient experience measures also experience increases but by a non-significant magnitude. I also find that HVBP does not have an impact on mortality rates.

The DID analysis also indicates that among measures which HVBP hospitals do respond to incentive payments, HVBP hospitals of different characteristics respond differently. The responsiveness of HVBP hospitals to HVBP is negatively correlated with whether they are for-profit hospitals, bigger in sized and treat a higher proportion of Medicare patients. This result suggests that the cost of compliance for hospitals to HVBP, which including improving and reporting quality, might outweigh the incentive payment, even for HVBP hospitals that would benefit from HVBP payment scheme the most.

Consistent with the extensive margin analysis, the intensive margin analysis also shows that conditional on participating in HVBP, hospitals' patient experience domain measures are also more responsive to expected incentive payment than hospital clinical outcome measures. Moreover, the intensive margin analysis additionally shows that among HVBP hospitals, hospitals that expect to receive more incentive payment in the future actually perform worse than hospitals that expect to receive less incentive payment.

Summary statistics of hospital characteristics by HVBP incentive payment has pointed out that the program redistributes money from large sized rural hospitals which treat many low-income, Medicare payment to smaller size urban hospitals which treat less low-income, Medicare patients. Given the results of small to no significant effects of HVBP on hospital quality measures, HVBP's impact might largely be distributional. Moreover, the direction of this re-distribution of funding might not be desirable.

It might well be that the smaller sized hospitals in the urban areas receive a higher amount of value-based incentive payment because they improve quality more than the big sized rural hospitals. However, as the DID analysis will show below, there are no significant improvements in many quality measures of participating hospitals relative to non-participating hospitals. The IV analysis also shows that high expected incentive payment actually discourage hospitals from improving quality. Therefore, the effects of HVBP might largely be re-distributional and the direction of this redistribution might not be desirable.

The analyses in this version of the paper have several drawbacks some of which can be improved upon. First, although the DID analysis has carefully controlled for hospital fixed effects, state fixed effects and other hospital observable characteristics, the control hospitals, i.e., Critical Access hospitals might be fundamentally different from Acute Care hospitals. The DID synthetic control approach might be more suitable to make analysis more robust.

This paper also does not provide an empirical test for mechanisms that give rise to the empirical results found here. For example, the results that HVBP hospitals improve on some dimension of patient experience quality but not mortality rates might be due that for hospitals reduction of mortality rates might be more difficult to improve than patient experience. However, it is out of this paper's cope, for example, to estimate the marginal cost of improving each quality measures.

Finally, this paper is not able to make a normative statement about HVBP's effects. For example, I am not able to answer the question of whether the effects that HVBP has on some of the hospital patient experience but not on mortality rates are actually welfare improving. This is an important question for designing optimal value-based payment scheme, especially if improving patient experience is costly.

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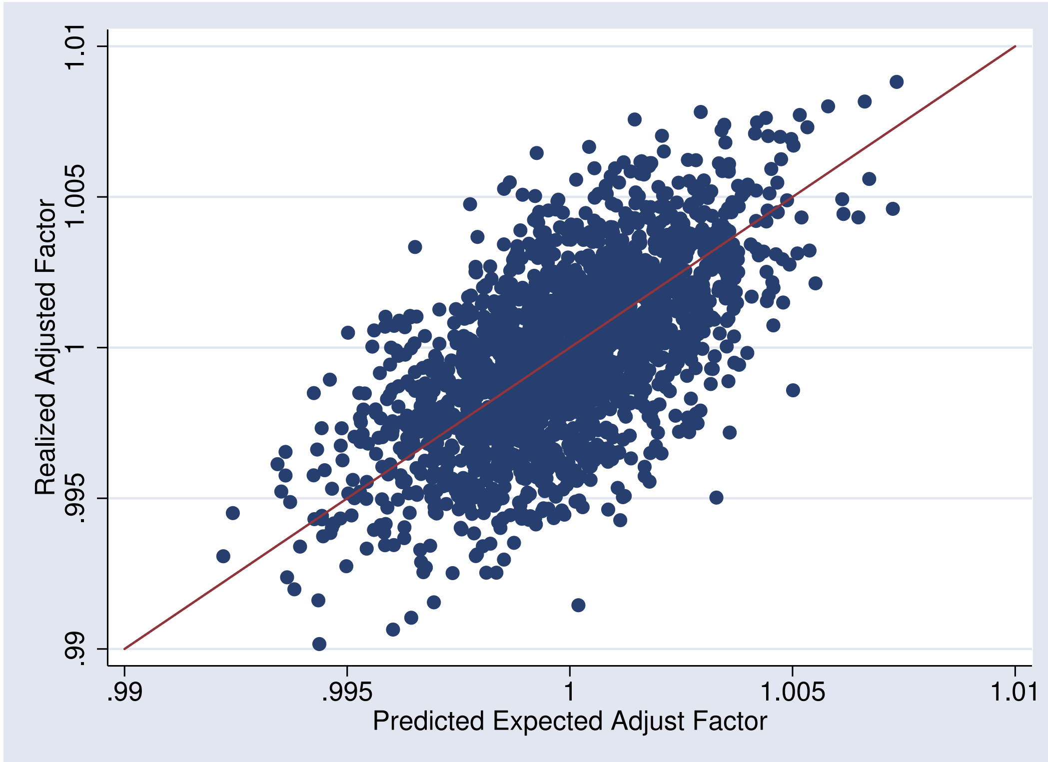


$R^2 = 0.44$

Figure 1.4: HVBP Realized Adjustment Factor versus Predicted Expected Adjustment Factor

Appendix

Calculation of scaled predicted Adjustment Factor I used to Center of Medicare and Medicaid (CMS) 's methodology to approximate for the Total Performance Score (TPS) for all HVBP hospitals. To translate TPS into Adjustment Factor, CMS uses the linear exchange function where the the slope is determined by the total budget available for this program. Because this budget available is exogenously determined by the CMS, the variations in Total Performance fully capture the variations in the Adjustment Factor.

I am not able to calculate exactly the Total Performance score with the publicly available, hospital-level Hospital Compare data. The reason is that in this data set, the measure dates of the mortality rate do not match the performance period used in the CMS's calculation of TPS. I am applying for medical, individual-claims data, which will allow me to obtain the mortality rates for the appropriate period. The patient experience outcome measures do not have this issue, and therefore can be used to proxy for Total Performance score. Because the weight of patient experience domain in this calculation varies from 30% to 50%, the proxy is able to capture well the variations in the real Total Performance score.

Domain\Year	Measure Names	2013	2014	2015	2016	2017
Patient Experience	Communication with Nurses	x	x	x	x	x
	Communication with Doctors	x	x	x	x	x
	Communication about Medicines	x	x	x	x	x
	Discharge Information	x	x	x	x	x
	Responsiveness of Hospital Staff	x	x	x	x	x
	Cleanliness and Quietness of Hospital Environment	x	x	x	x	x
	Overall Rating of Hospital	x	x	x	x	x
Clinical Care Outcome	Acute Myocardial Infarction 30-Day Mortality Rate	x	x	x	x	x
	Heart Failure 30-Day Mortality Rate	x	x	x	x	x
	Pneumonia 30-Day Mortality Rate	x	x	x	x	x
Efficiency	Medicare Spending Per Beneficiary			x	x	x
Safety	Surgical Site Infections - Colon Surgery				x	x
	Elective Delivery Prior to 39 Completed Weeks Gestation					x
	Complication/Patient safety for selected indicators Composite			x	x	x
	Methicillin-Resistant Staphylococcus aureus					x
	Clostridium difficile Infection					x
	Central Line-Associated Blood Stream Infection			x	x	x
	Catheter-Associated Urinary Tract Infection				x	x
Process Care Outcome	Fibrinolytic Therapy Received Within 30 Minutes of Hospital Arrival	x	x	x	x	x
	Primary PCI Received Within 90 Minutes of Hospital Arrival	x	x	x		
	Blood Cultures Performed in the Emergency Department Prior to Initial Antibiotic Received in Hospital	x	x	x		
	Initial Antibiotic Selection for CAP in Immunocompetent Patient	x	x	x	x	
	Discharge Instructions	x	x	x		
	Prophylactic Antibiotic Received Within One Hour Prior to Surgical Incision	x	x	x		
	Prophylactic Antibiotic Selection for Surgical Patients	x	x	x	x	
	Prophylactic Antibiotics Discontinued Within 24 Hours After Surgery End Time	x	x	x	x	
	Cardiac Surgery Patients with Controlled 6AM Postoperative Serum Glucose	x	x	x		
	Surgery Patients on a Beta Blocker Prior to Arrival That Received a Beta Blocker During the Perioperative Period	x	x	x	x	
	Surgery Patients with Recommended Venous Thromboembolism Prophylaxis Ordered	x	x			
	Surgery Patients Who Received Appropriate Venous Thromboembolism Prophylaxis Within 24 Hours Prior to Surgery to 24 Hours After Surgery	x	x	x	x	

Table 1.15: Full List of Quality measures included in HVBP program in 2013 - 2017

Table 1.16: Summary of hospital characteristics by the performance in the HVBP program - Incentive payment measured in percentage change

	(1) Positive Payment	(2) Negative Payment	(1) - (2)
Teaching Status	0.294	0.410	-0.116
	(0.012)	(0.014)	(0.020)
For profit	0.343	0.398	-0.054
	(0.012)	(0.015)	(0.016)
Urban	0.312	0.195	0.117
	(0.012)	(0.010)	(0.017)
No. of beds (100s)	2.117	3.117	-0.999
	(0.055)	(0.066)	(0.089)
No. of nurses(1000s)	3.000	4.339	-1.339
	(0.423)	(0.639)	(0.637)
Share of low income patients	0.144	0.187	-0.043
	(0.003)	(0.003)	(0.005)
Share of Medicare days	0.389	0.361	0.028
	(0.003)	(0.003)	(0.004)
No. of discharges (1000s)	0.844	1.189	-0.345
	(0.020)	(0.026)	(0.033)

Note: The HVBP payment is net percentage change in the Medicare payment, calculated by author using the Hospital Compare's incentive percentage and withhold percentage. The statistics reported are for fiscal year 2005. Each cell contains of mean and standard error, which are calculated using bootstrap.

Table 1.17: Summary of hospital characteristics by the performance in the HVBP program - Incentive payment measured in percentage change

	(1) Big winners	(2) Small winners	(1)-(2)	(3) Big losers	(4) Small losers	(3) - (4)	(1) - (3)
Teaching Status	0.23	0.36	-0.13	0.44	0.38	0.07	0.01
	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.04)
For profit	0.37	0.31	0.06	0.40	0.40	0.00	-0.11
	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
Urban	0.38	0.25	0.13	0.17	0.22	-0.05	-0.02
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
No. of beds (100s)	1.60	2.63	-1.03	3.27	2.96	0.31	0.03
	(0.08)	(0.07)	(0.10)	(0.09)	(0.08)	(0.11)	(0.14)
No. of nurses(1000s)	1.93	4.07	-2.14	3.97	4.71	-0.74	0.80
	(0.12)	(0.85)	(0.87)	(0.14)	(1.32)	(1.37)	(1.21)
Share of low income patients	0.13	0.15	-0.02	0.20	0.18	0.02	-0.02
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Share of Medicare days	0.39	0.38	0.01	0.35	0.37	-0.02	0.02
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
No. of discharges	0.60	1.08	-0.48	1.24	1.14	0.10	0.14
	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.05)	(0.06)

Note: Big winners (losers) are defined as HVBP hospitals that earn (lose) higher than the fifty percentile of payment of the winning (losing) group. The third colum is the difference between column1 and column 2. Column 6 is the difference between column 3 and column 4. Column 7 is the difference between column 1 and column 4. Each cell has a column of two statistics, mean and standard variation.

Table 1.18: Placebo Test for DID Analysis of HCAHPS measures - Placebo time of intervention: 2010

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
Post10	1.1***	0.7***	1.1***	0.9***	2.2***	0.6**	1.6***	1.8***
	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)	(0.2)
HVBP*Post10	0.3	-0.4*	0.0	-0.1	-0.9**	0.8***	-0.3	0.3
	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.2)	(0.2)	(0.2)
Ownership	0.0	-0.1	-0.2	0.3	0.2	0.4	-0.3	-0.3
	(0.3)	(0.3)	(0.4)	(0.3)	(0.4)	(0.4)	(0.2)	(0.4)
Teaching status	0.6*	0.3	0.2	0.4	0.2	-0.1	0.1	0.2
	(0.3)	(0.2)	(0.4)	(0.3)	(0.3)	(0.3)	(0.2)	(0.3)
No. of beds	0.2	0.2	0.3*	0.2*	-0.1	0.2	0.3*	0.5**
(100s)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.2)
No. of nurses	0.0	0.0*	0.1**	0.0	0.0	0.0	0.0	0.1
(100s)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of	-6.4***	-1.3	-6.5**	-3.1	-4.0	-4.8**	-5.4***	-9.2***
Medicare days	(1.8)	(1.6)	(2.5)	(2.2)	(2.5)	(1.8)	(1.6)	(2.4)
R^2	0.87	0.88	0.90	0.80	0.80	0.89	0.86	0.90
Observations	10255	10255	10255	10255	10255	10255	10255	10255

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Table 1.19: Updated DID Analysis of HCAHPS measures - Policy intervention in 2009

	Nurse Comn	Doctor Comn	Respon-siveness	Pain Mngn	Medicine Comn	Clean-ness	Discharge Info	Hospital Rating
Post09	2.5***	1.3***	2.7***	1.7***	3.8***	1.4***	4.0***	4.1***
	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)	(0.3)	(0.2)	(0.3)
HVBP*Post09	1.1***	-0.1	0.7*	0.1	-0.1	1.5***	-0.2	0.5
	(0.2)	(0.2)	(0.3)	(0.3)	(0.3)	(0.3)	(0.2)	(0.3)
Ownership	-0.4*	-0.2	-0.7**	-0.2	-0.4*	-0.1	-0.2	-0.6*
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)
Teaching status	0.4*	0.1	0.7**	0.2	0.4	0.2	0.3*	0.7**
	(0.2)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
No. of beds	0.4***	0.2*	0.4**	0.2**	0.3**	0.1	0.4***	0.4**
(100s)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
No.of nurses	0.0*	0.0	0.0**	0.0	0.0**	0.0**	0.0***	0.0***
(100s)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Share of	-10.0***	-1.8*	-11.9***	-5.5***	-11.2***	-5.4***	-14.1***	-12.2***
Medicare days	(1.0)	(0.8)	(1.2)	(1.1)	(1.2)	(1.1)	(1.0)	(1.3)
No.of	-0.7*	-0.2	-0.6	-0.3	-0.9*	-0.6	-1.6**	-0.4
discharges	(0.3)	(0.2)	(0.3)	(0.2)	(0.4)	(0.3)	(0.5)	(0.3)
(10,000s)								
R^2	0.98	0.81	0.83	0.67	0.68	0.79	0.69	0.84
Observations	24083	24083	24082	24079	24069	24083	24080	24083

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Table 1.20: Impact of HVBP on Clinical outcome measures - DID Analysis with heterogeneity

	Heart Attack Mortality	Heart Failure Mortality	Pneumonia Mortality
After HVBP	-0.588	0.847***	-0.588
	(0.532)	(0.199)	(0.532)
HVBP * After HVBP	-2.614	0.188	-2.614
	(1.722)	(0.908)	(1.722)
Ownership	-0.745	0.331	-0.745
	(0.738)	(0.289)	(0.738)
Teaching status	-1.295**	0.335	-1.295**
	(0.458)	(0.492)	(0.458)
Number of beds	1.196	-1.290**	1.196
(100s)	(0.922)	(0.491)	(0.922)
Number of nurses	0.382	0.166	0.382
(100s)	(0.660)	(0.576)	(0.660)
Share of	1.927	0.706	1.927
Medicare days	(2.807)	(1.289)	(2.807)
Number of discharges	-0.745	0.903	-0.745
(10,000s)	(1.823)	(0.968)	(1.823)
HVBP*Post11*Ownership	0.428	0.492	0.428
	(0.568)	(0.329)	(0.568)
HVBP*Post11*Teaching	1.139	-0.225	1.139
	(0.574)	(0.526)	(0.574)
HVBP*Post11*No. of Beds	0.242	0.003	0.242
	(0.370)	(0.366)	(0.370)
HVBP*Post11*No. of Nurses	-0.213	0.125	-0.213
	(0.665)	(0.525)	(0.665)
HVBP*Post11*Medicare	3.293	-0.223	3.293
share	(2.509)	(1.390)	(2.509)
HVBP*Post11s	-0.622	-0.588	-0.622
*No. of discharges	(1.200)	(1.059)	(1.200)
R^2	0.710082	0.585276	0.710082
Observations	215	547	215

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Table 1.21: Placebo Test for DID Analysis for Clinical outcome measures: Placebo policy in 2010

	Heart Attack Mortality	Heart Failure Mortality	Pneumonia Mortality
Post10	-0.4***	0.2***	-0.4***
	(0.1)	(0.0)	(0.1)
HVBP*Post10	-0.0	-0.0	-0.0
	(0.1)	(0.0)	(0.1)
Ownership	0.0	-0.0	0.0
	(0.1)	(0.1)	(0.1)
Teaching status	0.1	0.1	0.1
	(0.1)	(0.1)	(0.1)
Number of beds	-0.1	0.0	-0.1
(100s)	(0.0)	(0.0)	(0.0)
Number of nurses	-0.0	-0.0	-0.0
(100s)	(0.0)	(0.0)	(0.0)
Share of	2.1***	-1.3***	2.1***
Medicare days	(0.6)	(0.3)	(0.6)
R^2	0.82	0.84	0.82
Observations	7810	10982	7810

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Standard errors in parentheses. All regressions include HBVP fixed effect, state fixed effects and hospital fixed effects, and use cluster variance at hospital level.

Chapter 2

Relative importance of financial incentive vs quality and cost information in demand side policies

2.1 Introduction

Spending on health care services in the United States has grown rapidly over the past decades. Policy makers, large employers and insurers have made efforts to address cost growth without reduction in the quality of and the access to care. One approach to addressing cost growth is to exposing consumers with insurance to greater proportion of the full price for health care services. Examples of such approach is high-deductible insurance plans and tiered insurance plans (Brot-Goldberg et al., 2017; Trivedi et al., 2010). The other approach is to make price variations more transparent and to encourage patients to search on price transparency tools for high-value care providers (Whaley et al., 2014; Brown, 2019; Desai et al., 2017, 2016; Lieber, 2017) . While the individual impacts of these efforts have been documented, there is a lack of evidence on their relative effects. In this paper, I examine the relative importance of these two approaches in changing patients' choice towards higher-valued care.

I exploit the reference pricing (RP) initiative by CalPERS and Anthem Blue Cross (BC) starting from January 2012. This policy is a response to the observations that the outpatient service prices vary signficantly across regions and even within local markets in California, which can not be fully explained by variations in quality and costs. CalPERS and BC made it clear for patients that for some outpatient procedures, such as arthroscopy, colonoscopy, and cataract removal procedures, ambulatory surgery centers (ASCs) and hospital outpatient departments (HOPDs) provide comparable quality while ambulatory surgery centers are usually much cheaper. They also changed significantly the cost-sharing for patients who choose to go to HOPDs for those procedures, while keeping that for patients who choose to go ASCs the same.

In order to understand the magnitude of the financial incentive's impacts relative to the quality/cost information's impacts, I conduct two analyses. First, applying a difference-in-differences (DID) analysis on the medical claim data of CalPERS BC enrollees from 2008 to 2015, I estimate the impact of the RP program on facility choice of patients with the procedures subject to this program. The control group includes patients whose procedures are not covered by the RP and also not closely related to RP procedures. I find that relative to patients with the control group procedures, the probability of patients with RP procedures selecting an ASC after the RP program increased by 30.4%. I also estimate the RP program's spillover impact on facility choice of patients with procedures that are not covered by the RP but are related to RP procedures. The probability of patients with these procedures choosing an ASC increased by 22.5% after the program was implemented, in comparison for the control group procedures. The presence of the large spillover effect from the RP program to the patients who were not financially affected by it indicates the importance of the information on quality and cost that CalPERS and BC provided for their enrollees.

Second, I estimate nested logit demand models using the claim data samples before and after the RP program in order to examine the changes in patients' preference as well as patient's perception of ASCs' and HOPDs' quality. Focusing on patients with colonoscopy in the four most populated health service areas in California, I find that patients are more sensitive to the out-of-pocket payment after the RP program, and less sensitive to the distance to facility as well as the fit between facility type and their health risk. The estimated facility fixed-effects also reveal that after the RP program, the perception of HOPDs'quality drops significantly while the perception of ASCs' quality stays largely the same. I also use the pre-RP demand parameters to predict the market shares of ASCs and HOPDs when only financial incentives are changed, or when both financial incentives and quality information are both provided. This exercise attributes the change in patient behavior seen in the DID estimation to the financial incentive component and the information component of the RP program. I find that when holding preference parameters and perception of quality the same, the cost-sharing change implied by the RP program only explains 15.9% of the total change in patients choice. The change in perception of quality from the pre-RP levels to the post-RP levels explains additionally 71.1% of the total change. The remained part of the patient behavior change might be attributed to the changes in the demand parameters. This exercise highlights the importance of quality and cost information provision in any efforts that aims at making healthcare consumers more price sensitive.

This paper proceeds as follows. Section 2 describes details of the outpatient service industry and the reference pricing program. Section 3 presents the difference-in-differences estimation results. Section 4 presents the demand estimation strategy, results and the counterfactual analysis. Section 5 concludes.

