The Intended and Unintended Consequences of the Hospital Readmission Reduction Program

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Abstract

The Hospital Readmission Reduction Program (HRRP) is a prominent Pay for Performance (P4P) program of the Centers for Medicare and Medicaid (CMS) intended to reduce hospital readmissions. In this article, I use a regression kink design to examine whether hospitals that were penalized under the HRRP changed the process of care for patients targeted and untargeted by the policy, as measured by the amount and composition of resource use (e.g., length of stay, and spending on radiology, pharmacy, and laboratory). Estimates indicate that hospitals penalized for excess heart attack (AMI) readmissions decreased AMI readmissions by 30% and increased spending on AMI patients by 20%. This additional care had no impact on mortality. Interestingly, I find that these hospitals also increased the quantity of care for patients with diagnoses not targeted by the HRRP. Hospitals penalized for excess readmissions for relatively more frequent conditions (pneumonia and heart failure) did not respond to the HRRP incentives. I show using a conceptual model of hospital behavior that as the number of patients in the targeted condition rises, the hospital’s marginal cost of reducing the penalty increases by relatively more than the marginal benefit. This intuitive result is novel and fundamental to the discussion on the relative incentive to reduce readmissions across medical diagnoses and how P4P programs can be optimized to reflect this differential cost.

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1 Introduction

The Patient Protection and Affordable Care Act (PPACA) of 2010 created several new Medicare programs intended to improve health care quality, using Pay-for-Performance (P4P) payment strategies to reimburse health care providers. In such programs, reimbursement reflects provider performance on quality metrics based on adherence to certain care processes, scores on patient satisfaction surveys, or patient outcomes. P4P reimbursement has grown markedly. In 2010, almost all Medicare payments to hospitals were in the form of capitated payments under the Prospective Payment System, which pays a fixed reimbursement per episode of care. By 2016, around 30% of hospital reimbursements were tied to performance on some quality metric (Burwell, 2015). Recently, the Center for Medicare and Medicaid Services (CMS) announced that by 2019 it intends to tie up to 80% of all care providers’ reimbursements to the quality of care provided rather than the quantity of care. In this article, I study the effect of the Hospital Readmission Reduction Program (HRRP), a prominent P4P policy that is part of this initiative and links hospital Medicare reimbursements to readmissions.

The HRRP required CMS to reduce payments to hospitals with excess readmissions for certain types of patients beginning on October 1, 2012. This payment reduction (penalty) was intended to reduce the rate of hospital readmissions, which occur in approximately twenty percent of Medicare patients and cost the federal government an estimated $17 billion per year (CMS, 2014). The motivation for the HRRP is that many hospital readmissions are preventable and that the financial penalties will reduce these preventable readmissions.

This penalty associated with the HRRP, which was one percent in 2012 and is now three percent, has the potential to significantly affect hospital finances and the quality of inpatient care. In terms of finances, a reduction in Medicare payments of up to three percent represents a major loss of revenue for hospitals, particularly because Medicare represents approximately 35 percent of hospital revenue. Moreover, hospital profit margins are approximately four percent and twenty percent of hospitals have negative margins (American Hospital Association, 2014). Therefore, simple math suggests that a hospital that received the maximum penalty under the HRRP would have its profit margin reduced substantially and that the HRRP would increase the number of hospitals with negative margins.

In terms of quality of care, several studies have shown that hospitals respond to reductions in Medicare payments of approximately the same size as those imposed by the HRRP. For example, White and Yee (2013) reported that hospitals reduced staff and operating expenses in response to reductions in Medicare payments, and Shen and Wu (2013) found that reductions in Medicare payments were associated with increased patient mortality. Therefore, the penalties of the HRRP have the potential to significantly affect the quality of care. Changes in the quality of care, however, may not be uniform because the HRRP targets specific patients (Heart Attacks (AMI), Pneumonia (PN) and Heart Failure (HF)). As a result, hospitals may reallocate resources to focus

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1See, White & Wu (2013); Shen & Wu (2013); White & Yee (2013); Seshamani et al. (2006); Peasah et al. (2013).
on targeted HRRP patients and “shortchange” other patients. There is a common saying that you get what you pay for, and studies have found evidence of this (Lo Sasso and Helmchen, 2010; Bardach et al. 2013; Rosenthal et al. 2004; Young et al. 2007). However, the corollary is that you dont get what you dont pay for, and the HRRP may cause hospitals to spend more on some patients and less on others.

In sum, the HRRP has the potential to significantly affect hospital finances, and because of this, also affect the quality of patient care. To date, there has been limited quasi-experimental assessment of the HRRP\(^2\). In addition, no previous research has provided a conceptual model that details how hospitals may respond to the HRRP incentives. In this article, I examine whether the HRRP affected readmissions, hospital resource use, discharge status (e.g., to skilled nursing facilities) and mortality, both within the conditions that are targeted by the HRRP and conditions that are not a part of the HRRP. In short, I present evidence on whether the HRRP P4P program was successful in achieving its intended goals, and whether there were unintended consequences of the program, and if there were consequences, the mechanisms that possibly explain those effects.

My research contributes to both theory and policy. First, I develop a theoretical model that yields novel predictions about hospital responses to the HRRP and important insights into why those responses may differ by type of admission and hospital characteristics. For example, I highlight that under Medicare P4P programs that assess performance based on a fraction of a hospital’s Medicare inpatients but apply the resulting financial penalty on revenue from all of the hospital’s Medicare admissions, it is potentially more costly for hospitals to reduce readmissions for targeted conditions with a large number of admissions, than targeted conditions with a lower number of admissions. This economic insight is fundamental to the design of P4P programs in healthcare and how incentives should be optimized to reflect the differential cost of reducing readmissions across medical diagnoses.

Second, I study whether hospitals responded to the HRRP by changing treatment of inpatients, which is an important potential mechanism, particularly given the evidence that shows that other ways to reduce readmissions are largely ineffective\(^3\). I also examine outcomes, such as mortality that have been previously studied but for which results of previous studies are mixed\(^4\). Third, I test for spillover effects in terms of the inpatient quantity of care on non–HRRP conditions.

To accomplish these goals, I use a quasi–experimental research design — the Regression Kink (RK) — that has some advantage over methods typically used, specifically a

\(^2\)See Zuckerman et al. (2016), Gupta (2017), Carey and Lin (2015), Mellor, Daly and Smith (2016) and Desai et al. (2016).

\(^3\)Marusic et al. (2013), Alfeld et al. (2012), Davis et al. (2012), Bowles et al. (2011) & Finn et al. (2011) all executed random control trials on patients in the United States to test a variety of post–discharge interventions such as individualized post–discharge planning, self–care teaching, tele–monitoring, nurse practitioner visits and pharamcotherapeutic counselling and all found no effects on readmissions.

\(^4\)Two quasi–experimental studies have examined mortality and found conflicting results. Gupta (2017) showed that a 2 percent decline in 30 day readmission rates for Heart Failure patients was accompanied by a 1 percent rise in risk adjusted 30day mortality for the same patients. On the other hand, Gupta, Allen and Bhatt et al. (2016) found a 0.4 percentage point decline in 30–day mortality as a result of the HRRP.
difference—in—differences approach and high—quality administrative data from Medicare. The RK has the potential to yield estimates of the causal effects of the HRRP, and I provide considerable evidence of the validity of this approach.