2.2 Institutional detail

2.2.1 Industry

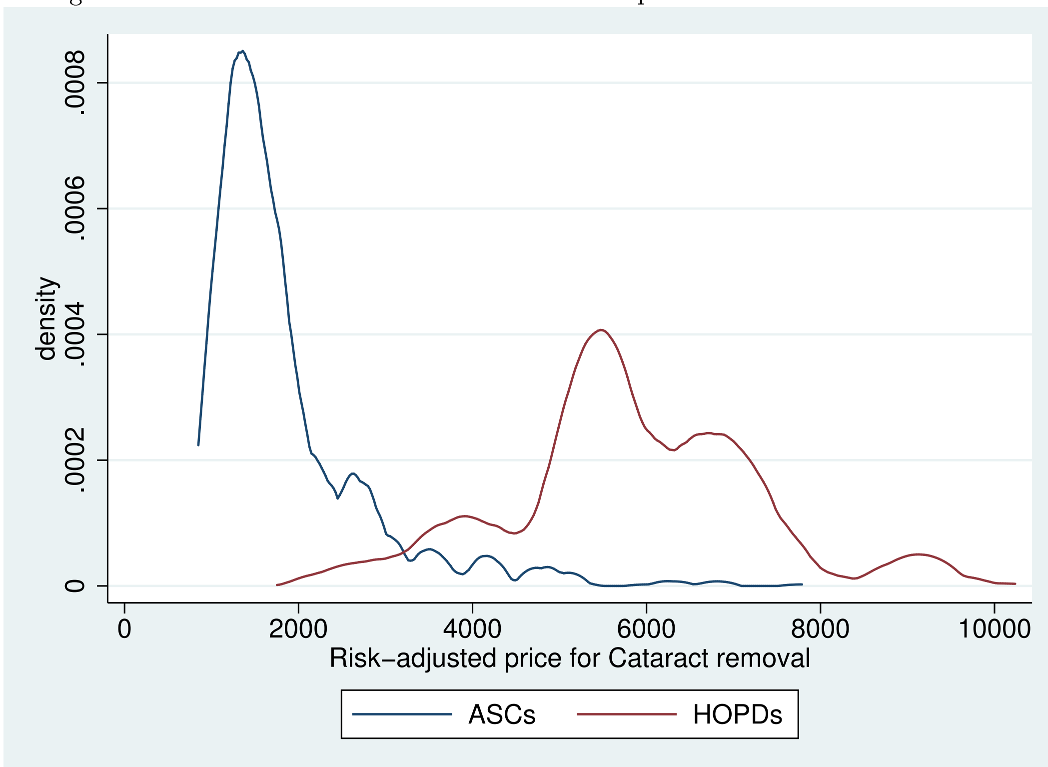
Changes in clinical technology and organizational capabilities permit an ever-increasing share of surgical and diagnostic procedures to be done as ambulatory rather than inpatient services. Hospitals have responded by developing outpatient departments that provide these services, but they face competition from ASCs. ASCs tend to treat lower risk patients at lower costs (MedPAC, 2017a; GAO, 2006; MedPAC, 2016), and have lower wait time and procedure time (Grisel and Arjmand, 2009; Munnich and Parente, 2014; Munnich and Richards, 2018; Robert and Courtemanche, 2011; Paquette et al., 2008). HOPDs tend to treat more risky, medically complex patients because they are better equipped to handle complications and emergencies (MedPAC, 2016).

The prices for procedures provided in HOPDs are typically much higher than those charged in ASCs because of the hospitals' higher costs and stronger bargaining position with insurers. Figure 1 shows the degree of price variations in the cataract removal procedure in California during the 2008-2015 period. The risk-adjusted price varies significantly from below $2000 to above $10,000. Moreover, while the price of this procedure at ASCs centers around just below $2000, the price of the same procedure at HOPDs is on average much higher, at around $6000.

2.2.2 Reference Pricing

Recognizing the large price variations, CalPERS and Anthem Blue Cross (BC) initiated a reference pricing program in order to help keep out-of-pocket costs down, while giving patients access to quality care (Cross, 2012). There are two component of this initiave: (1) increase cost-sharing for

Figure 2.1: Price distribution for cataract removal procedures at ASCs and HOPDs



patients at expensive care providers, (2) educate enrollees on the relative cost and quality of ASCs and HOPDs.

Since January 2012, CalPERS and BC provides a value-based insurance for colonoscopy, arthroscopy, and cataract surgery, in which t maxmium benefit for each rocedure in an outpatient hospital setting are \$1500 for colonoscopy, \$2000 for cataract surgery, and \$6000 for arthroscopy, respectively. If patients use an ambulatory surgery center or an outpatient hospital that provides these surgeries within the maximum benefit, patients will not have extra costs beyond the deductible and coinsurance. If patients use any outpatient hospital or ambulatory surgery center that charges above the maximum benefit, patients will have to pay the difference in cost, in addition to the deductible and coinsurance.

CalPERS and Anthem BC also made it clear that (1) within the same area, these procedures can be up to three times more expensive in an outpatient hospital than in an ambulatory surgery center, and (2) data shows that services at ambulatory surgery center are generally the same as in the outpatient hospital setting, and the average cost in an ambulatory surgery center is lower than in an outpatient hospital setting.

2.3 The effects of the reference pricing program on patients' facility choice

2.3.1 Empirical strategy and Data

To examine the impacts of the reference pricing on patients' facility choice, I conduct a difference-in-differences analysis using CalPERS medical claim data from 2008 to 2015. The variable of interest is the probability of a patient choosing an ASC when in need of an outpatient procedure. I analyze the trends of this variable for different procedure groups for 4 years prior and 4 years subsequent to the implementation of reference pricing payments. The treatment group includes CalPERS BC enrolless who undertook arthroscopy, colonoscopy and cataract removal procedures, which are subject to the reference pricing initiative.

The control group procedures should satisfy two selection criteria. First, the control group procedures should be the outpatient procedures which both ASCs and HOPDs have significant market shares. Second, the control group procedures should not be closely related to the procedures under the reference pricing because the information on quality and cost provided in the RP program might affect the choice of patients with the closely related procedures even if they are not affected financially. The selected procedures are skin related diseases (CPT codes 10040–19499), hemic related diseases (CPT codes 38100–38999), urinary related diseases (CPT codes 50010–53899), maternity related dieases (CPT codes 54000–55899, 55920–55980, 56405–58999, 59000–59899), endocrine related diseases (CPT codes 60000–60699). The regression of interest is given by

$$ASC_{itm} = \beta_0 RP_i + \beta_1 2012_t + \beta_2 RP_i \times 2012_t + \beta_X X_{itm} + d_t + d_m + e_{itm} \tag{2.1}$$

where ASC_{itm} is a dummy that takes a value of 1 if patient i at time t in market area m selects ASC, RP_i is a dummy for patient i undertaking an arthroscopy, a colonoscopy, or cataract removal procedure, 2012_t is a dummy for the year in or after 2012. X_{itm} includes patient characteristics such as age, white, gender, Charlson index. I also include year dummies d_t for every year between 2008 and 2015 and market area dummies d_m. The parameter of interest is β_2, which represents the change in the probability of a patient with a RP procedure choosing an ASC from before to after the RP program, relative to that of a patient without RP procedures.

I also examine the demand for ASCs of patients who undertake procedures that are not covered by the RP but are closely related to RP procedures. This is because of the potential spillover effect of the RP on the procedures outside the program. These procedures include musculoskeletal procedures

(CPT codes 20000–29999), digestive procedures (CPT codes 40490–49999), eye procedures (CPT codes 65091–68899). The DID regression is given by

$$ASC_{itm} = \beta_0 RelatedRP_i + \beta_1 2012_t + \beta_2 RelatedRP_i \times 2012_t + \beta_X X_{itm} + d_t + d_m + e_{itm} \quad (2.2)$$

where $RelatedRP_i$ is a dummy that takes a value of 1 if patient i undertakes a procedure that is related to RP procedures but are not directly impacted by the RP program. The parameter of interest is β_2, which represents the change in the probability of a patient with a related RP procedure choosing ASC from before to after the RP program, relative to that of a patient with one of control group procedures.

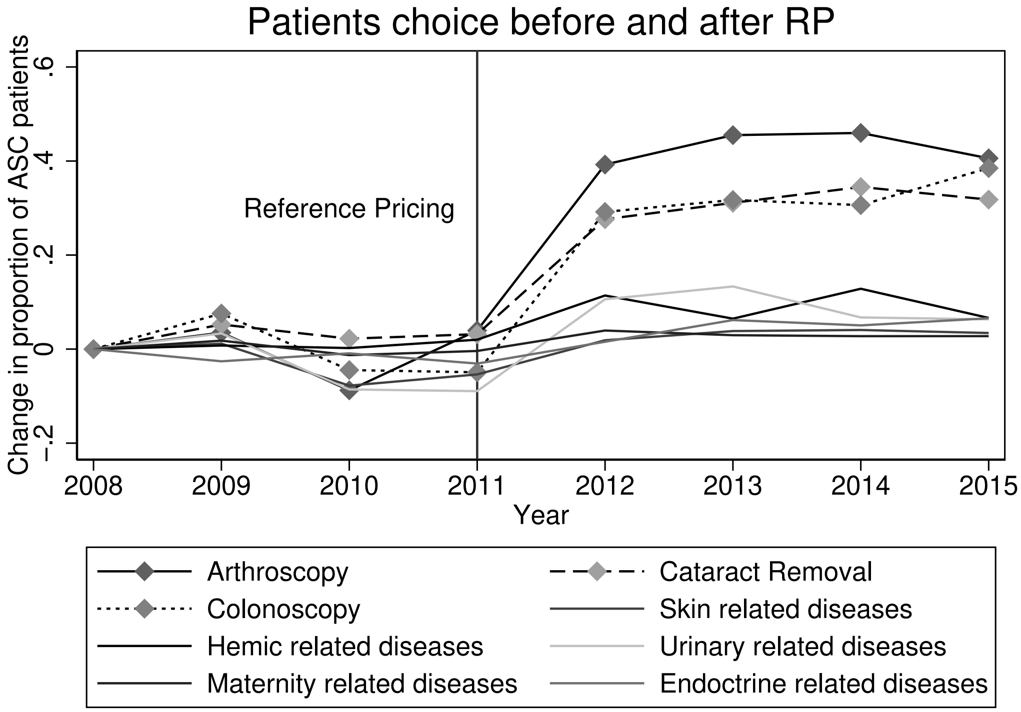
Table 2.1: Summary statistics of the RP procedures, the related RP procedures, and the procedures in the control group

	No. procedures		No. procedures 2008-2011		Average price 2008-2011	
	2008-2011	2012-2015	HOPD	ASC	HOPD	ASC
RP procedures						
Arthroscopy	2986	5183	3171	4998	6754	3757
Cataract Removal	2024	3721	1306	4439	5994	1864
Colonoscopy	15085	23293	14107	24271	2636	947
Related RP procedures						
Musculoskeletal diseases	5994	15083	12367	8710	4325	3344
Digestion diseases	9688	16766	14319	12135	4395	1418
Eye diseases	1537	2878	1796	2619	4857	1214
Control group procedures						
Skin diseases	5467	12235	13873	3829	3418	2013
Hemic diseases	729	993	1554	168	5454	2165
Urinary diseases	1951	3103	3926	1128	4552	3215
Maternity diseases	1693	3516	4966	243	1533	1831
Endocrine disease	255	308	527	36	5107	4029

The main dataset used for the DID analysis is the outpatient claim data of CalPERS Anthem Blue Cross enrollees from 2008 to 2015. The unit of observation in this data set is at the procedure level. Each observation contains limited demographic information about patients (such as age, race, zip code, diagnosis, etc.), limited information about the procedure performed (procedure codes), and identifying information about the facilities and the facility types where the procedure was performed.

Table 1 provides summary statistics of RP procedures, related RP procedures and procedures in the control group. Colonoscopy is the most popular procedure among all common outpatient procedures. The market shares of HOPD and ASC varies across different procedure groups. For example, while colonoscopy is predominantly performed in ASCs, musculoskeletal procedures are

Figure 2.2: Patients' faclity choice before and after RP



more commonly performed at HOPDs. Finally, the out-of-pocket payment at HOPDs are significantly higher than those at ASCs for all outpatient procedures.

2.3.2 Impact on facility choice of patients with RP procedures

Figure 1 shows the trends of the proportion of patients with RP procedures and control group procedures choosing ASCs. The trends are normalized by the 2008 values. As shown clearly, the proportion of patients choosing ASCs when in need of RP procedures increased significantly after the implementation of the RP program, relative to that of patients who choose ASCs with one of the control group procedures. Figure 1 also shows that the pre-2011 trends in the proportion of patients choosing ASCs are largely the same among RP procedures and control group procedures, satisfying the parallel trends assumption of the DID analysis. This observation is confirmed by placebo tests that assume the date of the RP to be January 2009 and January 2010. The results are reported in Appendix 2..1

Table 2 presents the estimation result of the DID regression in (2.1). The estimated coefficient β_1 suggests that the probability of a patients with RP procedures choosing ASCs increased 30.4% after the RP, relative to the patients who undertake the procedures in the control group. .

Table 2.2: The impacts of RP on facility choice of patients with the RP procedures

ASC_{it}	Coefficient	Std.error
RP_i	0.216***	(0.004)
2012_t	0.036***	(0.002)
$RP_i \times 2012_t$	0.304***	(0.004)
Age_i	0.002***	(0.000)
$Male_i$	-0.005***	(0.001)
Charlson $index_i$	-0.040***	(0.000)
Constant	0.170***	(0.005)
Observations	284,574	
R-squared	0.236	
Year FE	YES	
HSA FE	YES	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.3.3 Spillover impact on facility choice of patients with related RP procedures

Figure 2 graphs the trends of the proportion of patients who choose ASCs when in need of the procedures that are closely related to RP procedures but not subject to the RP, such as musculoskeletal procedures, digestive procedures, and eye procedures. It shows that even though patients who undertake these procedures are not directly impacted by the RP program financially, a significantly higher proportion of patients chooses ASCs after the RP program, relative to patients who needs procedures that are not related to RP procedures. These trends indicates a spillover effect that the RP program has over the related procedures. What might explain this spillover effect is that in the implementation of this RP program, CalPERS and Anthem BC made it clear of the relative quality and cost of the choices faced by their enrolles. Although the program only applied to three procedures in 2012, the relative quality and cost of facilities might apply to other procedures and that can induce the change in patients' facility choice shown in Figure 2.

Table 2 shows the estimation results of the regression (2.2). The main parameter of interest is the coefficient of the interaction term between $RelatedRP_i$ and 2012_t. This coefficient suggests that the proportion of the patients who are in need of related RP procedures and choose ASCs increased by 22.5% after the RP program, relative to that of the patients who have the procedures that are not closely related to RP procedures. This increase is smaller than the increase in the ASC market share among patients who undertake RP procedures, but suggests a significant spillover effect of the information that CalPERS and Anthem Blue Cross provided has on patients' choice.

Figure 2.3: Patients choice for the non-RP procedures before and after RP

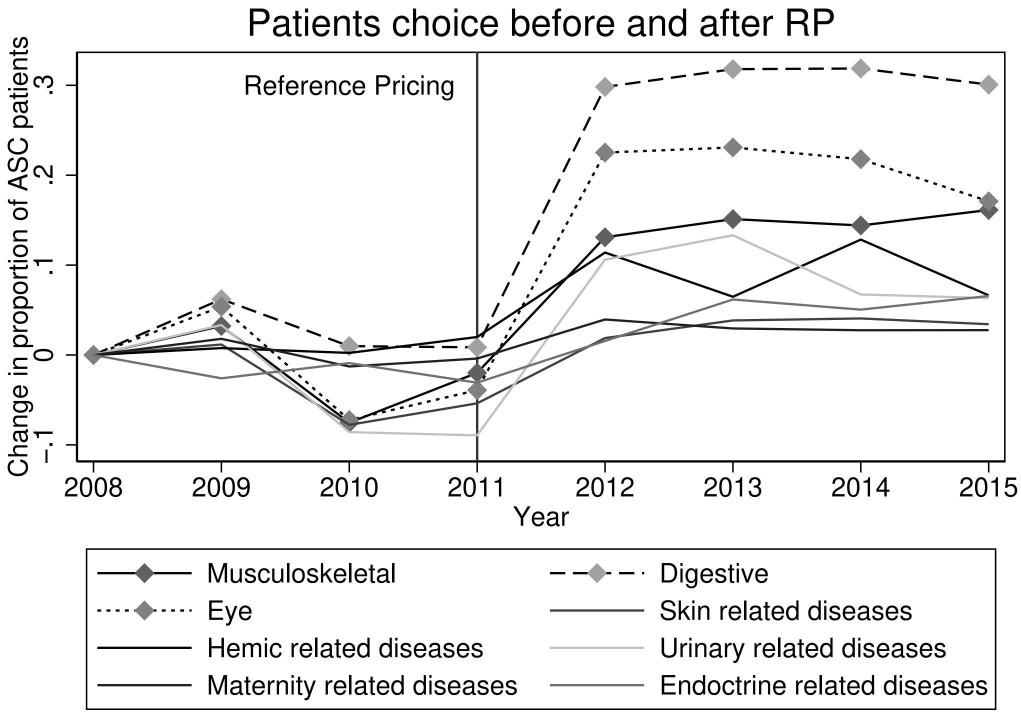


Table 2.3: The impacts of RP on facility choice of patients with procedures related to the RP procedures

ASC_{it}	Coefficient	Std.error
$RelatedRP_i$	0.155***	(0.004)
2012_t	0.006***	(0.002)
$RelatedRP_i \times 2012_t$	0.225***	(0.005)
Age_i	0.002***	(0.000)
$Male_i$	-0.012***	(0.002)
Charlson $index_i$	-0.031***	(0.000)
Constant	0.071***	(0.006)
Observations	232,282	
R-squared	0.185	
Year FE	YES	
HSA FE	YES	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.4 Decomposing the demand response into financial incentive's effects and quality/cost information's effects

2.4.1 Empirical strategy and Data

Section 3 shows that Reference Pricing has significant impacts on not only patients with RP procedures but also those with procedures related to RP procedures but not effected by the RP program. The potential explanation for this spillover effect is the information that CalPERS and Anthem BC provided enrollees on the relative quality and costs of ASCs and HOPDs.

In order to understand better the relative importance of information and financial incentive on patients' behavior, I examine the change in patients' perception of quality of ASCs and HOPDs before 2012 and after 2012. A measure of perceived quality is constructed from a demand model of patients' facility choice. I also perform a counterfactual analysis that predicts the demand pattern when only the cost-sharing changes, holding demand parameters and perception of the ASCs and HOPDs the same, and when both perception and cost-sharing changes as implied by the RP.

I specify patients' demand for an outpatient facilities with a nested logit model. Patient preferences depend on the out-of-pocket payment, distances, patient characteristics and facility types. Interactions between patient characteristics and facility type are included to allow coefficients to vary over the population along observable patient characteristic dimensions. For example, sicker patients may prefer HOPDs since they have emergency rooms, while healthier patients may be more willing to visits ASCs. The nested logit structure allows for the correlation between the preferences for facilities within the same type.

Formally, let i denote patient, g denote facility group, $g \in \{A, H\}$, and j denote a facility in each group. Patient utility is given by

$$u_{ijg} = -\lambda OOP_{ijg} + \alpha_{jg} + X_{ijg} d_g \beta + (1-\sigma)\,\epsilon_{ijg}$$

where OOP_{ijg} is the out-of-pocket payment and d_g is facility type g's fixed-effect. X_{ijg} is a set of patient's characteristics, such as $log(income_i)$, age_i, $gender_i$, and $distance_{ijg}$. σ is the dissimilarity parameter that indicates the correlation in patients' preferences for facilities within the same facility group. α_{jg} is the facility jg's fixed effect, which is interpreted as the unobserved quality perceived by patients. I estimate this demand model using the data from 2008 to 2011 and the data from 2012 to 2015 to compare examine the change in the perceived quality of ASCs and HOPDs as well as the demand parameters from before the RP to after the RP.

The main dataset used for the demand estimation is a subset of the CalPER outpatient claim. I forcused on the most common outpatient procedure, colonoscopy, and on the Health Special Areas Golden Empire, North, West and East Bay, which are most populated in California[1]. The unit of observation in this data set is at the procedure level. Each observation contains limited demographic information about patients (such as age, race, zip code, diagnosis, etc.), limited information about the procedure performed (procedure codes), and identifying information about the facilities and the facility types where the procedure was performed.

Table 2.4: Summary statistics of patient characteristics in the demand estimation

	2008-2011		2012-2015	
	ASC	HOPD	ASC	HOPD
Out-of-pocket cost	912.445	2733.633	1506.268	3019.755
	(752.317)	(1656.860)	(982.699)	(2065.804)
Distance	12.570	14.032	13.164	14.436
	(7.964)	(9.907)	(9.192)	(8.489)
Charlson index	0.014	0.092	0.010	0.052
	(0.188)	(0.506)	(0.194)	(0.266)
Age	57.052	56.289	56.084	56.593
	(7437)	(8.779)	(9.292)	(9.793)
Median income	79,787.39	72,523.69	76,614.79	71,218.98
	(27,931.66)	(18,426.96)	(23,438.74)	(17,159.38)
Female	0.525	0.563	0.548	0.577
	(0.499)	(0.496)	(0.497)	(0.495)
No. Observations	478	1346	1238	381

From this dataset, I compute several variables to include in the demand estimation. First, I compute the distance between patients and facilities. Patients' locations are identified using a 5-digit zip code; for facilities, exact addresses are available. Using the longitudes and latitudes of patient zip code's centroid and facility addresses, I calculate the travel distance as the straight line between two points. Second, I derive the Charlson co-morbidity index from each patient's diagnosis to proxy for that patient's health risk. Third, I link the claim dataset with the American Community Survey to obtain the median household income of a given patient's zip code.