Results of the analysis indicate that hospitals penalized for AMI readmissions reduced such readmissions. Hospitals penalized for AMI in round 1 of the HRRP; had lower readmissions one and two years after the first round penalty. For hospitals penalized for other outcomes (HF and PN), I do not find any effect of the HRRP. A likely mechanism for this reduction in AMI readmissions was increased expenditure (care) on AMI patients that was also found, along with some evidence of increased length of stay. Overall, I find no evidence of an effect of the HRRP on mortality or a substitution of resources away from conditions outside the HRRP and into conditions within the HRRP. However, I do find that there were positive spillovers, as measured by increased spending on inpatient care, for conditions closely related to AMI. This finding suggests that hospitals may provide a common level of quality across patients (Glied and Zivin, 2002).

2 Previous Research

There are a few studies that have examined the effect of the HRRP. Zuckerman et al. (2016) examined whether there was a break in the trend in hospital readmissions and 30-day mortality after the passage of the ACA in 2010 and in October 2012, which is when hospitals were penalized for the first time. The authors reported that the HRRP was associated with a decline in readmissions. However, the study did not have a comparison group and was a simple before—and—after assessment, which is an approach with well—known limitations. Desai et al. (2016) also utilized an interrupted time series approach and compared readmissions in penalized versus unpenalized hospitals over time. They reported that readmission rates declined significantly faster for targeted conditions, compared to non—targeted conditions.

Carey and Lin (2015) examined readmissions in New York State using a difference—in—differences approach and found a reduction in readmissions across all 3 conditions (AMI, HF, PN) targeted by the HRRP. Besides the limited external validity of this single state study, a potential problem with this study is that it compared readmissions in target (e.g., AMI) to non—target conditions. However, as I discuss below, theory predicts that non—target conditions may also be affected by the HRRP because of a potential reallocation of resources from non—targeted to targeted conditions, or because hospitals make systematic changes that affect all types of patients (Glied and Zivin, 2002).

Mellor, Daly and Smith (2016) use a triple difference approach to investigate the effect of the HRRP on readmissions and the process of care in Virginia hospitals, which limits the external validity of this study. They compare gastrointestinal patients with patients targeted by the HRRP (AMI, HF and PN) and obtain a triple difference estimate by comparing the difference across hospitals above and hospitals below the average national readmissions rate. They find that readmission rates only declined for AMI patients by an average of 2.5% but there was no evidence of a decline in
readmissions for HF or PN patients. Similar to Mellor et al. (2016), Gupta (2017) compared changes in outcomes for HRRP targeted patients (e.g., readmissions and mortality) pre— to — post HRRP of hospitals with low readmission rates prior to the HRRP to hospitals that had high readmission rates prior to the HRRP. Gupta (2017) reported that the HRRP penalty was associated with a 1.9 percentage points (9%) decline in readmission rates over the period from 2012 to 2014. In Gupta (2017), hospitals with a low probability of a penalty in upcoming years were used as a counter factual and the probability of a penalty was predicted using baseline readmissions and the share of Low Socioeconomic Status (SES) patients. In Appendix Table 2, I show that these two predictors (baseline readmissions and SES share) also predict a hospital’s penalties under the Hospital Value Based Purchasing Program— another Medicare P4P program that was implemented at the same time as the HRRP and targets mortality for the exact three HRRP targeted conditions.

Most recently, Ibrahim et al (2018) used a difference—in—differences approach that used Critical Access Hospitals (CAH) as a counterfactual to penalized hospitals. CAHs have a very specific process of care that differs from that of ordinary Medicare hospitals. A CAH is small (has 25 or fewer acute care inpatient beds) and geographically isolated. It must be located (more than 35 miles from another hospital). In addition, CAHs are not allowed to keep acute care patients for more than 96 hours. Thus, there are a priori reasons that make use of CAHs as a control group questionable.

Overall, previous studies seeking to evaluate the HRRP using quasi—experimental designs have relied on a difference—in—differences (DID) approach that exploits variation over time in the penalty, or between targeted and non-targeted patients, or between HRRP exempt hospitals (such as CAHs) and non—exempt hospitals. The validity of this approach depends on the parallel trends assumption. I provide a test of the parallel trends assumption using inpatient claims data dating as far back as 2006; which is two years preceding any existing DID analysis previously executed. In Appendix Table 1, I divide hospitals into 3 groups based on the level of penalty in round 1 of the HRRP. Appendix Table 1 shows that prior to the HRRP implementation, hospitals that ultimately received a large penalty veered towards higher readmission rates over time relative to hospitals that were not penalized. In addition, hospitals that ultimately received a large penalty had also reduced length of stay over time relative to hospitals that were not penalized under the HRRP. I therefore conduct this analysis, using an empirical approach that does not depend on the parallel pre—trends assumption.

Instead, I use a regression-kink design. The RK has several important advantages. First, in contrast to previous studies, the RK uses variation in the penalty amount due to a kink in the penalty formula imposed by CMS and does not rely on the parallel trends assumption. Secondly, the RK is unaffected by coincidental P4P programs that target the same group of hospitals or patients at the same period in time as the HRRP. This is particularly relevant since CMS has implemented several pay—for—performance programs around the same time as the HRRP, such as the Hospital Value Based Purchasing Program (HVBP) and programs that penalize hospitals for hospital acquired
conditions and the Bundled Payment Care Initiative (BPCI). These reforms target the same medical conditions as the HRRP (eg: HVBP and BCPI) and maybe mutually reinforcing to the HRRP (Ryan et al. 2017) and therefore in the absence of observing all treatments that occur in a given period of time, it is difficult to isolate the effect of the HRRP. I show empirically that the RK is unaffected by these coincidental policies. Finally, the RK allows me to examine the conditions outside the HRRP, since the RK does not rely on the non−targeted medical conditions as a counterfactual.

In addition, previous studies have mainly focused on readmissions and mortality, and no study has examined whether the HRRP has affected inpatient care that is a plausible response (see below for evidence). Similarly, no study has examined potential spillovers in treatment intensity to non−HRRP patients. Finally, while previous studies have examined mortality, no prior study has examined the specific care mechanisms that link reducing readmissions and mortality rates. My research addresses these gaps in knowledge.

3 Conceptual Model

3.0.1 Basic Predictions

There is considerable evidence that hospitals respond to financial incentives by changing inpatient treatment. For example, the switch to a DRG-based reimbursement system in Medicare is widely credited with causing a decrease in average length of stay in the hospital and changes in the processes of care (Khan et al. 1990a, 1990b; Rogers et al. 1990; Cutler 1995). More recent research on the effect of changes in Medicare payment rates also demonstrates that hospitals respond to financial incentives similar to the HRRP (Dafny 2005; Seshamani, Schwartz and Volpp 2006; Peasah et al. 2013).

Given this evidence on hospital behavior and the meaningful financial penalties of the HRRP, it is plausible to believe that hospitals will respond to being penalized under the HRRP. It is also plausible that the hospital response will include inpatient care, as other types of strategies to limit readmissions that focus on post−discharge care have been largely ineffective (Coleman and Chalmers 2006; Richard 2003; Joynt, Orav and Jha 2011; Kessler et al. 2014).

The theoretical model I develop is as follows. I assume that a hospital cares about

\[\text{conditions and the Bundled Payment Care Initiative (BPCI).}\]

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\[\text{5The HAC program began deducting payments from hospitals in FY 2014 but it was announced in 2011}\]

\[\text{around the same time the HRRP round 1 penalties were announced. The BCPI was announced in 2011 (the}\]

\[\text{same time as the HRRP) and states reductions in readmissions as one of its goals.}\]

\[\text{6For example, since the HVBP was implemented at the same time as the HRRP and targets the exact}\]

\[\text{medical conditions targeted by the HRRP, I test whether hospitals on either side of the HRRP}\]

\[\text{threshold vary in their HVBP bonuses and find no differential slope in HVBP penalties/bonuses on either side of the}\]

\[\text{HRRP threshold.}\]

\[\text{7However, the evidence is not uniform. For example, Ryan et al. (2014) studied the Premier Hospital}\]

\[\text{Quality Incentive Demonstration (HQID), which paid bonuses to high−performing hospitals in the mid−2000s,}\]

\[\text{and found small to no effects of bonuses on the quality of care. One problem confronting Ryan et al. (2014)}\]

\[\text{was that it did not have the power to detect small to moderate effects.}\]
profits ($\pi$) and the quantity of services ($q$) provided, which can be thought of as the quality of patient care. The hospital treats two types of patients: those with illness 1 and those with illness 2. Patients with each type of illness receive treatments denoted by $q_1$ and $q_2$, respectively. The cost of services for the two types of treatments ($q_1$ and $q_2$) is $c_1$ and $c_2$, respectively. The costs of treating each type of patient (e.g., $c_1 q_1$) increase with greater use of services. Finally, the hospital receives a fixed payment, $R_1$ and $R_2$, for each patient. There are two periods ($t = 1$ and $t = 2$).

The HRRP program imposes a 1% penalty through a lower fixed payment rate, $(\alpha, 0.99 < \alpha < 1)$ on all hospital inpatient reimbursements based on the number of readmissions in the past period. Moreover, the HRRP considers readmissions from only a limited number of illnesses to determine the penalty. In my model, this implies that the fixed payment for patients in period $t = 2$ depends on the number of readmissions in period $t = 1$, but only readmissions for patients with illness type 1.

This model can be described algebraically by the following. First, hospital preferences are denoted by:

$$
U^1 = U^1[\pi^1, f(Q^1)], \quad Q^1 = N_1 q_1^1 + N_2 q_2^1
$$

$$
U^2 = U^2[\pi^2, f(Q^2)], \quad Q^2 = N_1 q_1^2 + N_2 q_2^2
$$

$$
U = U^1 + U^2
$$

In equation (1), utility of the hospital ($U^{i=1,2}$) in each period ($t = 1$ and $t = 2$) depends on profits ($\pi^{i=1,2}$) and the total quantity of services 1 and 2 provided ($Q^i = N_1^i q_1^i + N_2^i q_2^i$). Superscripts refer to time periods and subscripts refer to illness types 1 and 2 and the services associated with each illness. The total utility of the hospital is the utility in period 1 plus the utility in period 2. Note that I ignore discounting of revenue in period 2.

Profits of the firm are given by:

$$
\pi^1 = N_1 (R_1 - c_1 q_1^1) + N_2 (R_2 - c_2 q_2^1)
$$

$$
\pi^2 = N_1 (\alpha(q_1^1)R_1 - c_1 q_1^2) + N_2 (\alpha(q_1^1)R_2 - c_2 q_2^2)
$$

In period 2 there is a penalty $(1 - \alpha)$ and the size of that penalty depends on the quantity of services provided for patients with illness type 1 in period 1 ($q_1^1$). This is consistent with the operation of the HRRP: the HRRP penalty in period $t = 2$ is determined by the number of readmissions associated with patients treated in period $t = 1$ with type 1 illness (e.g., AMI), but it applies to all patient types. Readmissions of patients with type 2 illness are not considered in determining the penalty.

I assume that the hospital can influence readmission rates and thus the size of the penalty $(1 - \alpha)$ by using more services to treat type 1 patients ($\frac{\partial \alpha}{\partial q_1^1} > 0$). This assumption is consistent with the substantial amount of evidence that shows that greater amounts of inpatient resource use is associated with better patient outcomes (Doyle 2005; Chandra and Staiger 2007; Doyle 2011; Card et al. 2009; Kaestner and Silber 2010). If penalized, the hospital receives $\alpha R_i$ instead of $R_i$ as payment for the patient with illness type $i = 1, 2$. 
The hospital maximizes its utility by choosing the amount of services to provide to patients with illness types 1 and 2. All other determinants of profits and utility (capitated payments $R_i$ and costs $c_i$) are exogenous. A unique aspect here is that Medicare reimbursements ($R$) are fixed and determined by the Center for Medicare and Medicaid Services. Hence, the hospital maximizes utility subject to the following budget constraint:

$$R_1 N_1 + R_2 N_2 = c_1 N_1 q_1 + c_2 N_2 q_2$$

In the absence of the HRRP this maximization problem yields the following first order conditions for the quantity of services provided in period $t = 1$ for patients with illness types 1 and 2:

$$\frac{\partial U^1}{\partial Q^1} = c_1 \frac{\partial U^1}{\partial \pi^1} + \lambda c_1$$
$$\frac{\partial U^1}{\partial Q^2} = c_2 \frac{\partial U^1}{\partial \pi^1} + \lambda c_2$$

The equations in (4) show that the hospital provides services up to the point until the marginal benefit of that service, which is the utility from providing more quality care (e.g., $\frac{\partial U^1}{\partial Q^1}$), is equal to the marginal cost, which is equal to the utility costs of the additional service ($c_1 \frac{\partial U^1}{\partial \pi^1} + \lambda c_1$).

In the presence of the HRRP penalty, the hospital’s maximizes the following:

$$L = (U^1[\pi^1, f(Q^1)], U^2[\pi^2, f(Q^2)]) - \lambda [R_1 N_1 + R_2 N_2 - c_1 N_1 q_1 - c_2 N_2 q_2]$$

and the choices of the hospital would be:

$$\frac{\partial U^2}{\partial \pi^2} \frac{\partial \alpha}{\partial q^1} [R_1 + \frac{N_2}{N_1} R_2] = c_1 \frac{\partial U^1}{\partial \pi^1} + \lambda c_1$$
$$\frac{\partial U^1}{\partial Q^2} = c_2 \frac{\partial U^1}{\partial \pi^1} + \lambda c_2$$

The equations in (6) show that the hospital provides services up the point until the marginal benefit of that service, which is the utility from providing more quality care (e.g., $\frac{\partial U^1}{\partial Q^1}$) plus the increase in profits in period $t = 2$ due to an increase in reimbursement rate $\frac{\partial \alpha}{\partial q^1} [R_1 + \frac{N_2}{N_1} R_2]$, equal to the marginal cost, which is equal to the utility costs of the additional service ($c_1 \frac{\partial U^1}{\partial \pi^1} + \lambda c_1$). Note that only the top equation in (6), which refers to treatment of patients with illness type 1, has the added revenue term in the
marginal benefit because it is only the readmissions for type 1 patients that determine the penalty in period $t = 2$. Note that in (4), the marginal benefit of providing additional services to patients with type 1 illness does not include the higher period 2 payments. Therefore, in the absence of the HRRP penalty, the firm would provide fewer services to patients with type 1 illness than when there is a penalty. These conditions also imply that the hospital would use relatively fewer services for patients with type 2 illness under the HRRP than without the HRRP. This is because of the budget constraint given by equation (3). An increase in spending on patients with illness 1 requires a decrease in spending on patients with illness 2\(^8\).