The demand estimation also requires a measure of out-of-pocket (OOP) payments. In order to compute this variable, I sum the out-of-pocket costs for all the procedures performed on the same day as the main procedure, for example, anesthesia, durable medical equipment, implants, etc. In this sense, out-of-pocket payments are the amount patients are responsible for during the whole outpatient treatment episode. This is in line with how Medicare structures its payment for HOPDs

[1] https://www.dartmouthatlas.org/faq/

and ASCs procedures, that is, as the whole package of services during each visit, including both main procedure and auxiliary services (MedPAC, 2016, 2017b). In addition, the demand estimation requires the out-of-pocket payment for the facilities that were available in patient's choice set but not chosen. This variable is not readily available. I predict this variable from a regression that regresses the out-of-pocket payment on patients characteristics and facility type and facility specific effects.

Table 4 summarizes patient characteristics by facility type for the periods before and after the Reference Pricing program. Statistics for ASC patients are listed in the columns 2 and 4 while statistics for HOPD patients are listed in the columns 3 and 5. The most striking differences between ASC patients and HOPD patients are in out-of-pocket payments and Charlson comorbidity index. The average out-of-pocket payment at HOPDs is significantly higher than that at ASCs, for both the years before and after the RP policy. Patients who go to HOPDs also have substantially higher risk than patients who go ASCs. Other characteristics such as age, gender and distance also show differences among ASC and HOPD patients, although the differences are small.

2.4.2 Demand estimation results

Estimates from the nested logit demand model provide insight into consumers' facility choice decisions. Table 5 displays the estimation results from the nested logit demand for the periods before and after the RP program.

Table 2.5: Demand estimates before and after the RP

	Before the RP, 2008-2011		After the RP, 2012-2015	
	Coeff	Std. error	Coeff	Std. error
Out-of-pocket cost	-1.104***	(0.004)	-1.259***	(0.208)
Distance	-0.142***	(0.009)	-0.095***	(0.007)
Age * Facility Type	-0.007	(0.010)	-0.001	(0.007)
Median Income * Facility Type	-0.255	(0.349)	0.086	(0.269)
Female * Facility Type	0.379	(0.168)	0.185	(0.132)
Charlson index * Facility Type	1.534***	(0.437)	0.679 ***	(0.271)
Dissimilarity paramters	1.012	(0.069)	0.726	(0.059)
Observations	1,824		1,619	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

First, the pre-RP and post-RP demand estimation results both show that patients' facility choice depends significantly on out-of-pocket payment, distance and patient health risk. Notably, the positive coefficients of the interaction term between Charlson index and facility type dummy indicates that higher Charlson index patients, i.e., patients with higher health risks, are less likely to visit

ASC's. This result reflects the difference in Charlson index among ASCs' and HOPDs' patients seen in the summary statistics.

Second, the estimation results show some interesting changes in the sensitiveness of patients choice with respect to OOP, distance and the fit between facility type and patients' health risk. For example, after the RP program, patients are more sensitive to the out-of-pocket payments than they were before the program. For a patient having a colonoscopy, to have the out-of-pocket payment lower by 10 dollars, he/she were willing to travel extra 77.746 miles before the RP, but 132.526 miles after the RP. Comparing the pre-RP and post-RP coefficients of the distance variable and the interaction term Charlson index $*$ Facility Type, patients seem to sort less on the health risk dimension and the distance dimension, and more on the out-of-pocket dimension after the program.

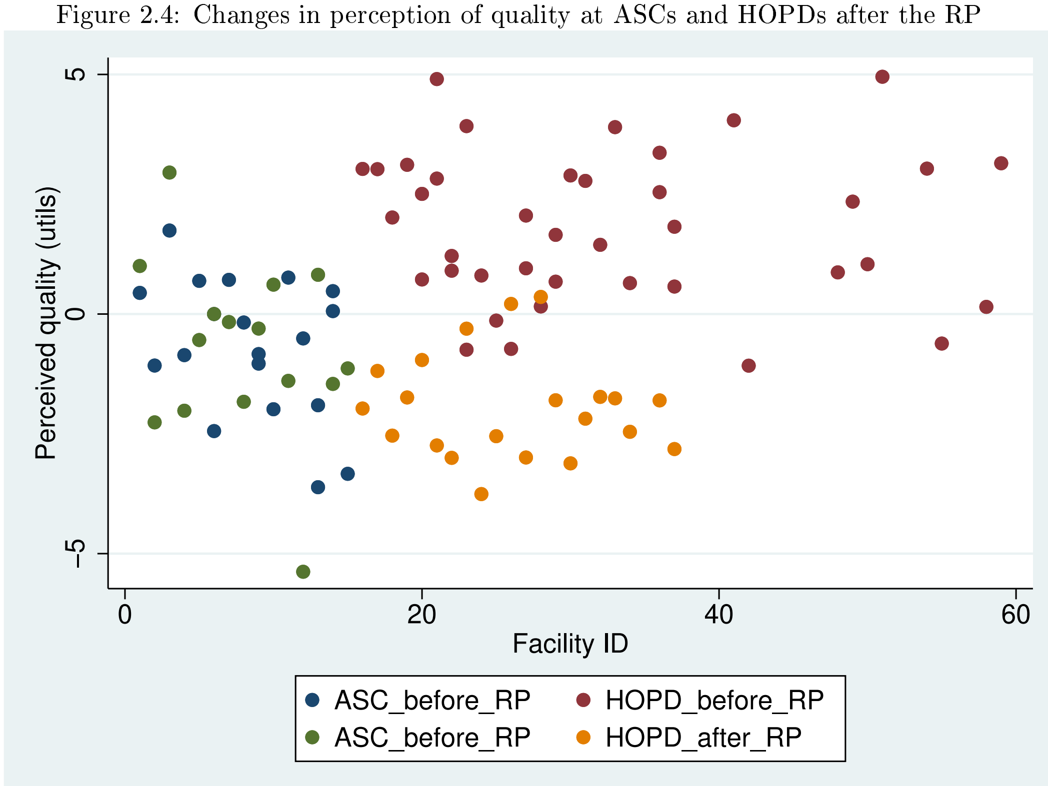
Turning to the quality of ASCs and HOPDs as perceived by patients, I find that while the perceived quality of ASCs do not change, the perceived quality of HOPDs drops significantly after the RP program. Figure 3 scatter plots the perceived quality of all facilities in the sample before and after RP.

2.4.3 Decomposing the importance of co-sharing and information changes

Subsection (2.4.2) shows the changes after the RP in patients' sensitiveness to the out-of-pocket payment, distance and their heatlth risk, as well as the changes in patients' perception of ASCs and HOPDs quality. In this section I decompose the overall changes in patients' behavior into the part that is due to cost-sharing changes and the part that is due to changes in perception of ASCs and HOPDs' quality. To do so, I predict the market share of ASCs when only the cost-sharing changes holding fixed patients' preference parameters and patients' perception, and when the cost-sharing as well as patients' perception change while the parameters are the same.

The results are reported in Table 6. For conoloscopy patients, ASC market share increased by 50.2% after the RP program (from 26.2% to 76.4%). Holding the preference parameters and the quality perception constant, the cost-sharing increase in HOPDs as imposed by the RP program increases ASC market share by only 8%. However, when allowing the quality perception to change from the level before the RP to the level after RP, the ASC market share increases by 43.7%. This means that changes in perception of ASCs and HOPDs quality explain 71.1% of the changes in patients' favor of ASCs ((43.7%-8%)/50.2%), and while the cost-sharing changes only explain 15.9%. This counterfactual exercise hightlights the importance of quality and cost transparency in patients' choice and in the effectiveness of policies that aim to make patients more price-sensitive.

Figure 2.4: Changes in perception of quality at ASCs and HOPDs after the RP



	2008-2011		2012-2015		Difference	(Std.error)
	Mean	(Std.error)	Mean	(Std.error)		
Perceived ASC quality	-0.667	(0.410)	-0.739	(0.486)	-0.073	(0.614)
Perceived HOPD quality	1.985	(0.331)	-1.945	(0.237)	-3.931***	(0.413)

Table 2.6: Importance of the cost-sharing changes and the perception changes

	2008-2011	2012-2015	When only the cost-sharing changes	When both the cost-sharing and perception change
ASCs Market share	0.262	0.764	0.342	0.689
Change in ASC Market share from the pre-RP period		0.502	0.080	0.437

2.5 Conclusion

In this paper I examine the relative importance of financial incentive and quality and cost information in changing healthcare consumers' facility choice by exploiting the reference pricing (RP) program implemented by the California Public Employee's Retirement System.

I find that the program led to a 30.4% increase in the demand for low-cost ambulatory surgery centers (ASCs) among patients who need the procedures covered by RP. The program also led to a 22.6% increase in the demand for ASCs among patients who need procedures related to RP procedures but are not directly impacted by the RP financially. The presence of the large spillover effect suggests the importance of the cost/quality information that RP provided patients with.

Furthermore, the demand estimation pre-RP and post-RP shows that patients are more sensitive to price and less sensitive to distance and their health risk after the RP. Their perception of HOPDs' quality dropped significantly while that of ASCs' quality stay the same. I estimate that the financial incentive change in the RP program explains about 15.9% of the total demand change, while the change in patient's perception of facility quality contribute about 71.1%.

These results imply that while policies such as increased cost-sharing can improve patients' choice toward higher-valued care, quality and cost transparency is critical for those policies to make greater impacts on patients' behavior.

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Appendix

2..1 Placebo test for the DID regressions

Table 2.7: Placebo test regression estimation results, using the two placebo years 2010, and 2011

ASC_{it}	Placebo year 2010		Placebo year 2011	
	Coefficient	Std.error	Coefficient	Std.error
$RelatedRP_i$	0.206***	(0.005)	0.203***	(0.004)
$After2010_t$	-0.054***	(0.003)		
$RelatedRP_i \times After2010_t$	0.003	(0.007)		
$After2011_t$			-0.035***	(0.003)
$RelatedRP_i \times After2011_t$			0.015*	(0.008)
Age_i	0.002***	(0.000)	0.002***	(0.000)
$Male_i$	0.001	(0.003)	0.001	(0.003)
Charlson $index_i$	-0.033***	(0.001)	-0.034***	(0.001)
Constant	0.056***	(0.009)	0.038***	(0.009)
Observations	79,895		79,895	
R-squared	0.182		0.179	
Year FE	YES		YES	
HSA FE	YES		YES	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.8: Placebo test regression estimation results, using the two placebo years 2010, and 2011 - Spillover effects

ASC_{it}	Placebo year 2010		Placebo year 2011	
	Coefficient	Std.error	Coefficient	Std.error
RelatedRP_i	0.139***	(0.006)	0.141***	(0.004)
After2010_t	-0.056***	(0.004)		
$\text{RelatedRP}_i \times After2010_t$	0.023***	(0.007)		
After2011_t			-0.006	(0.004)
$\text{RelatedRP}_i \times After2011_t$			0.035*	(0.008)
Age_i	0.002***	(0.000)	0.002***	(0.000)
Male_i	0.001	(0.003)	0.001	(0.003)
Charlson index_i	-0.027***	(0.001)	-0.027***	(0.001)
Constant	0.037***	(0.009)	-0.011***	(0.010)
Observations	59,800		59,800	
R-squared	0.130		0.130	
Year FE	YES		YES	
HSA FE	YES		YES	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 3

Public Price Setting with Insurance: The case of Medicare policies for the outpatient market

3.1 Introduction

Governments in the U.S. and many countries set reimbursement rates for healthcare services that are covered by public insurance. In some cases, the reimbursement rate depends on where the service is provided. For example, in the US, Medicare sets reimbursement rates of approximately $2600 for a shoulder joint replacement procedure performed at a hospital and $1300 for the same procedure provided at a surgery center. Medicare also specifies that patients are responsible for 20% of the reimbursement rates for all outpatient procedures across all care settings. Because Medicare beneficiaries do not face the full costs of treatments, they have limited incentives to avoid high-cost options. This paper examines how Medicare can jointly optimize reimbursement rates and coinsurance rates on outpatient procedures to induce patients to choose high net value care facilities while also protecting patients from financial risks.

Both the volume of outpatient procedures and Medicare's spending on them have increased significantly over the past decade (MedPAC, 2017a), largely due to technological advancements that allow more procedures to be performed safely in outpatient settings. The two main types of providers in the U.S. outpatient care market are hospital outpatient departments (HOPDs) and ambulatory surgery centers (ASCs). They compete over many outpatient procedures, where patients are typically discharged on the same day as the treatment. ASCs tend to treat lower risk patients at lower costs (MedPAC, 2017a; GAO, 2006; MedPAC, 2016), and have lower wait time and procedure time (Grisel and Arjmand, 2009; Munnich and Parente, 2014; Munnich and Richards, 2018; Robert and Courtemanche, 2011; Paquette et al., 2008). HOPDs tend to treat more risky, medically complex patients because they are better equipped to handle complications and emergencies (MedPAC, 2016).

Medicare uses different reimbursement systems for ASCs and HOPDs. Under current policy, the same outpatient procedure is reimbursed at a significantly higher rate when performed in HOPDs than in ASCs because hospitals must meet additional regulatory requirements and treat patients who are more medically complex (MedPAC 2003). However, the reimbursement differentials observed in practice may be too large to be justified by the variations in costs and in the quality of care between HOPDs and ASCs. Examining whether this is the case is challenging because of the lack of data on cost and quality of care at ASCs. Wynn et al. (2008) provides suggestive evidence that differences in payments exceed the differences in costs. In addition, a few studies suggest that ASCs and HOPDs deliver comparable health outcomes for low risk patients (Grisel and Arjmand, 2009; Robinson and Brown, 2013; Robinson et al., 2015a,c). These findings suggest that Medicare might be spending excessively on outpatient care performed in hospitals, especially for low risk patients. Since Medicare is mostly financed through taxation, this overspending is inefficient and can lead to significant dead weight losses. But simply reducing the reimbursement rates for HOPDs might not be the answer because patients bear a fixed proportion of these costs (determined by the coinsurance rate), and high reimbursement rates for HOPDs might incentivize patients to choose ASCs, which provide comparable quality of care at lower costs. What the optimal reimbursement rates are for HOPDs and ASCs depend in part on the coinsurance rate faced by Medicare beneficiaries, and this question has not been studied both theoretically and empirically.

In recent years, stakeholders have shown increasing interest in restructuring the reimbursement rates for outpatient procedures at HOPDs and ASCs while recognizing the differences in costs and quality across care settings. For example, the Medicare Payment Advisory Commission, a non-partisan legislative branch agency providing Congress with advice on the Medicare program, has recently made a number of recommendations designed to equalize reimbursement rates across care settings for outpatient services. In 2017, Medicare introduced "site-neutral" payment policies that lowered payment to HOPDs to the ASCs' reimbursement rates[1]. This policy closed the gaps

[1]The most recent legislation focused on off-campus provider-based sites located 250 yards or more away from the hospital's campus: https://www.beckershospitalreview.com/finance/12-things-to-know-about-site-neutral-payments.html

in reimbursement rates and patients' out-of-pocket payments between HOPDs and ASCs for some most commonly billed services[2]. While lowering Medicare spending, these policies might affect the allocation of patients between HOPDs and ASCs. The net effect of these "site-neutral" payment policies on social surplus is largely unclear.

I develop a theoretical model to characterize the optimal reimbursement rates for outpatient care providers and coinsurance rates for Medicare beneficiaries. The optimal reimbursement rates and coinsurance rates maximize consumer surplus subject to providers' participation constraints and Medicare's budget constraint. I show that reimbursement rates are optimally set at providers' marginal costs and coinsurance rates should be higher for the facilities with lower net value, where net value is defined as the difference between marginal benefit and marginal cost. In practice, Medicare sets coinsurance rates uniformly across HOPDs and ASCs. To my knowledge, there are no legal requirements for Medicare to keep the coinsurance rates the same across settings. However, Medicare might want to do so to reduce complexity in administration, and confusion among its beneficiaries. In scenarios where Medicare is constrained to set uniform coinsurance rates, I show that the optimal reimbursement rates are instead above marginal costs in order to incentivize better sorting into higher net value facilities.

In my empirical analysis, I quantify the optimal reimbursement rates and coinsurance rates and evaluate the welfare impacts if Medicare were to move from its current practice to the optimal policy. As a first step, I estimate the marginal costs of care at HOPDs and ASCs. Using financial data and cost reports, I estimate the cost functions for HOPDs and ASCs in Pennsylvania. I find that the marginal costs of main procedure groups at HOPDs are almost double the marginal costs of those at ASCs. For both HOPDs and ASCs, the marginal costs are significantly below current Medicare reimbursement rates.

I also estimate patients' valuation of care at these two care settings. Using Medicare claim data, I estimate a nested logit demand model of Medicare beneficiaries for outpatient care facilities. I find that the patients' facility choice is significantly responsive to out-of-pocket payments. I also find that low-risk patients perceive ASCs to be of higher value than HOPDs whereas high-risk patients perceive HOPDs to be of higher value than ASCs. Combining the marginal cost and the demand estimates, I find that ASCs offer significantly higher net value than HOPDs for standard procedures, and similar net value for more complex procedures.

In the counterfactual analyses, I first predict the welfare impacts of a site-neutral payment policy where Medicare reduces the HOPD reimbursement rates to the ASC rates. I find that this policy

[2] https://revcycleintelligence.com/news/site-neutral-payments-for-hospital-clinic-visits-starting-in-2019

pushes more patients to HOPDs, where the net value of care is the same or lower for most common procedure groups, resulting in a decrease in social welfare. I also estimate that when coinsurance rates are fixed at 20%, Medicare would optimally reduce the ASC reimbursement rates to ASCs' marginal costs, and increase the HOPD reimbursement rates. The resulting shifts in the prices faced by patients would incentivize sorting into the ASCs, increasing welfare by 3.1% to 6.4% while reducing Medicare spending on the outpatient market by 9% to 15%. However, when coinsurance can be set flexibly, the optimal reimbursement rates are set at marginal cost levels for both HOPDs and ASCs, and the coinsurance rate should be set higher for HOPDs. Setting both reimbursement rates and coinsurance rates optimally allows Medicare to achieve a welfare gain of 3.1% to 6.1% while reducing the its spending on the outpatient market by 15% to 23%.

This paper fits into the broader literature on optimal health care payment systems. A large part of this literature studies the differences in the incentives created by payment schemes such as cost-based payment, prospective payment, and mixed payment (see for example Ellis and McGuire (1986), Ellis and McGuire (1990), Ellis and Mcguire (1993)). In this paper, I take as given the existing prospective payment structure that Medicare implements for ASCs and HOPDs and quantify the optimal reimbursement rates for the procedures that are performed in both ASCs and HOPDs. Perhaps most closely related to this paper are the studies of Ellis and McGuire (1990); Ellis and Mcguire (1993). They point out that the price paid by insured patients can be set separately from the price paid to providers, implying that demand-side cost sharing and supply-side reimbursement rates are two distinct strategies for controlling health care costs.

This paper is also related to the literature on optimal insurance design. Conventional theory of optimal coinsurance rates for health insurance with moral hazard indicates that coinsurance should vary with the price responsiveness of demand for different medical services (Zeckhauser, 1970; Pauly, 1968). Recent discussion of optimal insurance design focuses on the theory of "value-based cost sharing" which stipulates that coinsurance should be lower for services with higher benefits relative to costs (Pauly and Blavin, 2008; Chernew et al., 2007). This paper examines reimbursement and coinsurance structure for healthcare services when there are two provider types with different quality and cost structures.

This paper also contributes to the outpatient care literature. There are four main areas in this literature: the differences in quality and costs of ASCs and HOPDs (Wynn et al., 2008; Avalere Health, 2016; Hollingsworth et al., 2012); the determinants of facility choices (Plotzke and Courtemanche, 2011; David and Neuman, 2011; Gabel et al., 2008; Weber, 2014); the impacts of payment policy on competition in this market (Munnich and Richards, 2018); and some discussions of the potential impacts of Medicare's site-neutral payment policy (Cassidy, 2014; Kondamuri et al., 2019). This paper contributes directly to this literature by proposing the optimal payment policy for outpatient procedures and comparing the welfare impacts of the proposed optimal policy with those of the recent Medicare site-neutral payment policy.

The paper proceeds as follows. Section 2 develops a model that characterizes the optimal reimbursement rates and coinsurance rates. Section 3 describes the data used in the empirical analysis. Section 4 presents demand estimation strategy and results. Section 5 presents cost function estimation strategy and results. Section 6 provides the results of the counterfactual analyses. Section 7 concludes.

3.2 Theory

I develop a simple theoretical model to understand how Medicare can set reimbursement rates and coinsurance rates to balance the allocative efficiency and the risk protection benefit of insurance. This model provides the characterization of the optimal policies. It also provides some guidance for the counterfactual analyses where I compute the optimal policies and the welfare impacts if Medicare were to implement those policy proposals.

In this model, Medicare sets reimbursement and coinsurance policy in order to maximize consumer surplus subject to patients' rationality, facility participation constraints and Medicare's budget constraint. The model assumes a demand system where facilities are vertically differentiated by their quality and ability to treat patients of different risk types. The assumptions allow me to formulate closed form solution for patients' demand system and simplifies the solution for optimal reimbursement and coinsurance policy. In the empirical analysis, I extend the model into the case with horizontally differentiated demand where patients' demand depends not only on facilities' quality and type, but also on how well they match with patients' health risks and other demographic characteristics.

I first introduce notation and set up Medicare's problem. I then discuss the first order conditions and the solution. Finally, I provide two comparative statics: (1) the relative magnitude of the optimal coinsurance rates in the case Medicare can set them flexibly, and (2) the optimal reimbursement rates when the coinsurance rates are fixed at an exogenous rate.

Model setup Assume that there are two facilities, hospital and ambulatory surgery center, which compete over an outpatient procedure, such as a shoulder joint replacement procedure. Let the marginal costs of the HOPD and the ASC be c_H and c_A, respectively. I assume that the procedure in HOPD is more costly than in ASC, i.e., $c_H \geq c_A$. This is in line with suggestive evidence in existing literature about ASCs and HOPDs' relative costs, and the cost function estimation results presented in Subsection 3.5.2.