3.1 Insights

The F.O.C in (6), also highlights a few interesting aspects of how the HRRP may impact the quantity of care provided to targeted patients (illnesses type 1). Note that the benefits of providing more services to patients with illness type 1 is larger the greater is the effect of those services on increasing ($\alpha$) and reducing the penalty ($\frac{\partial \alpha}{\partial q_1}$). This is relevant because, there is evidence that the productivity of reducing readmissions ($\frac{\partial \alpha}{\partial q_1}$) varies across medical conditions (Shah et al. 2015 and Jencks et al. 2009)\(^9\). This suggests that hospitals may not respond uniformly to the HRRP, but may focus on conditions in which they are most likely to be able to influence.

Another interesting implication of the F.O.C in (6) is that the cost of reducing the HRRP penalties is lower the smaller the share of HRRP targeted patients to non-HRRP patients. Since the HRRP targets only patients of type 1 ($N_1$), as $N_1$ increases relative to $N_2$ (the non-HRRP patients) the marginal benefit of increasing $q_1$ to avoid the penalty is lower. Thus, it is potentially more costly to reduce readmissions for targeted conditions with a large number of admissions, than targeted conditions with a lower number of admissions. A hospital penalized for conditions that represent a relatively small share of total admissions can focus care on a few number of patients to avoid the penalty. This hospital has a bigger incentive to respond than a hospital that has to focus care on a relatively large number of patients to avoid the same size penalty. Hence, HRRP conditions that are less prevalent, such as AMI, are conditions for which it is more likely to see a bigger response. This direct result from the conceptual model, has not been pointed out in earlier studies and could impact how hospitals

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\(^8\)The theoretical model I propose assumes substitution of resources away from conditions not targeted by the HRRP. However, other models such as Glied and Zivin (2002) assume that there is a common level of quality across patients. In such a model, the treatment intensity a physician chooses has some fixed cost, and the HRRP penalty may result in the increase in the quantity and/or quality of care for non-HRRP patients as well as HRRP patients.

\(^9\)Jencks et al. 2009 showed that for Pneumonia, most patients were readmitted to the hospital because of medical conditions not related to Pneumonia and potentially outside the hospital’s purview. I also analyzed the most frequent principal diagnosis ICD-9 code for all 30-day readmissions following AMI, Heart Failure or Pneumonia from 2007-2010 (the period prior to the HRRP) and found that while over 50% of readmissions following an AMI episode are attributed to coronary conditions (which are presumably within the control of the cardiology physician), less than 25% of readmissions following a Pneumonia episode are attributed to any pulmonary conditions.
respond to the HRRP.

Finally, this model does not suggest that hospitals with a larger share of Medicare patients are more likely to respond to the HRRP. Using, the exact model presented above, I add two other types of patients. \(N_3\) is a non-Medicare patient with a condition within the HRRP (e.g., a 40 year old admitted for AMI), and \(N_4\) is a non-Medicare patient with a condition not in the HRRP (e.g., a 40 year old admitted for a Kidney Infection). Both these patients (\(N_3\) and \(N_4\)) do not impact the probability of a penalty (their outcomes of care are not part of the HRRP assessment) and revenue from these patients is not affected by the HRRP penalty, thus the share of Medicare to Non-Medicare patients does not influence the first order condition in this setup. The share of Medicare to non-Medicare patients will impact how hospitals respond to the HRRP, if an additional assumption is made. If hospitals provide the exact amount of care \(q_1\) to both Medicare and non-Medicare patients admitted for the same medical condition, then the share of Medicare to non-Medicare patients will impact the FOC and the incentive to respond to the penalty\(^{10}\). Hence, conceptually it is the case that hospitals with a higher Medicare share will necessarily respond more to the HRRP.

### 3.2 Which Hospitals Respond?

The simple model above implies that all hospitals will respond to the HRRP penalty because \(\frac{\partial \alpha}{\partial q_1} > 0\) and all hospitals can theoretically reduce the penalty \((1-\alpha)\), although as discussed, some hospitals will have a greater incentive to do so than others. This is an unrealistic aspect of the model because not all hospitals are at risk of being penalized. The HRRP penalty applies only to hospitals with readmissions greater than a certain level. Specifically, CMS calculates Excess Readmission Ratios (ERR) for each targeted condition for each hospital and the payment adjustment level \((\alpha)\) is a mechanical function of the ERR. The ERR can be written as \(\text{ERR} = \frac{\tau_1(q_1)}{k}\). Hence, the ERR and ultimately the penalty size which is \((1-\alpha)\) depends on the quotient of the quantity of risk-adjusted readmissions in period 1 \((\tau_1)\), which I assume depends on the quantity of service provided to patients with illness type 1 in period 1, and a hospital specific threshold \(k\).

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\(^{10}\)With this assumption the budget constraint a hospital faces becomes:

\[
R_1N_1 + R_2N_2 + S_1N_3 + S_2N_4 = c_1N_1q_1 + c_2N_2q_2 + c_3N_3q_1 + c_4N_4q_2,\]

where \(S_1\) is the private insurance reimbursement for a HRRP type patient and \(S_2\) is the private insurance reimbursement for an non-HRRP type patient. Both HRRP patients, whether insured by Medicare or private insurance, receive a common quantity of care \(q_1\). The new F.O.C then becomes:

\[
\frac{\partial^2}{\partial q_1^2} + \frac{\partial}{\partial q_1} \left[ R_1 + \frac{\lambda}{\lambda_1} + c_1 \partial U_1 + c_1 \partial U_1^1 \partial \pi_1 \frac{N_3}{N_1} + c_1 \lambda \frac{N_3}{N_1} \right].\]

Note that now, the higher the share of Medicare patients (smaller \(N_3\)) the lower the cost of responding to the HRRP.
This setup is in line with the actual formula that determines the HRRP penalties. Specifically, when \((\tau_1(q_1) > k)\), the ERR exceeds 1 and the hospital is penalized.\(^{11}\)

The uncertainty of the probability of being penalized can now be formalized. Following the HRRP rule, the probability of being penalized is a function of the quantity of risk–adjusted readmissions in period 1(\(\tau_1\)), which as discussed above depends on the quantity of service provided to patients with illness type 1 in period 1, and a random component. Specifically, I assume that the probability of being penalized is the following:

\[
\rho = \Pr[\tau_1(q_1^1) - e > k], \quad e \sim N(\mu, \sigma^2)
\]

\(\rho = F[\tau_1(q_1^1) - k]\)

\[
\frac{\partial \rho}{\partial q_1} = \frac{\partial F}{\partial q_1} < 0
\]

In equation (7), \(k\), is the denominator in the hospital’s excess readmission score, \(\tau\) is the numerator in the hospital’s excess readmission score and is a function of the quantity of care. \(F\) is the cumulative normal distribution. Hospitals know the value of \(k\), for example, because they know the rule that CMS uses to calculate readmissions, or because it is a period after the first round of penalties when \(k\) was revealed to hospitals.\(^{12}\) The probability of being penalized will depend on the quantity of service provided to patients with illness type 1 and the variance of the distribution of the random component.

There are two implications of equation (7). First, the probability of being penalized depends on the productivity of spending \((\frac{\partial \rho}{\partial q_1})\) on readmissions. Second, the smaller the variance of the random component then the greater is the change in the probability of being penalized for any given change in the quantity of services provided for patient with illness type 1.\(^{13}\) Thus, firms will be less likely to respond when there is a large variance. Consider the case where the variance is very large and readmissions from year to year are not persistent. In this scenario, no hospital has an incentive to respond to the HRRP since the penalty is essentially randomly assigned. Another case, is when readmissions are extremely consistent from year to year. In this scenario, the HRRP excess readmission scores in round 1 mimic the exact incentive to respond to

\(^{11}\)The Excess Readmission Ratio is calculated as the ratio of predicted readmissions to expected readmissions. Predicted admissions (the numerator) is the number of 30-day readmission predicted for a hospital on the basis of a hospital’s performance with its observed case mix and a hospital’s estimated effect on readmissions (individual hospital random intercept). This is presented as a rate per 100 discharges. Expected readmissions (the denominator) is the number of 30-day readmissions expected for a hospital on the basis of average hospital performance with that specific hospital’s case mix and the average hospital effect, it is also a rate per 100 discharges. The ratio of predicted to expected readmissions produces the ERR. A hospital with an ERR greater than 1 is penalized and the penalty is a linear function of the readmission score.

\(^{12}\)When the HRRP was announced, CMS provided resources for hospitals to be able to anticipate their future scores. For example, the detailed method used to calculate the risk adjusted scores is posted on www.qualitynet.org and CMS has an online calculator (www.readmissionscore.org) where hospitals can input a patient’s characteristics and calculate his/her risk adjusted probability of a readmission based on the HRRP formula.

\(^{13}\)The variance of the random component may also differ by hospital.
the HRRP to prevent the next period’s penalty. The upshot of this discussion is, that empirically, hospitals that were not penalized under the HRRP that were close to being penalized may respond assuming they have the ability to influence the probability of being penalized \((\frac{\partial \rho}{\partial q^1})\). Similarly, a hospital that was penalized may not respond if they have little ability to influence the probability of being penalized \((\frac{\partial \rho}{\partial q^1} \text{ close to zero or a very large variance of } e)\).

The issue of which hospitals will respond is tackled into two ways. First, I provide evidence that the HRRP excess readmission scores in round 1 mimic the exact incentive to respond to the HRRP in round 2. I show and others have previously (Medicare Quality Chartbook (2010) and Thompson et al. (2017)), that there is an extremely high correlation in both the risk un−adjusted readmission rates, and excess readmission ratios from one period to another\(^{14}\). In Appendix Table 3, I report coefficients from a regression of readmissions rates in round 1 of the HRRP (the last pre−penalty period) on readmission rates in a previous period, which I refer to as round 0 of the HRRP (the penultimate exogenous period). The three coefficients across AMI, HF and PN are all higher than 0.8 suggesting a high level of persistence in readmission rates over time. Secondly, I also obtain estimates of the persistence in the excess readmission ratios (scores). To do so, I simulate HRRP excess readmission ratios for every hospital for each of the 3 HRRP conditions (AMI, HF and PN) in pre−HRRP periods. To generate these simulations, I rely on code provided by CMS, and the entire inpatient Medicare claims from 2006 to 2011. In Appendix Figure 1A, I show evidence that I am able to simulate the HRRP’s readmission measures (the excess readmission ratio) in round 1 with a correlation of 0.92. I then execute the same exercise but for a prior period, and show that both measures are correlated by 0.98 (Appendix Figure 1B). Hence, across two consecutive exogenous pre−periods there is no change in the excess readmission ratios for the hospital. This result supports the assumption that the penalty a hospital should expect in round 2 must be equal to the penalty it received in round 1.

Nevertheless, I also test explicitly for the possibility that hospitals that were not, but close to, being penalized may have responded if there is some uncertainty as to whether they will be penalized in the future. Specifically, I use a random inference approach to assess whether hospitals that just missed the penalty have also responded to the HRRP and if that has attenuated the Regression Kink estimates. These results are presented below, but note here that there is no evidence that this is the case.

4 Empirical Approach

To obtain estimates of the effect of the HRRP readmissions penalty on hospital behavior, I compare outcomes such as inpatient expenditures of hospitals penalized in round 1 of the HRRP to outcomes of hospitals not penalized. Outcomes are measured in the year after the penalty was announced (see below for details). To obtain the estimates of interest, I utilize a regression kink (RK) design.

\(^{14}\)The Medicare Quality Chartbook showed that the correlation between the HRRP Risk Standardized Readmission Rates from year to year between 2006-2008 is over 0.983.
The intuition of the RK approach is straightforward. The HRRP penalizes hospitals with an excess readmission ratio greater than 1.0. CMS determines the excess readmission ratio based on a comparison of expected versus actual readmissions using historical data on readmissions for that hospital\footnote{A detailed outline of the readmissions measure and methodology is described on the AHRQ website: https://www.qualitymeasures.ahrq.gov/summaries/summary/49197/unplanned-readmission-hospitalwide-allcause-unplanned-readmission-rate-hwr?q=readmissions}. A hospital with an excess readmission ratio of less than or equal to 1.0 is not penalized, but a hospital with an excess readmission rate greater than 1.0 is penalized, and penalties grow with the excess readmission ratio. Therefore, there is a “kink” (see Figure 1) in the relationship between the size of the HRRP penalty and the excess readmission ratio at the value of 1.0.

The regression kink research design is similar in spirit to the better-known regression discontinuity (RD) design (Lee and Lemieux 2010; Imbens and Lemieux 2008; and Gelman and Imbens 2014). The RD approach, however, is not appropriate in the case of the HRRP penalty because the readmission penalty (treatment) does not jump when it crosses the excess readmission ratio threshold of 1.0. Instead, the penalty increases in an approximately linear fashion with the excess readmission ratio starting at the threshold and then growing to one percent (or two or three percent in later years). Thus, identification of the effect of the HRRP in the RK design comes from a change in the effect (slope) of the excess readmission ratio on outcome Y, for example, inpatient spending. Like the RD approach, hospitals away from the threshold (“kink”) contribute to the estimate because hospitals away from the kink are used to estimate the slope of the regression line. For example, just to the right of the HRRP penalty threshold, the penalty is close to zero and hospitals have a relatively small incentive to respond. However, further away from the threshold the penalty grows linearly, as does the incentive to respond, and it is this changing incentive that identifies the slope. The RK allows the slope of the relationship between the penalty and outcome to change at the threshold. So, even though hospitals just to the left and right of the threshold have very similar incentives, and there is no discontinuity, the RK identifies the change in slope that, if valid, should occur at the kink (threshold). Below, I report the results of a test of whether, empirically, there is evidence of a change in slope at other points besides the threshold. I note here that the evidence confirms that the change in slope occurs only at the threshold.

Formally, the regression kink design, as described above, is implemented using regression methods and model specifications such as the following (Card et al. 2012):

\begin{align}
\text{PENALTY}_{jt+1} &= b_0 + b_1 \text{EXCESS\_RATIO}_{jt} + b_2 (\text{EXCESS\_RATIO}_{jt} \times \text{ABOVE}_{jt}) + \varepsilon_{jt} \\
\text{OUTCOME}_{jt+1} &= a_0 + a_1 \text{EXCESS\_RATIO}_{jt} + a_2 (\text{EXCESS\_RATIO}_{jt} \times \text{ABOVE}_{jt}) + u_{jt} \\
\text{OUTCOME}_{jt+1} &= \gamma_0 + \gamma_1 \text{EXCESS\_RATIO}_{jt} + \gamma_2 \text{PENALTY}_{jt} + \nu_{jt}
\end{align}

In equation (8), the size of the readmission penalty (PENALTY) of hospital “j” in year “t+1” depends on the excess readmission ratio (EXCESS\_RATIO) in year “t” and the interaction between a dummy variable indicating that the excess readmission ratio...
is greater than 1.0 (ABOVE) and the excess readmission ratio. This regression model mimics the formula that determines the readmission penalty. The readmission penalty is zero when the excess readmissions ratio is less than or equal to 1.0 and then the penalty is a linear function of the excess readmission ratio after the threshold of 1.0. Table 1 reports the estimates from equation (8) and verifies that the regression mimics the penalty formula; estimates show that the coefficient on the excess readmission ratio (“b1”) is virtually zero, which is expected because the penalty is zero prior to the excess readmission threshold.