I also assume that there is a continuum of patients with health risk r, with distribution $F(r)$ over the unit interval $[0, 1]$. Patients have the same level of wealth, w. These assumptions allow me to focus attention on the efficient allocation of patients into the two care settings based on patients' health risk. Note that the common wealth assumption implies that the risk protection benefit of insurance only varies with the out-of-pocket payments that patients are responsible for. In the empirical model, patients have variable income levels, which affects patients' facility choice.

With probability p , patients do not need the procedure. They pay premium of ϕ for the insurance coverage, and receive utility

$$u_0 = \nu(w - \phi) \tag{3.1}$$

where $\nu(.)$ is a concave function, reflecting the assumption that patients are risk-averse, and w is patients' wealth. With probability $1 - p$, patients need the procedure, and they choose between HOPD and ASC in order to maximize utility[3]. Their utility from getting treated at a facility depends on the facility's quality, their health risk and out-of-pocket payments. Specifically, the utility of a patient with health risk r who receives care at the HOPD and at the ASC are given, respectively, by

$$u_H = \nu(w - \phi - b_H p_H) + \alpha_H + \beta_H r \tag{3.2}$$

$$u_A = \nu(w - \phi - b_A p_A) + \alpha_A + \beta_A r \tag{3.3}$$

where b_H and b_A are the coinsurance rates at the HOPD and the ASC, p_H and p_A are the reimbursement rates. α_H and α_A are HOPD's and ASC's fixed effects. β_H and β_A represent marginal utilities at the HOPD and the ASC when patients' health risk increases incrementally. I assume $\beta_H > \beta_A$ to reflect the stylized fact that marginal utility with respect to risk is higher in HOPDs and that high risk patients tend to choose HOPDs over ASCs.

Medicare's policy instrument is a vector $\kappa = \{p_H, p_A, b_H, b_A, \phi\}$. Patients make a facility choice in order to maximize their utility given Medicare's policy parameters. Given the structure of the

[3]In this model I assume there is no outside option, so that the theoretical model is consistent with the empirical analysis where the demand estimation also assumes no outside option. The solution of the model with an outside option is largely similar. I provide details of the derivations in Appendix 3.7.4

utility functions, the resulting demand system is given by following a cut-off rule:

$$\text{Choice} = \begin{cases} H & \text{if } r \geq r_{AH} = \frac{1}{\beta_H - \beta_A} \left[\nu \left(w - \phi - b_A p_A \right) - \nu \left(w - \phi - b_H p_H \right) \right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \\ A & \text{if } r \leq r_{AH} \end{cases} \tag{3.4}$$

where r_{AH} is the health risk level at which patients are indifferent between the ASC and the HOPD. This cutoff gives the demand for HOPD and ASC as $Q_H = 1 - F(r_{AH})$ and $Q_A = F(r_{AH})$. Given patients' choice, I assume Medicare seeks to solve the problem:

$$\max_{\kappa = \{p_H, p_A, b_H, b_A, \phi\}} \int_0^{r_{AH}} \left[p u_A(\kappa, r) + (1-p) u_0 \right] dF(r) + \int_{r_{AH}}^1 \left[p u_H(\kappa, r) + (1-p) u_0 \right] dF(r) \tag{3.5}$$

subject to

$$r_{AH} = \frac{1}{\beta_H - \beta_A} \left[\nu \left(w - \phi - b_A p_A \right) - \nu \left(w - \phi - b_H p_H \right) \right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \tag{3.6}$$

$$\phi = p \left\{ (1 - b_H) p_H Q_H + (1 - b_A) p_A Q_A \right\} \tag{3.7}$$

$$p_H \geq c_H \tag{3.8}$$

$$p_A \geq c_A \tag{3.9}$$

The first constraint represents patients' incentive compatibility. The second constraint is Medicare's budget constraint, which says the Medicare's premium has to cover the cost of care remaining after patients contribute their cost-sharing. In reality, Medicare sets the premium to cover 25% of the cost of the program, and the remaining 75% is subsidized by Medicare fund. In this model I assume away this detail with the justification that this subsidization is not likely to affect patients' facility choice when they need the treatment. Finally, the last two constraints are the HOPD's and ASC's participation constraints, that is, the Medicare reimbursement rates have to be greater or equal to facilities' marginal costs.

Solution I now discuss the intuition of the optimal reimbursement and insurance policy. Detailed derivations are in Appendix 3.7.4. I show that the optimal reimbursement rates are at the providers' marginal costs, i.e., $p_H^* = c_H$, $p_A^* = c_A$. To understand this, consider the impacts on consumers' welfare of an increase in HOPD reimbursement rate. An increase in HOPD's reimbursement rate has a direct impact of increasing out-of-pocket payments for HOPD patients, which decreases HOPD patients' utility. It also indirectly affects premium ϕ in two ways. More expensive procedures in HOPD require a higher premium. However, more expensive procedures in HOPD also steer patients away from this provider type to the cheaper ASC, which will reduce the cost of the Medicare program, and hence reduce premium. Under the assumption that patients' price responsiveness is not too large, which is the case for demand for most types of health care services, higher reimbursement rates at HOPD will in net increase premium. This affects not only patients at HOPD but also those at ASC and those who do not need the treatment. In short, an increase in reimbursement rate lowers consumer surplus. The optimal reimbursement rate to a facility must therefore be set at the facility's marginal cost.

I also show that the optimal coinsurance rates solve a system of equations that balance risk protection benefit with allocative efficiency. The risk protection benefit decreases as coinsurance rates increase. In contrast, allocative efficiency increases as coinsurance rate increases because the extent of moral hazard is decreasing in coinsurance rates.

I now move to discuss two comparative statics derived from this model. The first comparative static compares the magnitude of the optimal coinsurance rates b_H^* and b_A^*. The second comparative static concerns the optimal reimbursement rates when coinsurance rates can not be set flexibly but are fixed at some exogenous level.

Comparative static 1: The optimal HOPD coinsurance rate is higher than the optimal ASC coinsurance rate, i.e., $b_H^* > b_A^*$. Combining the FOCs of b_H and b_A (as provided in Appendix 3.7.4), we have the following equality

$$\frac{c_A Q_A \nu'_A}{c_H Q_H \nu'_H} = \frac{\phi_{b_A}}{\phi_{b_H}} \tag{3.10}$$

The intuition for this equality is as follows. When coinsurance rates can be set flexibly, the optimal reimbursement rates for HOPD and ASC are set at their marginal costs. Coinsurance rates act as a steering device that balances the trade-off between risk protection and allocative efficiency. The left-hand side of equation (3.10) is the relative increase in patients' utility when their coinsurance rates decrease. The right-hand side of this equation is the relative increase in premium when the coinsurance rates decrease. Recall that premium reflects the cost of the Medicare program. Intuitively, this equality says that coinsurance rates are adjusted so that the relative marginal utility gain is equal to the relative marginal cost resulted from coinsurance changes.

In order to provide clearer intuition, I consider the special case where patients are close to risk-neutral, or where the risk protection benefit for HOPD patients is the same as that for ASC patients. When this is the case, the optimal coinsurance rates only try to achieve allocative efficiency. This allocation efficiency is achieved if

$$b_H p_H - b_A p_A = c_H - c_A \tag{3.11}$$

which says the optimal coinsurance rates are such that the difference in out-of-pocket payments in HOPD and ASC is equal to the difference in their marginal costs. Given HOPD's marginal cost is higher than ASC's marginal cost, this is achieved when the coinsurance rate at HOPD is set higher than the coinsurance rate at ASC.

In general, relative magnitude of optimal HOPD's and ASC's coinsurance rates depends on relative marginal costs, relative marginal value of HOPD and ASC as well as relative risk protection benefits of insurance for HOPD and ASC patients. Relative magnitude of HOPD and ASC coinsurance rates is therefore ambiguous. However, it is possible to show that when HOPD delivers similar marginal value as ASC at much higher marginal cost, i.e., $c_H \gg c_A$ and $\beta_H \approx \beta_A$, the optimal coinsurance rate at HOPD is higher than the optimal coinsurance rate at ASC.

Comparative static 2: Optimal reimbursement rates are higher than marginal costs when coinsurance rates are fixed at an exogenous level. Now I consider the optimal reimbursement rates when coinsurance rates are set at an exogenous level $\bar{b}$, e.g., 20% as in current Medicare policy. Consider again the special case where patients are close to risk-neutral or the risk protection benefit of insurance for ASC patients and HOPD patients are the same. The optimal allocation is achieved if $0.2\,(p_H - p_A) = c_H - c_A$. It is then clearly no longer optimal to reimburse HOPD and ASC at the marginal costs. Also recall that consumer surplus is decreasing in reimbursement rates, implying that one of the two facility participation constraints has to bind. Therefore, the optimal reimbursement rates would be at marginal cost for ASC, and above marginal cost for HOPD.

In general case, in order to achieve the same allocation as the optimal allocation under unconstrained coinsurance rates, the coinsurance rate $\bar{b}$ and the reimbursement rates must satisfy

$$\bar{b} p_A = b_A^* c_A$$

$$\bar{b} p_H = b_H^* c_H$$

As discussed before, $p_A^* = c_A$. Therefore, $\bar{b} = b_A^*$. The optimal reimbursement rate for HOPD has to be increased above its marginal cost.

Empirical model In order to empirically compute the optimal reimbursement and coinsurance rates and the welfare impacts if Medicare were to move from the current practice to the optimal policy, I extend the theoretical model in order to incorporate some data features. For example, I model the market as being composed of two groups of facilities, hospitals and ambulatory surgery centers, instead of two facilities as in the theoretical model. However, I maintain the assumption that facilities in each group of facilities share the same marginal cost. In Section 3.5.2 I provide estimates of marginal costs of outpatient procedure groups in ASCs and HOPDs. The result shows that, consistent with this assumption, a bulk of variations in marginal costs comes from the variation across facility types, not within each type.

I also extend the patients' facility demand to include not only their health risk, but also their demographic characteristics and distance to facilities. These variables are shown in Subsection 3.4.2 to be important to explain patients' facility choice.

The optimal policy solution to this empirical model is provided in Appendix 3.7.5. Because a closed form demand function is not available in this empirical model, it is not possible to derive comparative statics. However, the main results from the theoretical model still govern the design of the optimal reimbursement and coinsurance policy. First, reimbursement rates are optimally be set at facilities' marginal costs. Second, coinsurance rates are optimally set so that they balance risk protection and allocative efficiency. In the case where the risk protection benefit of ASC and HOPD patients are equal, coinsurance rates act to steer patients to achieve efficient allocation. Medicare can do so by setting coinsurance rate at HOPDs higher than coinsurance rate at ASCs. In the case where the risk protection benefits are different for ASCs patients and HOPD patients, the optimal coinsurance rate at HOPDs is higher than the optimal coinsurance rate at ASCs if HOPDs provide the same marginal value of care as ASCs but at much higher marginal costs. Finally, if Medicare is constrained to set the same coinsurance rates for all facility types at an exogenous rate, then the optimal reimbursement rates are above facilities' marginal costs.

I now turn to the empirical analysis of the ASCs' and HOPDs' demand and cost functions, and the computation of optimal policies and their welfare impacts. I start with describing the data used in the demand and supply estimation in the following section.

3.3 Data

3.3.1 Data for demand estimation

I model patients' choice by a nested logit demand model where patients' facility choice depends on patients' characteristics and facilities' characteristics. The main dataset used for demand estimation is the outpatient claim data of Medicare beneficiaries, which covers 20% of all outpatient procedures performed in Pennsylvania from 2012 to 2015. The unit of observation in this data set is at the procedure level. Each observation contains limited demographic information about patients (such as age, race, zip code, diagnosis, etc.), limited information about the procedure performed (procedure codes), and identifying information about the facilities and the facility types where the procedure was performed.

From this dataset, I compute several variables to include in the demand estimation. First, I compute the distance between patients and facilities. Patients' locations are identified using a 5-digit zip code; for facilities, exact addresses are available. Using the longitudes and latitudes of patient zip code's centroid and facility addresses, I calculate the travel distance as the straight line between two points. Second, I derive the Charlson co-morbidity index from each patient's diagnosis to proxy for that patient's health risk. Third, I link the claim dataset with the American Community Survey to obtain the median household income of a given patient's zip code.

The demand estimation also requires a measure of out-of-pocket (OOP) payments. In order to compute this variable, I sum the out-of-pocket costs for all the procedures performed on the same day as the main procedure, for example, anesthesia, durable medical equipment, implants, etc. In this sense, out-of-pocket payments are the amount patients are responsible for during the whole outpatient treatment episode. This is in line with how Medicare structures its payment for HOPDs and ASCs procedures, that is, as the whole package of services during each visit, including both main procedure and auxiliary services (MedPAC, 2016, 2017b). In addition, the demand estimation also requires the out-of-pocket payment for the facilities that were available in patient's choice set but not chosen. This variable is not readily available. However, using the payment schedule set by Medicare in the Outpatient Prospective Payment System for HOPDs and the Ambulatory Payment System for ASCs[4], I compute what the reimbursement rates are for each outpatient procedure at each facility given its facility type, and its geographic location.

In summary, the observed patient characteristics included in the demand estimation are *age*, *sex*, *race*, *income*, and *distance*. The observed facility characteristics included are facility fixed

[4]Both payment schedules are published at Center of Medicare and Medicaid Services' website.

effects and a facility type dummy, the latter of which is interacted with patient characteristics. Finally, unlike many existing papers that estimate demand for care of Medicare patients, I include out-of-pocket payment in the demand analysis. The main reason is that out-of-pocket payment amounts vary significantly across facilities in the outpatient care market. As will be shown later in the demand estimation results, out-of-pocket payment is an important variable that explains patients' facility demand.

For the computation of the optimal coinsurance rates and reimbursement rates, one will ideally estimate patients' facility demand for each and every procedure. However, too many outpatient procedures make this task infeasible. Therefore, in this paper, I focus only on the most common specialties: gastroenterology and ophthalmology, which together represent 40% of all ASCs in the US[5]. In addition, I also include in my analysis musculoskeletal procedures that treat bone/ muscle disorders - which are some of more medically complex and expensive conditions to treat[6].

Patients with traditional Medicare Fee for Service insurance are not subject to restricted networks of facilities. Therefore, patients' choice set might include all facilities in Pennsylvania. However, to reduce computation time, I define patients' choice set as including all facilities which are located in less than the 90th percentile of all travel distance from the patients' zip code. This results in zip code specific choice sets.

Table 1 summarizes patient characteristics by facility type. Statistics for ASC patients are listed in the first two columns while statistics for HOPD patients are listed in the last two columns. There are many more gastroenterology procedures and ophthalmology procedure done in ASCs than in HOPDs. However, more musculoskeletal procedures are performed in HOPDs. Across specialty groups, the most striking differences between ASC patients and HOPD patients are in out-of-pocket payments, Charlson comorbidity index and median household income. Across all procedures, the average out-of-pocket payment at HOPDs is significantly higher than that at ASCs. The difference ranges widely from around $135 to $250 (70% to 110%). Patients who go to HOPDs also have substantially higher risk than patients who go ASCs. The summary statistics also show that ASC patients tend to come from higher median income zip codes than HOPD patients. Other characteristics such as age, gender, race, and distance also show statistically significant differences among ASC and HOPD patients, although the differences are economically small.

Among Medicare recipients many pay either zero or little out-of-pocket amounts because they are covered by supplemental insurances (SI) such as Medicaid, employer-sponsored insurance, or

[5]http://www.medpac.gov/docs/default-source/reports/mar19_medpac_ch5_sec.pdf?sfvrsn=0
[6]https://www.cdc.gov/arthritis/data_statistics/cost.htm

Table 3.1: Summary statistics of Medicare outpatient patients

	ASC		HOPD		Difference
	Mean	Std	Mean	Std	
Gastroenterology procedures					
Out-of-pocket cost	129.91	47.81	265.35	234.56	-135.44***
Distance	9.21	5.53	9.19	6.13	0.02
Charlson index	0.06	0.32	0.81	1.58	-0.75***
Age	71.18	8.52	70.68	11.01	0.50***
White	0.91	0.29	0.86	0.35	0.05***
Income	83613.83	20409.59	78806.28	21595.73	4807.56***
Female	0.54	0.50	0.50	0.50	0.04***
Observations	11236		10148		21384
Ophthalmology procedures					
Out-of-pocket cost	220.05	123.37	370.94	202.31	-150.89***
Distance	11.04	6.76	9.58	6.17	1.46***
Charlson index	0.01	0.16	0.38	0.87	-0.37***
Age	75.36	7.63	75.93	8.37	-0.57***
White	0.92	0.27	0.90	0.31	0.02***
Income	84590.25	19888.64	79300.06	22646.37	5290.19***
Female	0.60	0.49	0.61	0.49	-0.02
Observations	9666		4868		14534
Musculoskeletal procedures					
Out-of-pocket cost	352.18	200.61	601.95	396.78	-249.78***
Distance	11.39	6.36	10.02	6.52	1.36***
Charlson index	0.04	0.26	0.47	0.95	-0.43***
Age	70.74	7.73	70.28	10.62	0.47
White	0.92	0.27	0.90	0.30	0.02*
Income	85495.39	18037.32	81252.39	21030.94	4243.00***
Female	0.59	0.49	0.61	0.49	-0.01
Observations	1101		3191		4292

Notes: Summary statistics are obtained from all Medicare patients who underwent gastroenterology, ophthalmology and musculoskeletal procedure in Pennsylvania from 2012 to 2015.

Medigap, etc. Medicare claim data alone does not identify who has and who has no supplemental insurance. In order to recover the true price responsiveness of patients who do pay out-of-pocket payments, it is important to weight patients with and without supplemental coinsurance properly. In order to do so, I utilize the Medicare Current Beneficiary Survey (MCBS) to estimate the regression that reflect Medicare's selection into supplemental insurances. The regression results is included in Appendix 3.7.1. I also simulate draws of patients' characteristics from this data to predict probability of patients having supplemental insurance. These probability will be used for the demand estimation. More details will be provided in Subsection (3.4.1).

3.3.2 Data for cost estimation

I estimate the cost functions for ASCs and HOPDs in order to derive marginal costs of outpatient procedures performed at these two settings. The cost function estimation utilize several data sources.

First, I use the Financial Analysis reports for ASCs in Pennsylvania, and the Medicare cost reports for hospitals. The Financial Analysis reports include net patient revenue, total operating margin, and most importantly total operating cost for each ASCs. The Medicare cost reports include information that allows me to extract hospital outpatient operating costs from hospital's total operating costs. The cost analysis is done on the facilities in Pennsylvania because Pennsylvania is the only state that collects and publishes total operating expenses for ASCs[7].

Second, I use the Hospital and Ambulatory Surgery Centers reports (2010-2017) from the Pennsylvania Department of Health Services' website[8]. The ASC reports include the outpatient operation volume for ambulatory surgery centers, the number of operating beds, indicators for amenities such as pharmacy, inhalation therapy, ultrasound, Xray, and specialties. The HOPDs reports include type of organization for hospitals, number of beds, number of CT scanners, X-ray, and MRI unit.

Additionally, I use the Medicare Wage Index to control for variations in labor costs across different urban and rural areas. Note that with the Medicare Wage Index, the variations in the labor costs only come from variations in different locations of facilities. Plausible differences in labor wages between ASCs and HOPDs are not captured in the data and the cost function estimation.

As shown later in the demand estimation, patients sort into different facility types by patient health risk. Therefore, patient health risk is likely an important characteristic that determines the marginal costs at ASCs and HOPDs. The publicly available Financial Analysis reports and the ASCs

[7]Medicare cost reports include variable for inpatient charge and outpatient charge. Theys also include cost-to-charge ratio. The outpatient costs is cost-to-charge multiplied with outpatient charge.

[8]http://www.phc4.org/default.htm

Table 3.2: Summary of facilities in Pennsylvania, 2015

	ASC		HOPD	
	Mean	Std	Mean	Std
Operating Cost (thousand $)	3460.94	3433.39	121076.17	110938.27
No. Outpatient Surgery	3634.69	2704.15	7419.39	6282.44
Medicare wage index	0.94	0.10	0.92	0.11
No. Beds	10.60	10.78	264.47	224.15
Clinical lab	0.09	0.29		
Cardio lab	0.01	0.11		
Pharmacy	0.05	0.22		
Inhalation therapy	0.06	0.24		
Ultrasound	0.09	0.28		
Xray	0.11	0.32		
No. CT scanners			2.84	2.24
No. MRI units			2.24	1.87
Multi-specialty	0.45	0.49	1	0
Ophthalmology	0.44	0.50		
Gastroenterology	0.23	0.42		
Musculoskeletal	0.33	0.47		
Observations	254		129	

Note: Clinical lab, Cardio lab, Inhalation therapy, Ultrasound, Xray are the dummy variables that indicate whether facilities have these amenities. Ophthalmology, gastroenterology, musculoskeletal are the dummy variables that indicate whether facilities provide these services. The statistics are obtained from year 2015, although the cost function analysis is performed on the data from 2010 to 2017.

and HOPDs reports do not have this variable. I proxy for this measure by the average Charlson index of Medicare patients at each facility.

Table 2 summarizes the characteristics of 254 ASCs and 129 HOPDs available in the data set for the year 2015. While HOPDs perform about twice as many outpatient surgeries as ASCs, HOPDs' total operating costs are much higher than ASCs'. HOPDs and ASCs have similar wage indices. If anything, ASCs have slightly higher average wage index than HOPDs, which might be explained by the observations that ASCs tend to be located in urban areas. Comparing the capital level and the infrastructure we see stark differences between HOPDs and ASCs. HOPDs are also equipped with many more operating beds than ASCs. The average number of CT scanners at a hospital is around 2.84 and the average number of MRI units is around 2.24 per hospital. In contrast, it is very uncommon to have such infrastructures as pharmacies, Xray machines or CT scanners in ASCs. Finally, unlike HOPDs, many ASCs are single specialty facilities, with gastroenterology and ophthalmology the most popular specialties.