In equation (9), the average outcome, for example, inpatient spending for AMI, of patients in hospital “j” in year “t + 1” depends on the excess readmission ratio (EXCESS_RATIO), and the interaction between the indicator of the threshold and the excess readmission ratio. If there is a causal effect of the HRRP penalty on outcomes, the coefficient (“a2”) should be non-zero, which would reflect the fact that the HRRP penalty applies only above the threshold excess readmission ratio of 1.0.

Note that the dependent variable is measured in year “t + 1”, which refers to the first year after the penalty was announced by CMS and known by the hospital. In round 1, CMS announced the penalty in August 2011 based on an analysis of data from 2008 to 2011, but penalties did not start until October 2012. Given this, for round 1, I will use years spanning Aug. 2011 to Aug. 2013 as the post penalty period.

Finally, equation (10) yields the estimate of treatment-on-the-treated-the effect of the HRRP penalty on hospital outcomes. Note that this is equivalent to a two-stage, least-squares instrumental variables approach where the instrument is the interaction term between the excess ratio and the indicator for being above the threshold. The variable penalty is predicted in equation (10) from estimates in equation (8).

Figures 1 through 3 illustrate the identification assumption of the RK design. Consider a case in which the association between inpatient spending in the post penalty period for a condition, for example, HF, and the excess readmission ratio remained constant as the excess readmission ratio increased from below 1.0, which is the penalty threshold, to higher levels. This finding would be evidence that the HRRP did not have an effect on inpatient spending because, as Figure 1 shows, the penalty sharply increases at the excess readmission ratio of 1.0, but there was no corresponding change in the association between inpatient spending and the excess readmission ratio at that point. Alternatively, if I observe a significant change in the association between inpatient spending and the excess readmission ratio at the threshold, then this is evidence that the HRRP had an effect.

Equations (8) through (10) are illustrative, although not far from the actual regressions I estimate. I add baseline covariates to equations (8) through (10) and show that this does not impact the estimates in magnitude, but increases efficiency. I also use a quadratic specification of the excess readmission ratio and analogous interaction terms in some models and compare the linear and quadratic models. The linear model cannot be rejected. In addition, I include and indicator for whether the hospital received a HBVP bonus in the first year of the HRRP program.

One complication in applying the RK design is that the readmissions penalty is
a function of the excess readmission ratio for three conditions: Heart Attack (AMI), Heart Failure (HF) and Pneumonia (PN). Thus, a hospital can be penalized if it has an excess readmission ratio greater than 1.0 on any, or all, of these conditions. This circumstance makes it difficult to identify the appropriate counterfactual hospital. For example, consider a hospital with excess readmission ratios of 0.9, 1.01 and 1.3 for AMI, HF and PN, respectively. For this hospital, the ideal counterfactual hospital might be one with excess readmission ratios of 0.9, 0.99 and 1.3 for AMI, HF and PN, respectively. This example reveals the dimensionality problem in defining appropriate comparison hospitals if we used all three excess readmission ratios.

To address this issue, I stratify the sample and focus on the effect of one cause of a readmissions penalty at a time. For example, to estimate the effect of a hospital incurring a penalty due to excess AMI readmissions, I limit the sample to hospitals with excess readmission ratios less than 1.0 for HF and PN (i.e., not penalized for HF and PN). Thus, I have a sample of hospitals that I can order with respect to the AMI excess readmission ratio that all have excess readmission ratios for HF and PN that are less than 1.0. One advantage of this approach is that it is straightforward. It allows for the use of one excess readmission ratio as the running variable, and, therefore, relies on a standard regression kink design. Out of the 2,569 penalized hospitals by CMS in round 1 (FY2013), 234 hospitals were penalized for only having excess AMI readmissions, 362 hospitals were penalized for only having excess HF readmissions and 315 hospitals were penalized for only having excess pneumonia readmissions. Therefore, the RK analysis includes 35% of hospitals that were penalized.

Another advantage of stratifying the sample is that allows for the identification of the effect of the HRRP by the main penalizing condition. There is a relatively weak correlation across conditions in terms of the penalty. That is, not all penalized hospitals are penalized across all the 3 HRRP conditions (AMI, HF and PN) and some hospitals have significantly high readmission rates in some conditions but not others. In round 1 of the HRRP, 31% of hospitals were penalized for all 3 conditions, 32% of hospitals were penalized for 2 conditions and 37% of hospitals were penalized for a single condition. This implies that a given hospital potentially faces differential cost and ability in reducing readmissions across diagnoses. Hence, identifying the response to the HRRP by the specific condition driving the penalty is therefore not only empirically convenient, but also interesting from both a theoretical and policy perspective.

Following the stratification described above, Table 1 presents the first-stage estimates from regression models (equation 8) of the relationship between the HRRP penalty and the excess readmission ratio for each condition: AMI, HF and PN. The main point to note about estimates in Table 1 is that below the excess readmission threshold, the readmission penalty is zero, as indicated by the coefficient on the excess readmission ratio (row 1). Also, note that that the coefficient estimate of the main effect of the dummy variable indicator that the excess readmission ratio is greater than 1.0 is virtually zero (row 2). This confirms that the appropriate approach is a regression kink design and a not a regression discontinuity design. There is no “jump” in

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16Including controls for the excess readmission ratio for the two other conditions eg:(HF and PN in the AMI sample) does not alter estimates.
treatment at the threshold, but a change in slope (kink)\(^{17}\). Finally, coefficients on the interaction between the excess readmission ratios and dummy indicators of an excess ratio greater than 1.0, for example 0.052 for HF, indicate that the maximum penalty is reached quickly (e.g., when excess readmission ratio is 1.2). The coefficients on the interaction terms are highly significant indicating a strong first stage, which is consistent with the HRRP formula.

5 Data

I used three, complementary datasets to conduct the analysis. I utilize the 100% sample of Medicare administrative inpatient records reported in the MEDPAR files from 2010 to 2013. The 2010 data is used in the assessment of the validity of the RK design, as it precedes the announcement of the penalties. The 2011 to 2013 data are used to assess the impact of the first round penalty.

The MEDPAR files contain detailed information on all inpatient episodes of care for fee-for-service Medicare enrollees. The outcomes I examine are total hospital charges and charges for specific services (e.g.: radiology, labs, pharmacy charges), length of stay, disposition status and destination (e.g.: home care or skilled nursing facility), number of surgical procedures and mortality (hospital mortality as well as 30, 60 and 90−day mortality).

I also study the effect of the HRRP on readmissions. The readmission ratios in the subsequent round are used to assess the effect of the HRRP penalty on readmissions itself. To obtain information on the readmission ratios for each condition (HF, PN and AMI), and the penalties in each round, I utilize the Inpatient Prospective Payment System (IPPS) files published by CMS in August of every year. I use IPPS files that describe scores for the first three consecutive rounds of the HRRP. Finally, to test the presence of heterogeneous effects in the response to the HRRP penalties. I obtain the share of a hospitals patients who are enrolled in Medicare in 2010 (the last baseline period), using the publicly available 2010 hospital Impact file.

I limit the sample to hospitals that were assessed and not exempt from the penalty\(^{18}\). In the first round, 2241 hospitals received penalties with 1,910 hospitals receiving penalties less than 1 percent. Another 887 hospitals had readmission ratios below 1 for all three conditions (AMI, HF, PN). Hence, a total of 3,128 hospitals were assessed for the HRRP penalties. The analysis includes any hospital that was assessed for the penalty.

\(^{17}\)While the penalty schedule is determined by the readmission score, CMS also uses variables such as the DRG weight (common across hospitals) and the cost of living index to determine the penalty amount. The R-squared for the regressions reported in Table 1 is over 0.8, indicating that while I am unable to replicate the penalty schedule perfectly, the readmission ratio and the interaction of the ratio at the threshold are able to explain 80% of the variation in the penalty amount across hospitals.

\(^{18}\)Not all hospitals were assessed for the HRRP. Hospitals that were not considered for the HRRP penalties, included hospitals with too few cases to evaluate (less than 25 cases during the entire 3−year assessment period), psychiatric, rehabilitation, long term care, children, cancer, critical access hospitals, and all hospitals in Maryland. In addition, I exclude hospitals with less than 50 cases during the entire 3−year assessment period, because CMS used a Bayesian shrinkage method that assigns these small hospitals a score close to the threshold but below 1.0.
HRRP and did not receive a penalty, as well as hospitals that receive a penalty for Heart Failure (HF), Pneumonia (PN) or Heart Attacks (AMI)\(^\text{19}\).

6 Results

6.1 Validity of the Research Design

Before presenting the results, I provide evidence of the validity of the RK research design. To assess the validity of the RK approach, I do the following. First, I estimated equation (9) for all the outcomes, but in a period preceding the HRRP (2010). The excess readmission penalty of each hospital is from round one of the HRRP, but outcomes were measured prior to the date penalties were announced. If the RK design is valid, I should find no regression kink for outcomes determined prior to the penalty at the excess readmission threshold because of the assumption that hospitals on either side of the threshold are comparable. The use of this type of “placebo” analysis is a commonly accepted way of establishing the plausibility of the RK research design.

Table 2 shows the estimates from equation (9) on 30–day readmissions for HF, AMI and PN but in the period prior to the HRRP. The most important point to note about estimates in Table 2 is that there is no evidence of a “kink” in the relationship between the excess readmission ratios and the outcomes examined. Estimates associated with the interaction terms between the indicator of an HRRP penalty and the excess readmissions ratios, are not significant and very small relative to the mean. The absence of a “kink” is consistent with the placebo nature of the analysis if the hospitals on either side of the excess readmission ratio thresholds are good comparisons for each other, I would not expect a “kink” at the threshold for outcomes determined prior to the implementation of the HRRP. In figure 4a, 4b and 4c, I present graphical evidence of the absence if a kink at the threshold.

Table 3 shows the estimates from equation (9) on mortality, total charges, length of stay and discharge destination in the period prior to the HRRP. In Figures 5 and 6, I present graphical evidence of the absence of a kink at the threshold in the pre–treatment period for inpatient length of stay and 30 day—mortality rates for patients admitted for AMI\(^\text{20}\).

In Table 4 I present estimates from another “placebo” analysis, but on patient characteristics in the prior period. I examine patients age, sex, race and the percentage of patients assigned DRGs that indicate multiple complications. In Figures 7 – 98, I illustrate these results graphically. In Figure 7, I present the relationship between the excess readmissions ratio and the percentage of black patients in the pre-treatment

\(^{19}\) These exemptions however did not exclude the majority of hospitals that treat most AMI, HF and PN conditions 85% of AMI Medicare inpatient admissions were treated in hospitals that are a part of the HRRP assessment Similarly, 83% of Medicare inpatient admissions and 98% of pneumonia Medicare admissions occurred in hospitals that are included in the HRRP and not exempt for any reason.

\(^{20}\) Table 3 provides the coefficient estimates for the regression in equation (9) for all three HRRP conditions (AMI, HF and PN). Graphically, all three conditions follow the same pattern shown in the AMI graphs in Figures 5 – 9.
period. Similarly, in Figures 8 and 9, I present the relationship between the percentage of patients coded as AMI with multiple complications, average age and the excess readmissions ratio. Again, these figures indicate the absence of a kink in the prior period. I also test the presence of a kink in hospital characteristics in the period prior to the HRRP. I find no evidence of a differential slope in share of Medicare patients, share of low-income patients (proxied for by Disproportionate Share Patient (DSH) percent)\(^{21}\), hospital teaching status or number of beds. I also test for a kink at the threshold in the bonuses/penalties due to the round 1 HVBP. Appendix Table 4 provides these estimates.

Second, I assessed whether the density of hospitals around the round 1 HRRP penalty (kink) is smooth. The purpose of this analysis is to show that hospitals did not anticipate being penalized and responded before the HRRP penalties were announced. The assessment period used to measure the penalties that were announced in August 2011 and used data for inpatients admitted between June 2008 and July 2011. The formula used to calculate the penalty and the conditions included in the calculation were only announced in August 2011. Thus, it is unlikely that a hospital was able to respond and avoid being penalized. Nevertheless, I show that there was no discontinuity in the density of hospitals around the penalty threshold.

As shown in Appendix Figure 2, I find no evidence that hospitals responded preemptively to avoid the penalty for hospitals in the AMI panel\(^{22}\). I formally test the continuity and smoothness of the distribution of hospitals at the readmissions penalty threshold for all 3 conditions (Appendix Table 5) following Card et al. (2012) using various sized bins. The evidence indicates no manipulation by hospitals at the threshold, which is consistent with the timeline of the policy announcement.

Overall, the evidence presented in this section strongly supports the validity of the regression kink design.

### 6.2 The impact of the HRRP on Readmissions

The first set of results I present are for readmissions. I first present readmissions which are measured using CMS’s calculations. I examine whether the HRRP penalty in round 1 affected the round 2 excess readmission ratio. Table 4 presents the reduced form (equation 9) estimates. The interaction of the excess ratio and the penalty indicator shows the effect (slope) of a 1 unit increase in the excess readmission ratio at the penalty threshold. A one — unit increase in the excess readmission ratio is defined as 0.01 change. The excess readmission ratio ranges from 0.9 to 1.1 (penalty threshold at 1) in the sample used in Table 4\(^{23}\).

\[\text{DSH Percent} = \left( \frac{\text{Medicare SSI Days}}{\text{Total Medicare Days}} \right) + \left( \frac{\text{Medicaid, Non-Medicare Days}}{\text{Total Patient Days}} \right)\]

\(^{21}\)The Heart Failure (HF) and Pneumonia (PN) panels follow the exact pattern shown for AMI.