3.4 Demand estimation strategy and results

3.4.1 Demand estimation

I specify the patients' demand for an outpatient facilities with a nested logit model. Patient preferences depend on the OOP, distances, patient characteristics and facility types. Interactions between patient characteristics and facility type are included to allow coefficients to vary over the population along observable patient characteristic dimensions. For example, sicker patients may prefer HOPDs since they have emergency rooms, while healthier patients may be more willing to visits ASCs. The nested logit structure allows for the correlation between the preferences for facilities within the same type.

As mentioned previously, many Medicare recipients pay either zero or little out-of-pocket costs because they are covered by supplemental insurances. In order to recover the true price responsiveness of patients who do pay out-of-pocket payments, I weight patients' utilities by the probability that they have supplemental insurance (SI). I compute these probabilities using patients' characteristics which are simulated from the Medicare Current Beneficiary Survey and the estimated regression that explains the enrollment into SI of Medicare beneficiaries. Using these predicted probabilities to weight utility functions, I estimate the demand parameters using simulated maximum likelihood estimation.

Formally, let i denote patient, g denote facility group, $g \in \{A, H\}$, and j denote a facility in each group. I specify two utility functions, one for patients who do not have supplemental coinsurance, and one for patients who do have supplemental coinsurance:

$$u_{ijg|\text{No SI}} = -\lambda OOP_{ijg} + \alpha_{jg} + X_{ijg} d_g \beta + (1-\sigma)\,\epsilon_{ijg} = V_{ijg|\text{SI}} + (1-\sigma)\,\epsilon_{ijg} \tag{3.12}$$

$$u_{ijg|\text{SI}} = \alpha_{ig} + X_{ijg} d_g \beta + (1-\sigma)\,\epsilon_{ijg} = V_{ijg|\text{SI}} + (1-\sigma)\,\epsilon_{ijg} \tag{3.13}$$

where OOP_{ijg} is the out-of-pocket payment[9], α_{jg} is facility jg's fixed-effect, and d_g is facility g's fixed-effect. X_{ijg} is a set of patient's characteristics, such as $log(income_i)$, age_i, $gender_i$, $race_i$, and $distance_{ijg}$. σ is the dissimilarity parameter that indicates the correlation in patients' preferences for facilities within the same facility group. For patients with no supplemental insurance, out-of-pocket payment contributes to the facility choice. For patients with supplemental insurance, they pay either zero or a small out-of-pocket payments, therefore OOP does not appear in their utility function.

[9]Note that OOP_{ijg} enters linearly into the utility model and $income_i$ enter into the utility model as $\log(income)$. This specification assumes that patients are closed to risk-neutrality. Given that the median income household is around \$ 80,000, while the average out-of-pocket payment is around \$300, this assumption is defendable.

Given these utility functions, the choice probability conditional on supplemental insurance status is given by

$$\Pr(i \text{ chooses facility } jg|i \text{ has SI}) = \frac{\exp\left(V_{ijg|\text{SI}}/\left(1-\sigma\right)\right)}{D_{ig|\text{SI}}} \cdot \frac{D_{ig|\text{SI}}^{1-\sigma}}{D_{iA|\text{SI}}^{1-\sigma} + D_{iH|\text{SI}}^{1-\sigma}}$$

and

$$\Pr(i \text{ chooses facility } jg|i \text{ has No SI}) = \frac{\exp\left(V_{ijg|\text{No SI}}/\left(1-\sigma\right)\right)}{D_{ig|\text{No SI}}} \cdot \frac{D_{ig|\text{No SI}}^{1-\sigma}}{D_{iA|\text{No SI}}^{1-\sigma} + D_{iH|\text{No SI}}^{1-\sigma}}$$

where $D_{ig|\text{SI}} = \sum_{j\in g} \exp\left(V_{ijg|\text{SI}}/\left(1-\sigma\right)\right)$ and $D_{ig|\text{No SI}} = \sum_{j\in g} \exp\left(V_{ijg|\text{No SI}}/\left(1-\sigma\right)\right)$. The probability of patient i choosing facility jg is

$$\begin{aligned}\Pr(i \text{ chooses facility } jg) &= \Pr(i \text{ chooses facility } jg|i \text{ has SI})\cdot\Pr(i \text{ has SI}) \\ &\quad + \Pr(i \text{ chooses facility } jg|i \text{ has No SI})\cdot\Pr(i \text{ has No SI})\end{aligned}$$

I simulate a vector of patient characteristics, Z_i^s, from the MCBS dataset, which include $education_i^s$, $marriage_i^s$, $health_i^s$, $smoking_i^s$, and $drinking_i^s$. Combining these simulated variables with the patient characteristics $(age_i, female_i, income_i, race_i)$ in the Medicare claim data, and the SI selection regression result, I predict the probability that patient i has supplemental insurance is:

$$\widehat{\Pr}_s(i \text{ has SI}) = \hat{\beta}_0 + \hat{\beta}_Z Z_i^s + \hat{\beta}_{age} age_i + \hat{\beta}_{female} female_i + \hat{\beta}_{inc} income_i + \hat{\beta}_{race} race_i$$

The likelihood function is given by:

$$\begin{aligned}\mathcal{L} &= \Pi_{i=1}^{N}\Pi_{g=\{A,H\}}\Pi_{j\in g}\Pr(i \text{ chooses facility } jg) \\ &\approx \frac{1}{S}\Pi_{i=1}^{N}\Pi_{g=\{A,H\}}\Pi_{j\in g}[\Pr(i \text{ chooses facility } jg|i \text{ has SI})\cdot\widehat{\Pr}_s(i \text{ has SI}) + \\ &\Pr(i \text{ chooses facility } jg|i \text{ has No SI})\cdot\widehat{\Pr}_s(i \text{ has No SI})]\end{aligned} \tag{3.14}$$

Some discussions about the demand estimation are warranted. First, the reader can think about the demand problem in the following way: after being recommended by their physician to have outpatient surgery, and perhaps to use a particular facility, patients make a two-part decision. They decide whether to have surgery, and then they decide where to have the procedure performed. The paper focuses on the second part of the decision: conditional on needing to undergo an outpatient procedure, which facility does the consumer choose? In particular, I look at how the bundle of facility characteristics and patient characteristics impacts consumer's care setting choices.

Second, the fact that physicians make recommendations to their patients about surgery location implies that patients are not making facility choice decisions in isolation. Therefore, utility can be thought of as some weighted mix of patient utility and physician utility. One might include fixed effects for referring physicians in order to separate patients' preferences from physicians' influences in the observed choice data. Unfortunately, due to limited information on referring physicians in the Medicare claim data set, this paper can not address this concern. However, the significant estimates of the λ coefficient on out-of-pocket payments across all procedure groups suggest that facility choice is sensitive to out-of-pocket payments. Therefore reimbursement and coinsurance policies are important and impactful policy instruments.

Third, there is also a concern that the demand for one facility type might reflect not only patients' preference but also the supply of facilities of that type around the patient's location. However, this is likely a small issue because the demand functions estimated for Pennsylvania's urban areas, where ASCs are as prevalent as HOPDs.

3.4.2 Demand estimation results

Recall, in modeling demand as a discrete choice problem, the objective is to estimate the coefficients $\theta = [\lambda, \alpha_{jg}, \beta_g, \sigma]$ from equations (3.12) and (3.13) by maximizing the simulated likelihood function given in equation (3.14). Estimates from the nested logit demand model provide insight into consumers' facility choice decisions. Table 3 displays the estimation results from the nested logit demand for each procedure group.

Demand estimates show that travel distance is a significant predictor of demand across all procedure groups. For example, for a patient undergoing a musculoskeletal procedure, an increase of travel distance by 1 mile has the same impact on demand as a price increase of $24.3. This result echoes repeated findings in the healthcare literature (see David and Neuman (2011); Capps et al. (2010); Weber (2014); Gaynor and Vogt (2003)) that distance matters to healthcare consumers.

Turning to the interactions between patient characteristics and the HOPD dummy variable, I find that higher Charlson index patients, i.e., patients with higher health risks, are less likely to visit ASC's. This result reflects the difference in Charlson index among ASCs' and HOPDs' patients seen in the summary statistics.

Table 3.3: Estimation results of Medicare patient demand for outpatient facilities in Pennsylvania, 2012-2015

	Gastroenterology procedures	Ophthalmology procedures	Musculoskeletal procedures
Distance	-0.224***	-0.172***	-0.133***
	(-16.41)	(-19.37)	(-6.57)
Out-of-pocket	-0.003***	-0.008***	-0.011***
	(-5.64)	(-9.35)	(-4.85)
Log(Income)*HOPD	-0.086	0.055	-0.075
	(-0.60)	(0.32)	(-0.20)
Charlson Index * HOPD	1.500***	2.788***	2.314***
	(17.77)	(11.91)	(6.30)
Age * HOPD	-0.003	0.011	-0.007
	(-1.05)	(1.95)	(-0.76)
White * HOPD	-0.111	-0.143	0.055
	(-0.96)	(-0.86)	(0.17)
Female * HOPD	-0.094	0.194*	0.045
	(-1.32)	(2.01)	(0.26)
Dissimilarity parameter	0.977***	0.901***	0.856***
	(15.55)	(17.63)	(6.22)
Number of cases	18,740	13,628	3,224
Number of facilities	89	63	64

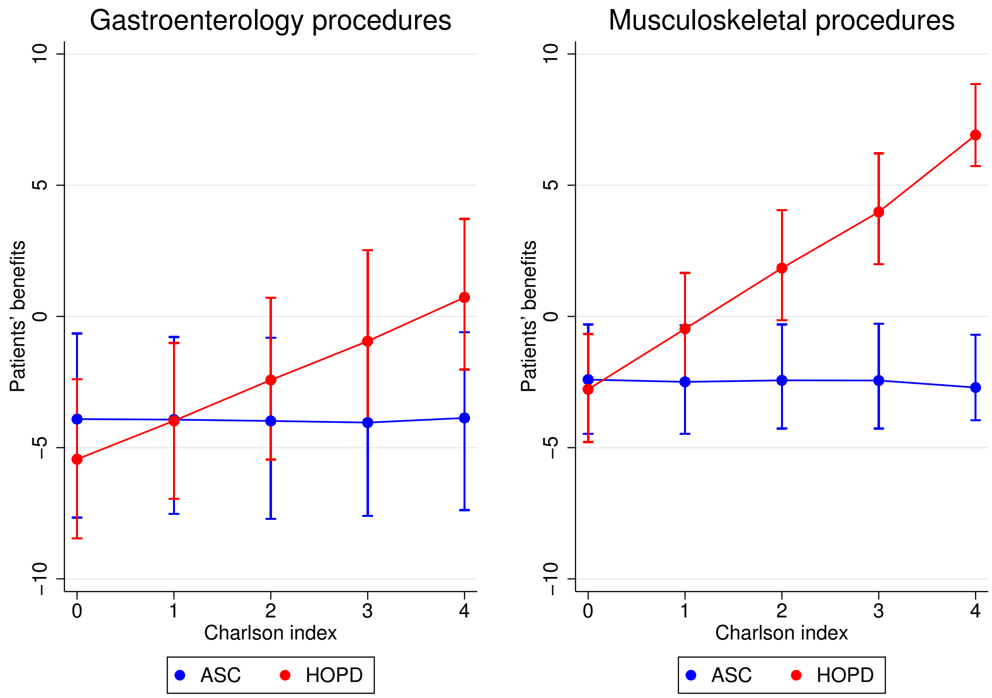
Notes: t statistics in parentheses, $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Finally, among patients without supplemental insurance, consumers' facility choice is sensitive to variations in out-of-pocket payments. For example, for a patient having a gastroenterology procedure, an increase in the out-of-pocket payment by 10 dollars decreases patients' utility by the same amount as traveling an extra 1.4 miles. For more complicated procedures such as those in the musculoskeletal group, the same increase in the out-of-pocket payment only decreases utility by the same amount as traveling an extra 1.04 miles for the treatment.

The variations in out-of-pocket payments that identify the OOP coefficient comes from several sources. First, unlike the Medicare inpatient market where small price variations justify the existing papers to drop the OOP variable from the demand estimation, the reimbursement rates that Medicare sets outpatient procedures vary significantly across ASCs and HOPDs. Second, even facilities within the same type have variable reimbursement rates if they are based in locations with different labor wages. Third, variations in the OOP also come from the variations in the number of auxiliary procedures that each facility performs.

Figure 3.1 summarizes patients' valuation of care at HOPDs and ASCs. The x-axis is the Charlson index reflecting patients' health risk, and the y-axis is the patients' valuation of care. Each red dot represents a patient's valuation of care at all ASCs available in his choice set. Each blue dot represents the patient valuation of care at all HOPDs in his choice set. The figures make it clear that, across all procedure groups, patients with low Charlson indices have higher valuation for ASCs than for HOPDs. However, patients with higher Charlson indices have significantly higher valuation of HOPDs than ASCs.

Figure 3.1: Patients' benefits from gastroenterology and musculoskeletal procedures at HOPDs and ASCs



Notes: Patients' benefits are calculated as $\hat{\alpha}_{jg} + X_{ijg}\hat{\beta}_g$. The dots are the average of patients' benefits from all facilities available in patients' choice set. The intervals graphed are the 95% confidence interval of the estimated patients' benefits.

3.5 Cost function estimation and results

3.5.1 Cost function estimation

The computation of optimal reimbursement rates and coinsurance rates, and their welfare impacts require some knowledge of marginal costs of outpatient procedures at ASCs and HOPDs. The lack of cost data at a procedure level does not allow the direct estimation of marginal cost functions. Therefore, I estimate cost functions using total operating costs of ACSs and HOPDs and then derive marginal costs of procedures at these two care settings.

The estimation strategy for the ASCs and HOPDs cost functions build on the literature of short-run cost function estimation. The cost function is given as $C^V = G(Y, W, K)$ where Y is a vector of output, W variable input prices, and K fixed capital inputs. The main behavioral assumption is that facilities minimize variable costs by choosing variable labor input given the capital stock, exogenous labor wage index and patients' demands for facility services.

I utilize the trans-log cost function because it imposes few a priori restrictions on the underlying nature of products and is consistent with the functional properties required by economic theory. In addition, the trans-log functional form has been shown to provide a reasonable approximation for a production technology when no explicit production or cost function is specified (Guilkey et al., 1983; Stern, 1994). The regression for ASCs' and HOPDs' cost functions are given by

$$\begin{aligned}
\ln C_{ht} &= \alpha_0 + \alpha_Y \ln Y_{ht} + Q_h + \alpha_W W_{ht} + \alpha_K \ln K_{ht} + \sum_j \alpha_{Z_j} Z_{htj} \\
&+ \frac{1}{2}\alpha_{Y^2} \left(\ln Y_{ht}\right)^2 + \alpha_{Y,W} \ln Y_{ht} W_{ht} + \alpha_{Y,K} \ln Y_{ht} \ln K_{ht} + \sum_j \alpha_{Y,Z_j} \ln Y_{ht} Z_{htj} \\
&+ \frac{1}{2}\alpha_{W^2} \left(W_{ht}\right)^2 + \alpha_{W,K} W_{ht} \ln K_{ht} + \sum_j \alpha_{W,Z_j} W_{ht} Z_{htj} \\
&+ \frac{1}{2}\alpha_{K^2} \left(\ln K_{ht}\right)^2 + \sum_j \alpha_{K,Z_j} \ln K_{ht} Z_{htj} \\
&+ \frac{1}{2}\sum_j \alpha_{Z_j^2} \left(Z_{htj}\right)^2 + \sum_j \sum_{j<j} \alpha_{Z_j,Z_k} Z_{htj} Z_{htk} + \varepsilon_{ht}
\end{aligned} \tag{3.15}$$

where C_{ht} is the total operating cost of facility h at time t, Y_{ht} is total number of outpatient surgeries performed, Q_h is the facility fixed effect which is interpreted as facility quality, W_{ht} is the Medicare Wage index, K_{ht} is fixed assets measured by the number of operating beds, Z_{ht} is a set of additional determinants of cost such as average patient severity, specialty, facility type, and facility's amenities. I estimate the cost functions for ASCs and HOPDs given in equation (3.15) using the fixed effects regression approach. In additional, because the cost function have many interaction terms while the panel data has just over 2000 observations for ASCs cost function estimation and 1000 observations for HOPD cost function estimation, I employ the Lasso estimation approach to select appropriate control variables.

A salient issue concerning the econometric specification is the endogeneity of the output variable, i.e., the number of surgeries. The fixed effects purge facility-specific fixed factors out of the error term, but endogeneity could still result due to remaining time-varying factors. In future work, following Gaynor and Anderson (1995), I plan to utilize county level socioeconomic and demographic variables to instrument for the number of surgeries and its interaction terms. These variables include the number of physicians per capita in the county, county population, county employment rate, county per capita income, the proportion of population in the county with any private insurance coverage, the number of Medicare beneficiaries, the percentage of population which is non-white, younger than 15, and older than 65. The exogeneity assumption is that these variables affect the total operating cost through no channels other than the facility demand.

Given the cost function estimates in equation (3.15), the marginal cost of a surgery at a facility h is calculated as the derivative of the total operating cost with respect to the number of surgeries:

$$MC_h = \frac{\partial \ln C_{ht}}{\partial \ln Y_{ht}} . \frac{\bar{Y}_{ht}}{\bar{C}_{ht}} \tag{3.16}$$

$$= \left(\alpha_Y + \alpha_{Y^2} \ln Y_{ht} + \alpha_{Y,Q} W_{ht} + \alpha_{Y,K} \ln K_{ht} + \sum_j \alpha_{Y,Z_j} Z_{jht} \right) . \frac{\bar{Y}_{ht}}{\bar{C}_{ht}} \tag{3.17}$$

To facilitate the comparison of the marginal cost of surgeries at HOPDs and ASCs, I will evaluate the derivative above at the average characteristics of all HOPDs and all ASCs, respectively.

3.5.2 Cost function results

Table 4 shows the estimation results of the ASCs' cost function and the HOPDs' cost function. Here I only report the coefficient estimates for the number of surgeries variable and for the interaction between this variable and the remaining variables. The reason is that these estimates enter into the calculation of the marginal cost of ASCs and HOPDs (as described in equation (3.16)).

The main drivers of marginal costs at ASCs are the number of surgeries and the number of beds. In addition, ASCs' amenities such as clinical labs and ultrasounds also increase their marginal costs. The regression estimates also suggest that specialty matters in explaining variations in marginal costs at ASCs. For example, facilities that provide services in gastroenterology and dentistry services have lower costs than facilities that provide other services.

For HOPDs, labor cost, teaching status, for-profit status, and the number of beds are the most important factors that explain the marginal costs. Hospitals with more beds, located in high labor wage areas, and with for-profit status tend to have higher marginal costs. Hospitals that have teaching status tend to have lower marginal costs.

From the ASCs' and HOPDs' cost function regressions, I derive the average marginal cost over all procedures provided at ASCs and HOPDs according to equation (3.16) and evaluate them at the mean of HOPDs and ASCs characteristics. I also calculate the average marginal cost of each procedure group provided at ASCs and HOPDs. I assume that the estimated average marginal cost is the weighted average of the marginal cost of all procedure groups, with the weights being

Table 3.4: Estimation results of ASCs and HOPDs cost functions

	ASC		HOPD	
	ln(Operating Cost)		ln(Operating Cost)	
No.Surgery	0.874***	(3.38)	-0.182	(-0.57)
No.Surgery Squared	-0.0280*	(-2.09)	0.0130	(0.59)
No.Surgery * No. Bed	0.0453**	(3.12)	0.123*	(2.14)
No.Surgery * Wage index	0.167	(0.96)	0.295***	(4.45)
No.Surgery * Severity	0.180	(1.54)	0.205	(1.43)
No.Surgery * Cardio Lab	-0.00455	(-0.01)		
No.Surgery * Electro Cardio	-0.0282	(-0.76)		
No.Surgery * Pharmacy	0.0726	(0.83)		
No.Surgery * Clinical Lab	0.0789*	(1.96)		
No.Surgery * Inhalation Therapy	0.0219	(0.46)		
No.Surgery * Ultrasound	-0.137*	(-2.29)		
No.Surgery * X-ray	-0.0412	(-1.17)		
No.Surgery * Gastroenterology	-0.0148**	(-3.20)		
No.Surgery * Musculoskeletal	0.0615	(1.29)		
No.Surgery * Dentistry	-0.0753***	(-3.55)		
No.Surgery * Urology	0.0467	(0.94)		
No.Surgery * OB/GYN	-0.0722	(-1.64)		
No.Surgery * Plastic	0.0145	(0.38)		
No.Surgery * Ophthalmology	-0.0352	(-0.97)		
No.Surgery * Teaching			-0.173**	(-2.98)
No.Surgery * For Profit			0.0534**	(3.04)
No.Surgery * No.CT scanners			-0.0283	(-1.79)
No.Surgery * No.MRI units			-0.00410	(-0.27)
N	2284		1013	
No.Variables of interest	318		228	
No.Controls	161		20	
No. Controls selected	105		19	
Chi-square	58060.1		599467.4	
p-value	0		0	

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

the procedure group volumes. I also assume that the Ambulatory Procedure Classification (APC) weights, which Medicare uses to rank the resource intensity for procedures, reflect the true relative magnitude of their marginal costs. These two assumptions give the system of equations that allow me to calculate the procedure group marginal cost:

$$AvgMC_{ASC} = \frac{MC_{Gastro} * N_{Gastro} + MC_{Ophthal} * N_{Ophthal} + MC_{Muscul} * N_{Muscul}}{N_{Gastro} + N_{Ophthal} + N_{Muscul}} \tag{3.18}$$

$$\frac{MC_{Gastro}}{MC_{Ophthal}} = \frac{APC_{Gastro}}{APC_{Ophthal}} \tag{3.19}$$

$$\frac{MC_{Gastro}}{MC_{Muscul}} = \frac{APC_{Gastro}}{APC_{Muscul}} \tag{3.20}$$

Table 3.5: Estimated marginal costs by facility type and by procedure group

	Average MC	(Std. error)	APC weight	No.of cases	MC	Medicare payment
ASCs						
Musculoskeletal	388.04	(27.43)	12.30	23,313	242.08	519.11
Ophthalmology	388.04	(27.43)	18.06	23,891	355.41	751.05
Musculoskeletal	388.04	(27.43)	29.15	22,524	573.70	1210.01
HOPDs						
Musculoskeletal	695.49	(23.64)	17.09	36,690	499.87	1161.97
Ophthalmology	695.49	(23.64)	20.16	15,044	589.76	1439.93
Musculoskeletal	695.49	(23.64)	30.95	41,784	905.32	2121.01

Table 5 reports the estimated average marginal costs and the estimated marginal costs of each procedure groups at ASCs and HOPDs. There is a significant difference between the estimated ASCs' and HOPDs' average marginal costs. The average marginal cost of a surgery at ASCs is \$388.04 whereas the average marginal cost of a surgery at HOPD is \$695.49. At the procedure group level, musculoskeletal procedures have the highest APC weight, and therefore are the most costly procedure group, followed by ophthalmology and gastroenterology. The marginal cost of these procedure groups at HOPDs are much higher than the marginal costs at ASCs. Notably, both of these marginal costs are much lower than the current average Medicare reimbursement rates.

As mentioned previously, due to the lack of ASC cost data, estimates of ASCs' marginal cost is nearly non-existent elsewhere in literature. The only study that attempts to compare HOPDs' and ASCs' cost is Wynn et al. (2008). Using cost reports of hospitals in California, they calculate hospital cost per APC weight unit. They also calculate the same measure for a set of ambulatory surgery centers in California using ASCs' procedure data and their financial reports. Consistent with my estimates, they find that the estimated ASCs' costs are much lower (about 66% to 71%) than the estimated HOPD costs.

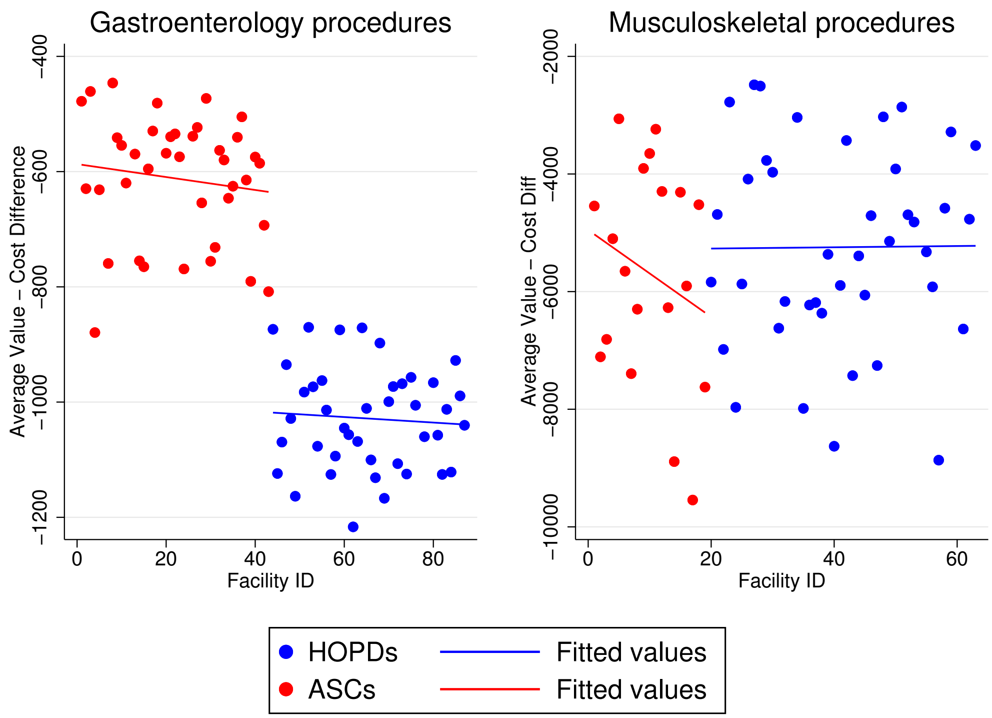
The calculation of the marginal costs of each procedure group at HOPDs and ASCs assumes that Medicare's APC weights for procedure groups reflect the true relative magnitude of procedure groups' marginal costs. In order to test this assumption, I use an additional data set on ambulatory procedures at ASCs and HOPDs[10] to estimate the same regression in equation (3.15) for each procedure group. Since ASCs often provide a small number of specialties, the data has enough power to detect the variations in total operating costs that are attributed to the variations in each procedure group's volume. Therefore, it is possible to estimate the marginal cost of each procedure group provided in ASCs. In contrast, HOPDs provide multiple procedure groups, the data, therefore, does not have enough power to detect the contribution of each procedure group to total operating costs. Therefore, the estimation of HOPDs' marginal costs at the procedure group level is noisy. Given ASCs' marginal cost estimates at the procedure group level, I compare the normalized APC weights that Medicare assigns for each group with the normalized marginal cost estimates. The normalization is with respect to the APC weight and the estimated marginal cost of the gastroenterology procedure group. I find that the normalized Medicare APC weights reflects the normalized marginal cost reasonably well. Estimation results for marginal costs of procedure groups at ASCs and the comparison between the APC weights and ASCs' marginal costs are detailed in Appendix 3.7.3.

3.5.3 ASCs' and HOPDs' value - cost difference

Combining the patients' valuation and the marginal cost of ASCs and HOPDs, I calculate the net value of HOPDs and ASCs and graph them in Figure 3.2. The left figure represents the average of the value - cost difference of ASCs and HOPDs for gastroenterology procedures, while the right figure represents the same measure for musculoskeletal procedures. The facilities are indexed by Facility ID. ASCs' values are represented in red dots and HOPD's values are represented in blue dots. As seen clearly in the left hand side figure, ASCs offer a significantly higher net value than HOPDs for gastroenterology patients. This is because, given that most gastroenterology patients are low risk, the average patients' valuation of ASCs is not very different from those of HOPDs. However, the marginal cost estimation shows that HOPDs' average marginal cost is significantly higher than ASCs' average marginal cost. In contrast, in the right hand side figure, there is no

[10] This additional dataset is the Ambulatory Procedure data from Health Cost containment Council http://www.phc4.org/

Figure 3.2: Net value of gastroenterology and musculoskeletal procedures at ASCs and HOPDs



Notes: Value to cost differences are defined by $\hat{\alpha}_{jg} + X_{ijg}\hat{\beta}_g - \widehat{MC}_g$

evidence that ASCs' net value is different from HOPDs' net value for musculoskeletal procedures. For this procedure group, patients have relatively higher health risks, the higher cost at HOPDs is generally offset by the higher value of care that they provide.

The differences in net value of ASCs and HOPDs have direct implications for the optimal allocations of patients across facility types. For gastroenterology procedures, since patients have higher net value at ASCs, it is optimal for reimbursement rates to incentivize more patients to undertake treatments at ASCs. This allocation is achieved if Medicare increases HOPDs' coinsurance rate while decreasing ASCs' coinsurance rate. In the case where coinsurance rates are fixed uniformly across care settings, the price variation between HOPDs and ASCs will have to be large in order to incentivize more patients to sort into ASCs. For musculoskeletal procedures, the allocation of patients between ASCs and HOPDs might be more even since the difference in net value between ASCs and HOPDs is not significant. As a result, the optimal variation in reimbursement rates and coinsurance rates for musculoskeletal procedures does not need to be as large as those for gastroenterology procedures.

The following section combines the demand and cost estimation results to examine empirically what the allocation of patients into ASCs and HOPDs should look like and what the optimal payment scheme and coinsurance rates are to achieve that allocation.

3.6 Counterfactual Analysis

3.6.1 The welfare impacts of Medicare's site neutral payment policy

In this section, I use the demand and marginal cost estimates to examine the welfare impacts of a site-neutral payment policy. It is a simplified version of the recent legislations that the Center of Medicare and Medicaid Services (CMS) implemented to close the gap in reimbursement rates for HOPDs and ASCs and lower costs for common services under the outpatient care payment system. For example, in 2017, Medicare ruled that off-campus provider-based sites located 250 yards or more away from the hospital's campus will receive the same reimbursement rates as ASCs' reimbursement rates. In 2019, CMS began to pay HOPDs the same rates as ASCs for outpatient clinical visits [11]. In this section, I predict the welfare impacts of the counterfactual scenario where Medicare reduces the HOPDs' reimbursement rate to the current ASCs' rates for gastroenterology, ophthalmology and musculoskeletal procedures.

In order to measure the welfare impacts of this policy, I first calculate the new out-of-pocket payments that resulted from this policy change. I obtain the national unadjusted reimbursement rates to HOPDs and ASCs for all outpatient procedure codes from the CMS' website. I then follow CMS's formula to adjust 60% of the HOPD reimbursement rates and 50% of the ASC reimbursement rates by the Medicare wage index. In doing so, I obtain HOPD and ASC reimbursement rates for all outpatient procedures in all facilities in the sample. I also obtain the counterfactual reimbursement rates if HOPDs are reimbursed at ASCs' rates. Recall that in constructing the out-of-pocket payments for the demand estimation, I include not only the facility fees but also the auxiliary procedure fees. The counterfactual out-of-pocket payments will only have the reimbursement rates of the main procedures changed, while the auxiliary procedure fees are assumed fixed. I also assume that the site-neutral payment policy does not change the frequency at which the auxiliary procedures are provided. Using demand estimates, the marginal cost estimates and the counterfactual out-of-pocket payments, I simulate counterfactual market shares, premium, consumer surplus, care provider surplus and total surplus.

[11] https://www.beckershospitalreview.com/finance/12-things-to-know-about-site-neutral-payments.html

Table 3.6: Wefare impacts of the site-neural payment policy

	Gastroenterology		Ophthalmology		Musculoskeletal	
	ASC	HOPD	ASC	HOPD	ASC	HOPD
Out-of-pocket payment						
Before site-neutral	119.375	193.876	189.623	318.810	326.642	542.204
After site-neutral	119.375	119.553	189.623	187.637	326.642	325.982
Market share						
Before site-neutral	.777	.222	.574	.425	.503	.496
After site-neutral	.749	.250	.364	.635	.264	.735
Premium Change	($)	(%)	($)	(%)	($)	(%)
Premium	-15548.24	-12.115	-35789.08	-21.491	-16046.45	-23.647
Surpluses change	($)	(%)	($)	(%)	($)	(%)
Consumer surplus	41710.5	1.234	254200.4	15.705	87073.13	6.223
Procedure surplus	-427231.1	-12.645	-1086124	-67.104	-473093.1	-33.813
Total surplus	-3727.781	-1.695	-5807.117	-4.433	-3254.555	-6.258

The results are reported in Table 6. The site-neutral payment equalizes the reimbursement rates for HOPDs and ASCs and closes the gaps between the out-of-pocket payments that ASC and HOPD patients pay. For example, gastroenterology patients pay out of pocket approximately $195 at HOPDs and $119 at ASCs before the site-neutral payment policy. Under this policy, the out-of-pocket payments at HOPDs are reduced to the out-of-pocket payment level at ASCs. As expected, the site-neutral payment policy encourages more patients to undergo treatment at hospitals. Given that coinsurance rates stay the same, the lower HOPD reimbursement rates lead to a decrease in the premium by 12% to 24% across procedures. Since government funds subsidize Medicare beneficiaries 75% of the premium, this means that government spending on the Medicare also falls by 12% to 24%.

Consumer surplus increases because more patients can now enjoy higher value hospital care but pay roughly the same amount as they would in ASCs. However, providers' profit decreases due to ASCs having fewer patients and HOPD earning less for each patients they treat. Summing the changes in consumer surplus, provider surplus and premium, the estimates suggest that the site neutral payment policy results in a decrease in total surplus for all procedure groups. Intuitively, the negative change in the total surplus is due to the fact that more patients are encouraged to use care at HOPDs while ASCs provide higher or equal net value for all procedure groups.

The magnitude of the decrease in the total surplus varies across procedure groups. Gastroenterology and ophthalmology procedures exhibit smaller decreases in total surplus. This is due to variations across procedure groups in the demand responsiveness and the magnitude of the out-of-pocket payment changes resulting from the site-neutral payment policy.

3.6.2 Optimal reimbursement rates when the coinsurance rates are set exogenously

The previous section shows that while the site-neutral payment reduces Medicare spending on the outpatient care market, it leads to allocative inefficiency, and in sum, reduces total surplus. In this section, I examine what the reimbursement rates should be in order to maximize social surplus if the coinsurance rates must be maintained at the current 20% level. I also compute the welfare impacts if Medicare were to move from the current practice to this constrained optimal reimbursement scheme.

The optimal reimbursement rate structure is essentially a pair of HOPD and ASC payment rates, which are nationally adjusted by the Medicare wage index to obtain the payment scheme for all HOPDs and ASCs given their geographical locations. This optimal payment scheme induces the patient choices that maximize the total surplus. Recall that the total surplus is decreasing in the out-of-pocket payments. Therefore, optimally, at least one reimbursement rate has to be set at the marginal cost of the providers. Also recall from subsection 3.2 that, if the coinsurance rates are set at an exogenous rate, at least one type of facilities is reimbursed above their marginal cost. The previous analysis also suggests that ASCs provide higher or equal net value relative to HOPDs for all procedure groups. Thus, the optimal allocation of patients would have more patients going to ASCs. Intuitively, ASCs are optimally reimbursed at their marginal costs, and HOPDs are optimally reimbursed higher than their marginal cost to induce patients to sort into ASCs. To compute the optimal reimbursement rates, I search for the HOPD markup that gives rise to the reimbursement scheme which maximizes the social surplus.

Table 7 reports for each procedure group the optimal markups, the optimal reimbursement rates for ASCs and HOPDs, the resulting market shares, the changes in premiums, consumer surplus and procedure surplus, and total surplus changes if Medicare moves from the current practice to this optimal payment structure.

The current reimbursement policy implies that ASCs and HOPDs receive markups about 1.7 to 2.1 times their marginal costs. A grid search of the optimal markups suggests that ASCs should be paid their marginal costs, and HOPDs should have higher markups than those implied by the current payment scheme. For example, for the gastroenterology procedure group, HOPDs should be reimbursed 7 times higher than their marginal cost. This implies that at the optimum, the payment differentials between ASCs and HOPDs should be even larger than the existing ones. This result suggests that given the 20% coinsurance rate, the current payment differentials are not enough to deter patients from going to high cost HOPDs.

Table 3.7: The optimal reimbursement rate given the 20% coinsurance rate and the welfare impacts

	Gastroenterology		Ophthalmology		Musculoskeletal	
	ASC	HOPD	ASC	HOPD	ASC	HOPD
Estimated marginal costs						
Marginal cost	287	581	421	686	680	1053
Markups						
Status quo	1.80	1.99	1.78	2.09	1.77	2.01
Optimal	1	7	1	4	1	3.25
Reimbursement rates						
Status quo	519.11	1161.97	751.04	1439.93	1210.01	2121.01
Optimal	352.00	4877.99	461.66	2993.19	888.78	4432.59
Market shares						
Status quo	.77	.22	.57	.42	.50	.49
Optimal	.93	.06	.90	.09	.68	.31
Premium Change	($)	(%)	($)	(%)	($)	(%)
Premium	-53207.75	-10.36	-282914.5	-15.47	-12628.94	-8.98
Surpluses change	($)	(%)	($)	(%)	($)	(%)
Consumer surplus	499840	3.69	710577.5	10.97	-22563	-.40
Provider surplus	-431570.5	-6.96	-5873453	-63.03	-101824.3	-2.55
Total surplus	56621.25	6.43	24770.75	4.72	6409.56	3.08

Under the proposed optimal reimbursement rates, most patients in the gastroenterology and ophthalmology groups choose ASCs and more patients in the musculoskeletal procedure group also substitute away from HOPDs to ASCs. Premiums are decreased by 9% to 13% under these optimal reimbursement rates. Because HOPD reimbursement rates are increased, more, if not most patients, receive care at lower-cost ASCs. Consumer surplus increases for gastroenterology and ophthalmology procedures but decreases for musculoskeletal procedures. Procedure surplus decreases for all procedure groups despite HOPD reimbursement rates increasing, because ASCs are reimbursed less for each patient and more patients are treated at ASCs under the proposed policy. Summing the impacts on the premium, consumer surplus, and facility surplus, the result suggests that increasing the variations in the HOPD and ASC payment rates increases the social welfare by 3.1% to 6.4%.

It is also notable that the optimal HOPD markup is much higher for the gastroenterology procedure group than for the musculoskeletal procedure group. This result is consistent with the net value provided by ASCs and HOPDs to gastroenterology and musculoskeletal patients. ASCs on average provide higher net value than HOPDs for gastroenterology patients. Therefore, HOPDs' reimbursement rates have to be significantly higher than ASCs' reimbursement in order to encourage patients to switch to ASCs. For musculoskeletal procedures, HOPDs on average provide equal net value as ASCs. Therefore the optimal HOPDs reimbursement rates need not to have a very high markup.

Table 3.8: The optimal reimbursement rates and the coinsurance rates and the welfare impacts

	Gastroenterology		Ophthalmology		Musculoskeletal	
	ASC	HOPD	ASC	HOPD	ASC	HOPD
Estimated marginal costs						
Marginal cost	287	581	421	686	680	1053
Optimal reimbursement rates						
Reimbursement rate	287	581	421	686	680	1053
Coinsurance rates						
Status quo	.20	.20	.20	.20	.20	.20
Coinsurance rates	.05	.95	.15	.75	.6	.9
Market shares						
Status quo	.77	.22	.57	.42	.50	.49
Optimal	.91	.08	.89	.10	.67	.32
Premium Change	($)	(%)	($)	(%)	($)	(%)
Premium	-221939	-15.46	-410799.3	-20.25	-226025	-23.49
Surpluses change	($)	(%)	($)	(%)	($)	(%)
Consumer surplus	1527146	11.30	1030760	15.92	-1142101	-20.40
Provider surplus	-4896967	-79.06	-8750890	-93.91	-3250028	-81.40
Total surplus	53447.94	6.07	24792.75	4.73	6418.547	3.08

To summarize, instead of equalizing the reimbursement rates as in the site-neutral policy, Medicare can improve total welfare by widening the ASC - HOPD reimbursement gap even more in order to ensure more people sort into high net value ASCs.

3.6.3 Optimal reimbursement rates and coinsurance rates and the welfare impacts

In this subsection, I examine what the optimal reimbursement rates and coinsurance rates are if Medicare can set the coinsurance rates flexibly. I also compute the welfare impacts if Medicare were to move from the current practice to the optimal reimbursement and coinsurance rate scheme.

In Subsection 3.2 I show that when Medicare is able to set coinsurance rates flexibly, the optimal policy is to reimburse HOPDs and ASCs at their marginal cost levels and to allow the coinsurance rates to steer patients to the higher net value setting. To compute the optimal coinsurance rates, I search over a grid of coinsurance values from 0.05 to 0.95 for the pair of coinsurance rates for HOPDs and ASCs, which, together with the optimal reimbursement rates, induces patients' choice that maximize total surplus. The values 0 and 1 are excluded from the grid search because in reality some patients are risk averse, and thus the optimal coinsurance rates cannot be a corner solution. Table 8 reports for each procedure group the optimal reimbursement rates, the optimal coinsurance rates, the resulting market shares, the change in premium, consumer surplus, provider surplus and total surplus when Medicare were to move to the optimal payment structures.

Table 3.9: Welfare impacts of varying the coinsurance rates for HOPDs and ASCs

	Gastroenterology		Ophthalmology		Musculoskeletal	
	ASC	HOPD	ASC	HOPD	ASC	HOPD
Reimbursement rates						
Status quo	519.11	1161.97	751.04	1439.93	1210.01	2121.01
Optimal	287	581	421	686	680	1053
Coinsurance rates						
Status quo	.2	.2	.2 .	2	.2	.2
Optimal	.05	.2	.05	.2	.05	.2
Market shares						
Status quo	.77	.22	.571	.429	.50	.49
Optimal	.79	.20	.574	.425	.52	.47
Premium Change	($)	(%)	($)	(%)	($)	(%)
Premium	-154899.3	-30.17	-318517.1	-47.81	-118403.4	-43.62
Surpluses change	($)	(%)	($)	(%)	($)	(%)
Consumer surplus	1861227	13.77	2299053	35.51	881518.5	15.75
Provider surplus	-4777000	-77.13	-8661619	-92.95	-3217682	-80.59
Total surplus	9110.688	1.03	388.75	.07	1595.25	.76

The current policy sets a uniform coinsurance of 20% for all procedures at all outpatient providers. My calculations suggest that at optimum, the coinsurance rate for HOPDs has to be much higher than the coinsurance rate for ASCs so that patients avoid low net value HOPDs more frequently. Under this payment scheme, most patients choose to go to ASCs. The premium decreases significantly because the reimbursement rates for both ASCs and HOPDs decrease, and patients contribute more to the cost of the treatments. The provider surplus also decreases significantly because the reimbursement rates are cut down to marginal cost levels. For gastroenterology and ophthalmology procedures, consumer surplus increases because more patients now receive care at ASCs, where both the treatment prices and the coinsurance rates decrease. For musculoskeletal procedures, consumer surplus decreases because although the treatment prices decrease, the optimal coinsurance rates are higher at both care settings. However, summing the changes in consumer surplus, premium change, and provider surplus, the optimal policy results in an increase in total surplus by approximately 3.1% to 6.1%.

A similar amount of welfare gain is also achieved in the counterfactual analysis in Subsection 3.6.2, where the coinsurance rates are fixed at 20%. The advantage of the unconstrained optimal policy over the constrained optimal policy in Subsection 3.6.2 is that it decreases the premium even further by about 5%. This large reduction is due to the fact that reimbursement rates are reduced to the marginal cost levels, instead of having to be raised above the marginal cost for HOPDs to achieve allocative efficiency. As mentioned previously, the US government uses Medicare funds to subsidize Medicare beneficiaries for 75% of the premium cost. Therefore, taking into account the shadow cost of public funds, the unconstrained optimal policy that varies the coinsurance rates is particularly relevant and attractive given the extra reduction in Medicare spending.

The reader might argue that the high coinsurance rates proposed in the optimal policy above might deter patients from obtaining the treatment, and that that behaviors are not captured in the analysis because there is no outside option. To address this concern, I compute the welfare impacts if Medicare reduces the reimbursement rates to the marginal cost levels, keeps the HOPD coinsurance the same, but reduces the ASC coinsurance rate in order to induce more patients to ASCs. The results are reported in Table 9. It shows that Medicare can still achieve a positive welfare gain by only lowering the ASC coinsurance rate, conditional on reducing the reimbursement rates for both provider types to their marginal costs.

3.7 Conclusion

In this paper, I study how Medicare can optimally set reimbursement rates and coinsurance rates for the outpatient procedures that can be performed in either hospital outpatient departments (HOPDs) or ambulatory surgery centers (ASCs).

I show that theoretically, the optimal reimbursement rates are set at providers' marginal costs and coinsurance rates should be higher for the facility types that have lower net value. Through empirical analysis, I show that such policy changes in Medicare's payment structure can increase total welfare by 3% to 6% while simultaneously reducing Medicare spending by 15% to 23%. These welfare improvements and cost savings are possible because currently both HOPDs and ASCs are reimbursed at rates that exceed their respective marginal costs, and the uniform coinsurance rate across care settings do not incentivize sufficient sorting into ASCs, which provide comparable care to patients with lower risks at much lower costs.

I also show that when Medicare is constrained to keep the same coinsurance rates across care settings, Medicare should optimally increase the HOPD - ASC reimbursement differential to incentivize more patients to sort into ASCs. Compared to the scenario where Medicare is able to optimally vary coinsurance rates, this constrained policy results in a smaller Medicare cost saving of 6% to 8%. Given that Medicare spent $333 billion on outpatient services in 2018[12], and facility fees make up about 66% to 85% of the total cost of each outpatient visit [13], Medicare would forgo additional savings between $10.98 billion and $14.15 billion if it keeps the coinsurance rates the same across care settings.

[12]https://www.kff.org/medicare/issue-brief/the-facts-on-medicare-spending-and-financing/
[13]https://www.medicare.gov/procedure-price-lookup/cost/29827

Finally, my empirical analyses also suggest that Medicare's recent "site-neutral" policy, which equalizes reimbursement rate between HOPDs and ASCs but keeps the coinsurance rates the same at 20%, instead incentivizes greater sorting into HOPDs, resulting in a welfare loss. Overall, my analyses advocate that Medicare should employ both reimbursement and insurance policies simultaneously in order to improve efficiency in the allocation of care and to reduce Medicare spending.

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Appendices

3.7.1 Appendix for selection into supplemental insurance

A significant proportion of Medicare beneficiaries have supplemental insurance to cover out-of-pocket payments. This supplemental insurance includes Medigap insurance, Medicaid, employer-sponsored insurances, etc. However, the Medicare claim dataset does not identify supplemental insurance enrollment status, and does not record the real out-of-pocket payment that patients face. Most of the patients with supplemental insurance face small or zero out-of-pocket amounts. The demand estimation has to take this fact into account in order to estimate the true responsiveness of patients to the out-of-pocket payment. I do so by weighting the utility of patients who pay the full out-of-pocket amount and the utility of patients who do not pay the out-of-pocket payments properly. I weight them by the probability of having the supplemental insurance and the probability of not having the supplemental insurance. In order to calculate this probability, I utilize the publicly available version of the Medicare Current Beneficiary Survey to obtain the information on supplemental insurance coverage and patient's characteristics. I estimate the relationship between supplemental coinsurance and enrollee's characteristics through a logit regression, given by

$$SI_i = \alpha_0 + \alpha_D D_i + \alpha_H H_i + e_i \tag{3.21}$$

SI_i is the dummy for whether patient i has supplemental insurance, D_i is a set of demographic characteristics such as gender, age, race, income level, location, education and marriage status, and H_i is a set of health status variable, including self reported health status, dummy for smoking and drinking. The estimated relationship is reported in the table 2.

Table 3.10: Selection into supplemental insurance

	Coefficient	Std.error
Female	0.0919	(0.71)
Age	0.581***	(6.20)
Race	0.0782	(1.02)
Income level	1.374***	(10.00)
Metro location	0.197	(1.43)
Education level	0.688***	(3.74)
Marriage status	0.285***	(4.39)
General health status	0.219***	(3.93)
Smoking status	-0.429**	(-2.88)
Drinking status	-0.222**	(-3.02)
Constant	-4.347***	(-7.29)
Peusdo R-squared	0.265	
Observations	2190	

Notes: The regression is estimated on the publicly available version of the 2015 Medicare Current Beneficiary survey. t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The regression result suggests that income is the strongest predictor of the enrollment into supplemental insurance. Medicare recipients with higher incomes are more likely to have supplemental insurance. Similarly, Medicare recipients who are older, married, have higher education are also more likely to select themselves into supplemental insurance plans. Interestingly, patients with supplemental insurance are more likely to have better health statuses, not to smoke and not to drink. This relationship is inline with the Fang et al. (2008)'s findings that patients are advantageously selected into Medigap plans.

3.7.2 Appendix for ASC and HOPD outcomes

60-day readmission rate vary across procedure groups. For example, for patients who undergo gastroenterology procedures, it is more likely that they will gave another outpatient visits within a 60-day period if the first visits are at hospital. The opposite is true for patients who have opthalmology procedures. For patients with musculoskeletal procedures, the readmission rates are the same between those who visit ASC first and those who visit HOPD first.

I also summarize the rate of which a patient has another outpatient visits at HOPDs. [*I am going to get a better estimate of hospital transfer, the rate of which a patient has another outpatient visits at HOPDs is a misleading measure of hospital transfer*]

Table 3.11: Readmission rate and Readmission rate to HOPDs

	ASC		HOPD		Difference
	Mean	Std	Mean	Std	
Gastroenterology procedures					
60-day readmission rate	1.033	0.23	1.052	0.34	-0.020***
60-day readmission rate to HOPD	0.004	0.06	0.036	0.19	-0.032***
Observations	15470		15411		30881
Ophthalmology procedures					
60-day readmission rate	1.413	0.63	1.372	0.74	0.040**
60-day readmission rate to HOPD	0.003	0.05	0.031	0.46	-0.028***
Observations	10625		4360		14985
Musculoskeletal procedures					
60-day readmission rate	1.022	0.15	1.020	0.14	0.002
60-day readmission rate to HOPD	0.001	0.03	0.019	0.14	-0.018***
Observations	2538		4280		6818

3.7.3 Appendix for cost estimation

Using the PHC4 data to estimate the Cost functions for individual procedure groups in ASCs. The main estimation results are included in the table below

Figure 3.3 demonstrates a scatter plot of the normalized APC weights against the normalized ASC marginal cost for the six most popular procedures group provided in ASCs, which are gastroenterology, musculoskeletal, skin related, cardio, nervous and ophthalmology procedures. The scatter plot suggests that the normalized Medicare APC weights reflects the normalized Marginal Cost reasonably well.

Figure 3.3: Compare the ASC's APC weight and the estimated MC cost

G:/Users/yentran/Google Drive/5. Site neutral payment/Results/compare_APC

3.7.4 Appendix for Section: Theoretical Model

Theoretical model without the outside option

Medicare problem

Table 3.12: ASC Cost Function from Ambulatory Procedure data set, 2015 - 2017

	(1) Gastro	(2) Musculo	(3) Skin	(4) Cardio	(5) Nervous	(6) Ophthal
Log(No.Surgeries)	.210	-.077	0	0	0	-.544
Squared Log(No.Surgeries)	-.002	.024*	.019	.100	-.0166	.0217
No.Bed	-.031	-.026	-.019	.277*	.0254	-.014
Wageindex	-.104	.004	.543	1.190	-.003	.821
Avg. Charlson Index	.1789*	-.018	.349	-.277	-.0180	.240
Spec_oral	-.006	-.019	-.083	.152	.0267	-.067
Spec_colon	.005	.073*	.020	.431	.0472	.126***
Spec_orthopedic	-.017	-.144**	-.020	-1.575	.0104	.011
Spec_thoracic	.156**	-.301	.076	.372	-.098	-.422
Spec_family	-.151*	.258***	.139	.193	.060	-.385
Spec_urology	.074*	-.103*	-.093	1.138	.0176	.047
Spec_internal medicine	.011	.037	-.107*	1.030**	-.026	.191
Spec_plastic	-.020	.045	.026	-.584	-.001	-.041
Spec_ophthalmology	-.012	.013	-.054	.731	-.047	-.438
Ind_Cardio Lab	.071	.164	-.331	-.305	-.300	-.840***
Ind_ Electro Cardio	.037	-.045	-.013	1.200**	-.038	-.163
Ind_Pharmacy	-.123	.191	-.003	-2.333*	-.167	-.229
Ind_Clinical Lab	.107*	-.074	.028	.6565	.533	1.112***
Ind_Inhalation	-.093***	-.125	.306*	-.6107	-.011	.129
Ind_Ultrasound	-.053	.068	.056	-.212	-.01615	-1.314*
N	409	257	310	105	296	177

Notes: Data on the number of surgeries for each procedure group is obtained from the Ambulatory Procedure data (2015 - 2017), which are provided by the Pennsylvania Health Care Cost Containment Council

$$\max_{\kappa=\{p_H,p_A,b_H,b_A,\phi\}} \int_0^{r_{AH}} \left[p u_A(\kappa,r) + (1-p)\, u_0\right] dF\left(r\right) + \int_{r_{AH}}^1 \left[p u_H(\kappa,r) + (1-p)\, u_0\right] dF\left(r\right)$$

s.t.

$$r_{AH} = \frac{\lambda}{\beta_H - \beta_A}\left[\nu\left(w-\phi-b_A p_A\right) - \nu\left(w-\phi-b_H p_H\right)\right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \tag{3.22}$$

$$\phi = p\left\{\left(1-b_H\right) p_H \left[1 - F\left(r_{HA}\right)\right] + \left(1-b_A\right) p_A F\left(r_{HA}\right)\right\} \tag{3.23}$$

$$p_H \geq c_H \tag{3.24}$$

$$p_A \geq c_A \tag{3.25}$$

With little algebra, we can simplify the objective function to

$$W = (1-p)\,\nu\left(w-\phi\right) + p\left[\nu\left(w-\phi-b_H p_H\right) + \alpha_H\right] + p\left(\beta_H - \beta_A\right) r_{AH} F\left(r_{AH}\right)$$
$$+ p\beta_A \int_0^{r_{AH}} r dF\left(r\right) + p\beta_H \int_{r_{AH}}^1 r dF\left(r\right)$$

And we can also rewrite the Medicare problem as

$$\min -W \text{ s.t } c_H \leq p_H,\ c_A \leq p_A$$

Lagrangian of this problem is

$$L = -W + \lambda_H\left(c_H - p_H\right) + \lambda_A\left(c_A - p_A\right)$$

FOC w.r.t p_H :

$$-\lambda_H = -\left(1-p\right)\phi_{p_H}\nu' + p\left(-\phi_{p_H} - b_H\right)\nu'_H + p\left(\beta_H - \beta_A\right)\left[F\left(r_{AH}\right) + r_{AH} f\left(r_{AH}\right)\right]\frac{\partial r_{AH}}{\partial p_H}$$
$$+ p\beta_A r_{AH} f\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial p_H} - p\beta_H r_{AH} f\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial p_H}$$

or

$$\left[-\left(1-p\right)\phi_{p_H}\nu' + p\left(-\phi_{p_H} - b_H\right)\nu'_H + p\left(\beta_H - \beta_A\right) F\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial p_H}\right] + \lambda_H = 0$$

Recall that

$$\begin{aligned} r_{AH} &= \frac{1}{\beta_H - \beta_A}\left[\nu\left(w - \phi - b_A p_A\right) - \nu\left(w - \phi - b_H p_H\right)\right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \\ \frac{\partial r_{AH}}{\partial p_H} &= \frac{1}{\beta_H - \beta_A}\left[\left(-\phi_{p_H}\right)\nu_A^{'} - \left(-\phi_{p_H} - b_H\right)\nu_H^{'}\right] \end{aligned}$$

sub these into the FOC w.r.t. p_H to achieve

$$-\left(1-p\right)\phi_{p_H}\nu' - pF\left(r_{AH}\right)\phi_{p_H}\nu_A^{'} - p\left(1 - F\left(v_{AH}\right)\right)\left(\phi_{p_H} + b_H\right)\nu_H^{'} = -\lambda_H$$

since $\phi_{p_H} > 0$, $(1 - v_{AH}) > 0$, $\phi_{p_H} + b_H > 0$, the LHS <0 , meaning $\lambda_H > 0$. Thus, optimally $p_H = c_H$

The same reasoning applies for reimbursement rate of ASCs. Essentially, since consumer surplus is decreasing in ASC reimbursement rates, the optimal reimbursement rate makes the ASC's participation constraint bind, i.e., $p_A = c_A$ FOC w.r.t p_A

FOC w.r.t b_A:

$$\begin{aligned} -\left(1-p\right)\phi_{b_A}\nu' - p\phi_{b_A}\nu_H^{'} + p\left(\beta_H - \beta_A\right)\left(F\left(r_{AH}\right) + r_{AH}f\left(r_{AH}\right)\right)\frac{\partial r_{AH}}{\partial b_A} \\ + p\beta_A r_{AH} f\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial b_A} - p\beta_H r_{AH} f\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial b_A} = 0 \end{aligned}$$

so

$$-\left(1-p\right)\phi_{b_A}\nu' - p\phi_{b_A}\nu_H^{'} + p\left(\beta_H - \beta_A\right)F\left(r_{AH}\right)\frac{\partial r_{AH}}{\partial b_A} = 0$$

calculate the derivatives

$$\begin{aligned} r_{HA} &= \frac{1}{\beta_H - \beta_A}\left[\nu\left(w - \phi - b_A p_A\right) - \nu\left(w - \phi - b_H p_H\right)\right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \\ \frac{\partial r_{AH}}{\partial b_A} &= -\frac{1}{\beta_H - \beta_A}\left[\left(\phi_{b_A} + p_A\right)\nu_A^{'} - \phi_{b_A}\nu_H^{'}\right] \\ \frac{\partial r_{AH}}{\partial b_H} &= -\frac{1}{\beta_H - \beta_A}\left[\phi_{b_H}\nu_A^{'} - \left(\phi_{b_H} + p_H\right)\nu_H^{'}\right] \end{aligned}$$

sub into the RHS of 3.26

$$\begin{aligned} \left(1-p\right)\phi_{b_A}\nu' + p\phi_{b_A}\nu_H^{'} &= -p\left(\beta_H - \beta_A\right)F\left(r_{AH}\right)\frac{1}{\beta_H - \beta_A}\left[\left(\phi_{b_A} + p_A\right)\nu_A^{'} - \phi_{b_A}\nu_H^{'}\right] \\ \left(1-p\right)\nu' + pQ_H\nu_H^{'} &= -pQ_A\left(1 + \frac{p_A}{\phi_{b_A}}\right)\nu_A^{'} \end{aligned} \tag{3.26}$$

Similarly for b_H,

$$(1-p)\,\nu' + pQ_A\nu_A^{'} = -pQ_H\left(1+\frac{p_H}{\phi_{b_H}}\right)\nu_H^{'} \tag{3.27}$$

Subtracting 3.26 from 3.27 yields:

$$\begin{aligned} pQ_H\nu_H^{'} - pQ_A\nu_A^{'} &= -pQ_A\left(1+\frac{p_A}{\phi_{b_A}}\right)\nu_A^{'} + pQ_H\left(1+\frac{p_H}{\phi_{b_H}}\right)\nu_H^{'} \\ pQ_H\nu_H^{'}\left(1-1-\frac{p_H}{\phi_{b_H}}\right) &= -pQ_A\nu_A^{'}\left(1+\frac{p_A}{\phi_{b_A}}-1\right) \\ Q_H\nu_H^{'}\frac{p_H}{\phi_{b_H}} &= Q_A\nu_A^{'}\frac{p_A}{\phi_{b_A}} \end{aligned} \tag{3.28}$$

Calculating ϕ_{b_A} and ϕ_{b_H} and subbing into this equality we have

$$\begin{aligned} \frac{\phi_{b_A}}{p_A}\cdot\frac{1}{Q_A\nu_A^{'}} &= \frac{\phi_{b_H}}{p_H}\cdot\frac{1}{Q_H\nu_H^{'}} \\ \mathbf{(1-b_H)\,p_H-(1-b_A)\,p_A} &= \frac{\beta_{\mathbf{H}}-\beta_{\mathbf{A}}}{\lambda}\mathbf{Q_A Q_H}\left(\frac{\mathbf{1}}{\nu_{\mathbf{A}}'}-\frac{\mathbf{1}}{\nu_{\mathbf{H}}'}\right) \end{aligned}$$

Note that if $u\,()$ is linear (risk-neutrality case) we have

$$\begin{aligned} [(1-b_H)\,p_H-(1-b_A)\,p_A] &= 0 \\ (1-b_H)\,p_H &= (1-b_A)\,p_A \\ \mathbf{b_H} > \mathbf{b_A} &\text{ because } p_H > p_A \end{aligned}$$

If $u\,()$ is not linear, we still have that

$$(1-b_H)\,p_H-(1-b_A)\,p_A > 0$$

therefore it is inconclusive whether $b_H > b_A$ or the other way around. However, rearrange the FOC

$$\begin{aligned} 1-b_H &= \frac{1}{p_H}\left[(1-b_A)p_A+\frac{\beta_H-\beta_A}{\lambda}Q_AQ_H\left(\frac{1}{\nu_A'}-\frac{1}{\nu_H'}\right)\right] \\ &= (1-b_A)\frac{p_A}{p_H}+\frac{1}{p_H}\frac{\beta_H-\beta_A}{\lambda}Q_AQ_H\left(\frac{1}{\nu_A'}-\frac{1}{\nu_H'}\right) \end{aligned}$$

If $p_H \gg p_A$ and that $\beta_H \sim \beta_A$, than $1-b_H < 1-b_A$. i.e., if the prices difference is large, but the quality difference are small then the $b_H > b_A$

Theoretical model with outside option

With the outside option, the utilities of all alternatives are $u_N = \nu(w-\phi)$, $u_A = \nu(w-\phi-b_A p_A) + \alpha_A + \beta_A r$, and $u_H = \nu(w-\phi-b_H p_H) + \alpha_H + \beta_H r$. The system of demand is defined by two cut-off values , r_{HA} and r_{AN}. They are given by :

$$
\begin{aligned}
r_{HA} &= \frac{1}{\beta_H - \beta_A}\left[\nu(w-\phi-b_A p_A) - \nu(w-\phi-b_H p_H)\right] + \frac{\alpha_A - \alpha_H}{\beta_H - \beta_A} \\
r_{AN} &= \frac{1}{\beta_A}\left[\nu(w-\phi) - \nu(w-\phi-b_A p_A)\right] - \frac{\alpha_A}{\beta_A}
\end{aligned}
$$

So we have a system of demands for A, H and N:

$$Q_N = r_{AN}$$

$$Q_A = r_{HA} - r_{AN}$$

$$Q_H = 1 - r_{HA}$$

The objective function can be simplified to:

$$
\begin{aligned}
W = \int_0^1 u(v)\,dF(v) &= (1-p)\,\nu(w-\phi) + p\beta_A r_{AN} F(r_{AN}) + p(\beta_H - \beta_A)\, r_{AH} F(r_{AH}) \\
&\quad + p\left[\nu(w-\phi-b_H p_H) + \alpha_H\right] + \beta_A p \int_{r_{AN}}^{r_{HA}} r dF(r) + \beta_H p \int_{r_{HA}}^{1} r dF(r)
\end{aligned}
$$

So rewrite the Medicare problem as

$$\min -W \text{ s.t } c_H \le p_H,\ c_A \le p_A$$

Lagrangian

$$L = -W + \lambda_H(c_H - p_H) + \lambda_A(c_A - p_A)$$

The FOCs w.r.t p_H and p_A in this case are similar to the FOC in the case without the outside option. They also give the same result, which is that the optimal reimbursement rates should be at the marginal costs, i.e., the participation constraints bind.

The FOCs w.r.t to the coinsurance rates give the similar expressions as the case without the outside option. The difference is in the appearance of the quantity for people who decide not to have the treatment.

$$\frac{1}{1+\gamma(w-\phi)\,b_H p_H} = \frac{1}{1-p+pQ_N}\left\{-pQ_H\left[\frac{p_H}{\phi_{b_H}}+1\right]-pQ_A\frac{\nu_A^{'}}{\nu_H^{'}}\right\}$$
$$\frac{1}{1+\gamma(w-\phi)\,b_A p_A} = \frac{1}{1-p+pQ_N}\left\{-pQ_A\left[\frac{p_A}{\phi_{b_A}}+1\right]-pQ_H\frac{\nu_H^{'}}{\nu_A^{'}}\right\}$$
$$\phi = p\left[(1-b_H)\,p_H\,(1-r_{HA})+(1-b_A)\,p_A\,(r_{HA}-r_{AN})\right]$$

From these FOCs we also have

$$(1-p)\,\nu' + pQ_N\nu' + pQ_A\nu_A' + pQ_H\nu_H' = -\frac{pp_HQ_H\nu_H'}{\phi_{b_H}}$$
$$(1-p)\,\nu' + pQ_N\nu' + pQ_H\nu_H' + pQ_A\nu_A' = -\frac{pp_AQ_A\nu_A'}{\phi_{b_A}}$$

This implies

$$\frac{p_HQ_H\nu_H'}{\phi_{b_H}} = \frac{p_AQ_A\nu_A'}{\phi_{b_A}} \Rightarrow \frac{\phi_{b_H}}{p_H}.\frac{1}{Q_H\nu_H'} = \frac{\phi_{b_A}}{p_A}.\frac{1}{Q_A\nu_A'}$$

Solving for ϕ_{b_A} and ϕ_{b_H} , and substituting in this equality yields

$$(1-b_H)\,p_H\,(\beta_AQ_H+\beta_AQ_A)-(1-b_A)\,p_A\,(\beta_HQ_H+\beta_AQ_A) = Q_HQ_A\left(\frac{1}{\nu_A'}-\frac{1}{\nu_H'}\right)\ (\star)$$

If $\nu(.)$ is linear, $\nu_A^{'} = \nu_H^{'} = 1$, or if patients at HOPDs and ASCs have the same risk protection benefit from insurance, $\nu_A^{'} = \nu_H^{'}$,

$$(1-b_H)\,p_H\,(\beta_AQ_H+\beta_AQ_A)-(1-b_A)\,p_A\,(\beta_HQ_H+\beta_AQ_A) = 0$$

Then

$$\frac{(1-b_H^*)\,mc_H}{(1-b_A^*)\,mc_A} = \frac{\beta_AQ_A+\beta_HQ_H}{\beta_AQ_A+\beta_AQ_H}$$

If $\beta_H/mc_H > \beta_A/mc_A$, $\beta_HQ_H/mc_H < \beta_AQ_A/mc_A$. Moreover $mc_H > mc_A$, $\beta_AQ_A/mc_H < \beta_AQ_A/mc_A$. Thus we have

$$\frac{\beta_A}{mc_H}Q_A + \frac{\beta_H}{mc_H}Q_H < \frac{\beta_A}{mc_A}Q_A + \frac{\beta_A}{mc_A}Q_H$$

This implies

$$1-b_H^* < 1-b_A^* \Rightarrow b_H^* > b_A^*$$

If $u()$ is not linear, rearrange equation $(\star)$

$$
\begin{aligned}
1-b_H &= \frac{Q_H Q_A\left(\frac{1}{u'_A}-\frac{1}{u'_H}\right)+(1-b_A)\,p_A\,(\beta_H Q_H+\beta_A Q_A)}{p_H\,(\beta_A Q_H+\beta_A Q_A)} \\
&= \frac{1}{p_H}\frac{Q_H Q_A}{\beta_A Q_H+\beta_A Q_A}\left(\frac{1}{u'_A}-\frac{1}{u'_H}\right)+(1-b_A)\,.\frac{p_A}{p_H}.\frac{\beta_H Q_H+\beta_A Q_A}{\beta_A Q_H+\beta_A Q_A}
\end{aligned}
$$

If $\beta_H \approx \beta_A$ and that $p_H \gg p_A$, then $1-b_H<1-b_A$, i.e., $b_H>b_A$.

3.7.5 Appendix for Section : Empirical model

The equations that solve for b_H and b_A are

$$
\frac{1}{1-p}\left[-p\left(1+\frac{p_A}{\phi_{b_A}}\right)Q_A-p\frac{u'_H}{u'_A}Q_H-(1-\sigma)\left(\frac{u'_H}{u'_A}-1-\frac{p_A}{\phi_{b_A}}\right)D\right]=\frac{1}{1+\gamma b_A p_A} \tag{3.29}
$$

$$
\frac{1}{1-p}\left[-p\left(1+\frac{p_H}{\phi_{b_H}}\right)Q_H-p\frac{u'_A}{u'_H}Q_A-(1-\sigma)\left(\frac{u'_A}{u'_H}-1-\frac{p_H}{\phi_{b_H}}\right)D\right]=\frac{1}{1+\gamma b_H p_H} \tag{3.30}
$$

The followings provide the derivations required to achieve these equations. Consumer surplus is

$$
\begin{aligned}
W &= \sum_i \sum_{jg}\left[pV_{ijg}P_{ijg}+(1-p)\,V_i P_{ijg}\right] \\
&= \sum_i \left\{\sum_{jA}\left[pV_{ijA}P_{ijA}+(1-p)\,V_i P_{ijA}\right]+\sum_{jH}\left[pV_{ijH}p_{ijH}+(1-p)\,V_i P_{ijH}\right]\right\} \\
&= \sum_i p\left[\sum_{jA}V_{ijA}P_{ijA}+\sum_{jH}V_{ijA}P_{ijH}\right]+\sum_i (1-p)\,V_i
\end{aligned}
$$

Lagrangian takes the form:

$$
\mathcal{L}=-\sum_i p\left[\sum_{jA}V_{ijA}P_{ijA}+\sum_{jH}V_{ijA}P_{ijH}\right]-\sum_i (1-p)\,V_i+\lambda_A\,(c_A-p_A)+\lambda_H\,(c_H-p_H)
$$

FOC w.r.t. p_A is given by

$$
\sum_i p\left[\sum_{jA}\left(\frac{\partial V_{ijA}}{\partial p_A}P_{ijA}+V_{ijA}\frac{\partial P_{ijA}}{\partial p_A}\right)+\sum_{jH}\left(\frac{\partial V_{ijH}}{\partial p_A}P_{ijH}+V_{ijH}\frac{\partial P_{ijH}}{\partial p_A}\right)\right]+\sum_i (1-p)\,\frac{\partial V_i}{\partial p_A}+\lambda_A=0
$$

To simplifying notation, I omit the subscript i in the following calculation and will add it back in the final expression of the FOC. Recall that

$$\begin{aligned} P_{jA} &= P_{j|j\in A}P_A \\ &= \frac{e^{V_{jA}/(1-\sigma)}}{D_A}.\frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}} \end{aligned}$$

where $D_A^{1-\sigma} = \sum_{h\in A} e^{V_{hA}/(1-\sigma)}$. Thus

$$\frac{\partial P_{jA}}{\partial p_A} = \frac{\partial P_{j|j\in A}}{\partial p_A}P_A + P_{j|j\in A}\frac{\partial P_A}{\partial p_A}$$

We compute $\partial P_{j|j\in A}/\partial p_A$

$$\frac{\partial P_{j|j\in A}}{\partial p_A} = \frac{\partial}{\partial p_A}\left(\frac{e^{V_{jA}/(1-\sigma)}}{\sum_{h\in A} e^{V_{hA}/(1-\sigma)}}\right) = 0$$

This makes sense because increasing prices of all ASC facilities does not change the probability of choosing an ASC over another ASC. We next compute $\partial P_A/\partial p_A$.

$$\begin{aligned} \frac{\partial P_A}{\partial p_A} &= \frac{\partial}{\partial p_A}\left[\frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\right] \\ &= (1-\sigma)\frac{\partial D_A}{\partial p_A}\frac{D_A^{-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}} - \frac{D^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\frac{(1-\sigma)\,D_A^{-\sigma}\frac{\partial D_A}{\partial p_A}+(1-\sigma)\,D_H^{-\sigma}\frac{\partial D_H}{\partial p_A}}{D_A^{1-\sigma}+D_H^{1-\sigma}} \end{aligned}$$

$$\frac{\partial D_A}{\partial p_A} = \frac{\partial}{\partial p_A}\left[\sum_{jA} e^{\lambda\nu(w_i-\phi-b_Ap_A)+\alpha_{iA}+X_{ijA}\beta_A}\right] = -\lambda\nu_A'\left(\phi_{p_A}+b_A\right)D_A$$

$$\frac{\partial D_H}{\partial p_A} = \frac{\partial}{\partial p_A}\left[\sum_{jH} e^{\lambda\nu(w-\phi-b_Hp_H)+\alpha_{jH}+X_{ijH}\beta_H}\right] = -\lambda\nu_H'\phi_{p_A}D_H$$

so

$$
\begin{aligned}
\frac{\partial P_A}{\partial p_A} &= (1-\sigma)\frac{\partial D_A}{\partial p_A}\frac{D_A^{-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}} - \frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\frac{(1-\sigma)D_A^{-\sigma}\frac{\partial D_A}{\partial p_A}+(1-\sigma)D_H^{-\sigma}\frac{\partial D_H}{\partial p_A}}{D_A^{1-\sigma}+D_H^{1-\sigma}} \\
&= -(1-\sigma)\lambda\nu_A'(\phi_{p_A}+b_A)D_A\frac{D_A^{-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}} - \\
&P_A(1-\sigma)\frac{-D_A^{-\sigma}\lambda\nu_A'(\phi_{p_A}+b_A)D_A - D_H^{-\sigma}\lambda\nu_H'\phi_{p_A}D_H}{D_A^{1-\sigma}+D_H^{1-\sigma}} \\
&= (1-\sigma)\lambda P_A P_H\left[\nu_H'\phi_{p_A} - \nu_A'(\phi_{p_A}+b_A)\right]
\end{aligned}
$$

Therefore

$$
\frac{\partial P_{jA}}{\partial p_A} = P_{j|j\in A}\frac{\partial P_A}{\partial p_A} = P_{jA}P_H(1-\sigma)\lambda\Delta\nu_{p_A}'
$$

where $\Delta\nu_{p_A}' = \nu_H'\phi_{p_A} - \nu_A'(\phi_{p_A}+b_A)$. We are left to calculate $\partial P_{jH}/p_A$. Recall that $P_{jH} = P_{j|j\in H}P_H$. The first term is given by $P_{j|j\in H} = \frac{e^{V_{jH}}}{\sum_h e^{V_{jH}}}$ and $\frac{\partial P_{j|j\in H}}{\partial p_A} = 0$. The second term is

$$
\frac{\partial P_H}{\partial p_A}P_H = \frac{D_H^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}} = 1 - P_A \Rightarrow \frac{\partial P_H}{\partial p_A} = -\frac{\partial P_A}{\partial p_A}
$$

Therefore

$$
\frac{\partial P_{jH}}{\partial p_A} = P_{j|j\in H}\frac{\partial P_H}{\partial p_A} = -P_A P_{jH}(1-\sigma)\lambda\Delta\nu_{p_A}'
$$

with $\Delta\nu_{p_A}' = \nu_H'\phi_{p_A} - \nu_A'(\phi_{p_A}+b_A) < 0$. Substitute the derivative of the market share with respect to p_A into the FOC of p_A, we have:

$$
\begin{aligned}
&\sum_i p\sum_{jA}\left(-\lambda\nu_{iA}'(\phi_{p_A}+b_A)P_{ijA} + V_{ijA}P_{ijA}P_{iH}(1-\sigma)\lambda\Delta\nu_{ip_A}'\right) \\
&\quad + \sum_i p\sum_{jH}\left(-\lambda\nu_{iH}'\phi_{p_A}P_{ijH} - V_{ijH}P_{iA}P_{ijH}(1-\sigma)\lambda\Delta\nu_{ip_A}'\right) \\
&\qquad + \sum_i (1-p)\frac{\partial V_i}{\partial p_A} + \lambda_A = 0
\end{aligned}
$$

so

$$-\lambda_A = -\sum_i p\left[\sum_{jA}\lambda\nu'_{iA}\left(\phi_{pA}+b_A\right)P_{ijA}+\sum_{jH}\lambda\nu'_{iH}\phi_{p_A}P_{ijH}\right]-\sum_i\left(1-p\right)\nu'\phi_{p_A}$$
$$+\sum_i p\left(1-\sigma\right)\lambda\Delta\nu'_{ip_A}P_{iA}P_{iH}\left[\sum_{jA}V_{ijA}P_{ij|j\in A}-\sum_{jH}V_{ijH}P_{ij|j\in H}\right]$$

Assume that the change in patient utility due to price change and premium change is higher than the change in patient's utility due to demand change (because the demand response is small), then $\lambda_A > 0$. Therefore, $p_A^* = c_A$. Similarly, $\lambda_H > 0$ and $p_H^* = c_H$

Now we consider the FOCs of b_A and b_H. FOC w.r.t. b_A :

$$\sum_i p\left[\sum_{jA}\left(\frac{\partial V_{ijA}}{\partial b_A}P_{ijA}+V_{ijA}\frac{\partial P_{ijA}}{\partial b_A}\right)+\sum_{jH}\left(\frac{\partial V_{ijA}}{\partial b_A}P_{ijH}+V_{ijH}\frac{\partial P_{ijA}}{\partial b_A}\right)\right]+\sum_i\left(1-p\right)\frac{\partial V_i}{\partial b_A}=0$$

Again I am going to omit the subscript ik and only add back in the final expression. First I am Recall that

$$P_{jA} = P_{j|j\in A}.P_A = \frac{e^{V_{jA}/(1-\sigma)}}{D_A}.\frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}$$

where $D_A = \sum_{j\in A} e^{V_{jA}/(1-\sigma)}$. Similar as before, $\frac{\partial P_{j|j\in A}}{\partial b_A} = 0$ and

$$\frac{\partial P_A}{\partial b_A} = \frac{\partial}{\partial b_A}\left[\frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\right]$$
$$= \left(1-\sigma\right)\frac{\partial D_A}{\partial b_A}\frac{D_A^{-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}-\frac{D^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\frac{\left(1-\sigma\right)D_A^{-\sigma}\frac{\partial D_A}{\partial b_A}+\left(1-\sigma\right)D_H^{-\sigma}\frac{\partial D_H}{\partial b_A}}{D_A^{1-\sigma}+D_H^{1-\sigma}}$$

$$\frac{\partial D_A}{\partial b_A} = \frac{\partial}{\partial b_A}\left[\sum_{jA}e^{V_{jA}}\right] = -\lambda\nu'_A\left(\phi_{b_A}+p_A\right)\sum_{jA}e^{V_{jA}} = -\lambda\nu'_A\left(\phi_{b_A}+p_A\right)D_A$$
$$\frac{\partial D_H}{\partial b_A} = \frac{\partial}{\partial b_A}\left[\sum_{jH}e^{V_{jH}}\right] = -\lambda\nu'_H\phi_{b_A}\sum_{jH}e^{V_{jH}} = -\lambda\nu'_H\phi_{b_A}D_H$$

$$\frac{\partial P_A}{\partial b_A} = \left(1-\sigma\right)\frac{\partial D_A}{\partial b_A}\frac{D_A^{-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}-\frac{D_A^{1-\sigma}}{D_A^{1-\sigma}+D_H^{1-\sigma}}\frac{\left(1-\sigma\right)D_A^{-\sigma}\frac{\partial D_A}{\partial b_A}+\left(1-\sigma\right)D_H^{-\sigma}\frac{\partial D_H}{\partial b_A}}{D_A^{1-\sigma}+D_H^{1-\sigma}}$$
$$= \left(1-\sigma\right)\lambda P_A P_H\left[\nu'_H\phi_{b_A}-\nu'_A\left(\phi_{b_A}+p_A\right)\right]$$

Come back to the derivative:

$$\begin{aligned}
P_{jA} &= P_{j|j\in A}.P_A \\
\frac{\partial P_{jA}}{\partial b_A} &= P_{j|j\in A}\frac{\partial P_A}{\partial b_A} \\
&= P_{j|j\in A}\left(1-\sigma\right)\lambda P_A P_H\left[\nu'_H\phi_{b_A}-\nu'_A\left(\phi_{b_A}+p_A\right)\right] \\
&= P_{jA}P_H\left(1-\sigma\right)\lambda\left[\nu'_H\phi_{b_A}-\nu'_A\left(\phi_{b_A}+p_A\right)\right] \\
&= P_{jA}P_H\left(1-\sigma\right)\lambda\Delta\nu'_{b_A}
\end{aligned}$$

We then calculate the derivative $\partial P_{jH}/\partial b_A$. Recall $P_{jH}=P_{j|j\in H}P_H$ and

$$\begin{aligned}
\frac{\partial P_{j|j\in H}}{\partial b_A} &= 0 \\
P_H = 1-P_A \Rightarrow \frac{\partial P_H}{\partial b_A} &= \frac{-\partial P_A}{\partial b_A}
\end{aligned}$$

so

$$\frac{\partial P_{jH}}{\partial b_A}=P_{j|j\in H}\frac{\partial P_H}{\partial b_A}=-P_AP_{jH}\left(1-\sigma\right)\lambda\Delta\nu'_{b_A}$$

Substituting the derivatives into the FOC w.r.t b_A yields

$$\sum_i p\left[\sum_{jA}\left(\frac{\partial V_{ijA}}{\partial b_A}P_{ijA}+V_{ijA}\frac{\partial P_{ijA}}{\partial b_A}\right)+\sum_{jH}\left(\frac{\partial V_{ijA}}{\partial b_A}P_{ijH}+V_{ijH}\frac{\partial P_{ijA}}{\partial b_A}\right)\right]+\sum_i\left(1-p\right)\frac{\partial V_i}{\partial b_A}=0$$

$$\begin{aligned}
&\sum_i p\sum_{jA}\left[-\lambda\nu'_A\left(\phi_{b_A}+p_A\right)P_{ijA}+V_{ijA}P_{ijA}P_{iH}\left(1-\sigma\right)\lambda\left[\nu'_H\phi_{b_A}-\nu'_A\left(\phi_{b_A}+p_A\right)\right]\right] \\
&\quad+\sum_i p\sum_{jH}\left[-\lambda\nu'_H\phi_{b_A}P_{ijH}-V_{ijH}P_{ijH}P_{iA}\left(1-\sigma\right)\lambda\left[\nu'_H\phi_{b_A}-\nu'_A\left(\phi_{b_A}+p_A\right)\right]\right] \\
&\qquad-\sum_i\left(1-p\right)\lambda\nu'\phi_{b_A}=0
\end{aligned}$$

Simplifying

$$\begin{aligned}
&-\left(\phi_{b_A}+p_A\right)\sum_i p\sum_{jA}\nu'_A P_{ijA}-\phi_{b_A}\sum_i p\sum_{jH}\nu'_H P_{ijH}=0 \\
&+\left(1-\sigma\right)\sum_i p\sum_{jA}V_{ijA}P_{ijA}P_{iH}\Delta\nu'-\left(1-\sigma\right)\sum_i s\sum_{jH}V_{ijH}P_{ijH}P_{iA}\Delta\nu'-\left(1-s\right)\nu'\phi_{b_A}
\end{aligned}$$

simplifying further

$$\sum_i p \sum_{jA} \nu'_A P_{ijA} = p\nu'_A \sum_{jA}\sum_i P_{ikjA} = p\nu'_A Q_A$$

$$\sum_i p \sum_{jH} \nu'_H P_{ijH} = p\nu'_H \sum_i \sum_{jH} P_{ijH} = p\nu'_H Q_H$$

$$\sum_i p \sum_{jA} V_{ijA} P_{ijA} P_{iH} \Delta\nu' = p\Delta\nu' \sum_{jA}\sum_i V_{ijA}P_{ijA}P_{iH} = p\Delta\nu' \sum_i P_{iH}P_{iA}\sum_{jA} V_{ijA}P_{ij|j\in A}$$

$$\sum_i p \sum_{jH} V_{ijH} P_{ijH} P_{iA} \Delta\nu' = p\Delta\nu' \sum_i P_{iH}P_{iA}\sum_{jH} V_{ijH}P_{ij|j\in H}$$

where $Q_A = \sum_{jA}\sum_i P_{ikjA}$ and $Q_H = \sum_i \sum_{jH} P_{ijH}$. Rearrange:

$$-\left(\phi_{b_A} + p_A\right) p\nu'_A Q_A - \phi_{b_A} p\nu'_H Q_H - (1-p)\,\nu'\phi_{b_A} = 0$$

$$-(1-\sigma)\, p\Delta\nu' \sum_i P_{iH}P_{iA}\left[\sum_{jH} V_{ijH}P_{ij|j\in H} - \sum_{jA} V_{ijA}P_{ij|j\in A}\right]$$

Denote $D = \sum_i P_{iH}P_{iA}\left[\sum_{jH} V_{ijH}P_{ij|j\in H} - \sum_{jA} V_{ijA}P_{ij|j\in A}\right]$. Divide both sides with $(1-p)\,\nu'_A\phi_{b_A}$, and Taylor expand ν'_A around ν', we yield the equations3.30 and 3.29, which and that reflect the balance between risk protection benefit and allocation efficiency.

$$\frac{1}{1-p}\left[-p\left(1+\frac{p_A}{\phi_{b_A}}\right)Q_A - p\frac{u'_H}{u'_A}Q_H - (1-\sigma)\left(\frac{u'_H}{u'_A} - 1 - \frac{p_A}{\phi_{b_A}}\right)D\right] = \frac{\nu'}{\nu'_A}$$

Note that

$$\nu'_A = \nu'\left(w-\phi-b_A p_A\right) \approx \nu'\left(w-\phi\right) + \nu''\left(w-\phi\right)\left(-b_A p_A\right)$$

$$\Rightarrow \frac{\nu'_A}{\nu'} \approx 1 + \left(-\frac{\nu''\left(w-\phi\right)}{\nu'\left(w-\phi\right)}\right) b_A p_A \approx 1 + \gamma b_A p_A$$

where $\gamma = -\frac{\nu''(w-\phi)}{\nu'(w-\phi)}$ defined as the absolute risk aversion coefficient at the wealth level $w-\phi$. Substituting this into the RHS of the equation above to yield the equations that reflect the balance between risk protection benefit and allocation efficiency.