\(^{22}\)The results presented in table 5 use only hospitals with an excess ratio between 0.9 and 1.1 (a narrow bandwidth). The entire distribution of hospitals ranges from 0.8 to 1.2. I also estimated models with varying bandwidth and results were similar to those reported in Table 5.
In Table 5, the top panel presents estimates for the HF sample. The excess readmission ratio (main effect) in round 1 is positively associated with the excess readmission ratio for HF in round 2 of the HRRP (column 2). For example, for hospitals below the threshold in round 1, a 0.1 increase in the round 1 excess readmission ratio is associated with a 0.08 increase in the round 2 excess readmission ratio. The key estimates, however, are those on the interaction between the excess readmissions ratio and the penalty indicator. In column 1 the estimate is -0.001 and not statistically significant. This estimate indicates that for a hospital that was penalized in round 1, an increase in the round 1 excess readmissions ratio is associated with a decrease in the round 2 excess readmissions ratio. A 0.1-unit increase in the round 1 excess readmissions ratio for hospitals that were penalized in round 1 is therefore associated with a 0.07 (0.08 - 0.01 = 0.07) unit increase in the round 2 excess readmissions score. Figure 10a illustrates this result and it is clear from figure 10a that there is negligible difference in the slope on either side of the threshold.

Two other results are shown in the top panel of Table 5. These two results are for conditions targeted by the HRRP (PN and AMI) that the hospital was not penalized for. In column 2, I present the effect of the HF round 1 excess readmission ratio on the AMI round 2 excess readmission ratio. In column 3, I present the effect of the HF round 1 excess readmission ratio on the PN round 2 excess readmission ratio. Overall, estimates in the top panel of Table 5 suggest that the HRRP had no effect on hospital readmission for HF hospitals. There is no evidence that hospitals penalized for HF attained lower HF scores in any of the 3 HRRP conditions (AMI, HF, PN).

The middle panel of Table 5 presents similar estimates for the AMI sample. Here too, the excess readmission ratio in round 1 (main effect) is positively associated with the round 2 excess readmission ratio (for AMI) and the estimate is statistically significant. For AMI, there is evidence that the HRRP decreased readmissions. For hospitals that were not penalized in round 1, a 0.1 increase in the excess readmission ratio was associated with a 0.07 increase in the round 2 excess readmission ratio. The same increase in the round 1 excess readmission ratio for hospitals that were penalized is associated with only a 0.04 increase in the round 2 excess readmission ratio. Figure 10b illustrates the marked and significant change in the slope for the AMI round 2 excess readmission ratio. The estimates in table 5 suggest that the HRRP caused Penalized hospitals to reduce readmissions for AMI.

The bottom panel of Table 5 presents estimates for Pneumonia. Like the other two conditions, the excess readmission ratio in round 1 (main effect) is positively associated with the round 2 excess readmission ratio for PN, and the estimate is statistically significant. In this case, estimates for the interactions between the round 1 excess ratio and penalty indicator is small and does not suggest a kink at the threshold. In short, there is little evidence that the HRRP penalty caused any significant or economically meaningful change in the excess readmission ratios for pneumonia (see figure 10c).

I also extend the period of analysis to include periods of round 2 and round 3 of the HRRP. However, the assignment of the penalty is still based on the round

\[24\] I also estimated a regression discontinuity model where I only include the excess readmission ratio and an indicator for the penalty threshold. I find no evidence of a jump in the round 2 excess ratio, size or probability of a penalty at the threshold for any of the 3 conditions.
1 of the HRRP. It is not feasible to use the round 2 penalty for assignment given
the prior evidence that the excess readmission ratio was affected by round 1 penalty.
Appendix Table 6 shows the estimates of the interaction of the penalty and the round
1 readmission score for the round 3 score. The results confirm the earlier findings that,
among hospitals penalized for AMI in round 1, there is a kink in the round 3 score
(although not statistically significant the coefficient increases in magnitude). Hospitals
penalized for HF or PN show no differential slope in terms of the round 3 score or the
round 3 penalty probability. This result is also strikingly clear in figures 11 a, b and
c. Specifically, in figure 11 a, there is a clear kink in the data at the round 1 AMI
threshold for the round 3 AMI score. Overall the evidence also indicates that as HF
and PN penalized hospitals had more time to potentially reduce readmissions due to
the HRRP, there seems to be no effect of the HRRP on the excess readmission scores
for these conditions.

A complementary analysis to that in Table 5 is to test the presence of a kink in
the risk un−adjusted readmission rates at the threshold post the HRRP. These are
crude readmissions, not calculated using CMS’s method. In the top panel of table 6,
I present the HF 30-day readmission reduced form results for hospitals penalized for
HF. Column 1 shows the reduced form estimates for the first year post the HRRP and
column 2 shows the reduced form estimates for the second year post the HRRP. The
key estimates, again, are those on the interaction between the excess readmissions ratio
and the penalty indicator. In column 1 the interaction term estimate is -0.0007 and not
statistically significant. In column 2, the estimate is -0.000015 and also not statistically
significant. Hence, much like the evidence on the excess readmission ratios for HF,
there is no evidence that the HRRP penalty caused any significant or economically
meaningful change in the risk un−adjusted readmissions for HF patients (see figure
12a and 12b).

The middle panel of table 6, reports the reduced form kink estimates for AMI 30-
day risk un−adjusted readmissions. The estimate on the interaction term in column 1
(1 year post the HRRP) is -0.011 and not statistically significant (although 18 percent
larger in magnitude than the exante estimate). The estimate on the interaction term
in column 2 (2 years post the HRRP) is -0.0025 and highly statistically significant.
Hence, 2 years post the HRRP, for hospitals that were not penalized in round 1, a 0.1
increase in the excess readmission ratio was associated with a 0.022 increase in 30-day
readmissions. The same increase in the round 1 excess readmission ratio for hospitals
that were penalized only for AMI is associated with only a -0.003 increase in 30-day
readmissions.

Figure 12b illustrates the marked and significant change in the slope for AMI
30-day readmissions post the HRRP. Note here that both a reduction in 30−day
readmission rates for AMI (table 6) and a reduction in the HRRP’s excess readmission
ratios for AMI (table 5), were found. This is the first main result of the paper and
in the sections that follow, I explore in detail the potential mechanisms that hospitals
could have used to reduce these readmissions.
6.3 A Test for the Presence of a Kink to the Left of the HRRP Threshold

An important question for how to interpret estimates is whether hospitals that were not penalized responded. An analysis of whether hospitals that just missed being penalized responded will clarify what the differences in outcomes between hospitals that were and were not penalized under HRRP represent. A test for whether hospitals to the left of the penalty threshold responded is motivated by a randomization inference procedure that produces a distribution of placebo estimates in regions without a policy kink\textsuperscript{25}. Simply, I alter the excess readmission threshold a large number of times and reestimate the regression kink model to construct a distribution of estimates. However, I only use hospitals that are not penalized by the HRRP (i.e., hospitals to the left of the actual policy kink). The assumption here is that at some point in the distribution, there are certain hospitals that are far enough from the penalty and have no incentive to respond to the HRRP. This assumption is not restrictive since not all hospitals have an incentive to respond to the HRRP. Given this assumption, if indeed there is a response to the HRRP that precedes the actual policy kink, then at some point to the left of the true threshold a kink will be observed. I therefore estimate regression kink coefficients along the entire left-hand side of the HRRP policy kink, to determine if anywhere to the left of the HRRP policy kink hospitals began altering readmissions or their process of care. I first report these left-hand side kink estimates, for total charges, readmission scores and mortality for the AMI sample - the main condition where HRRP effects on readmissions and charges were observed.

Appendix Figure 3a shows the distribution of RK estimates for the relationship between the round 2 AMI score and the round 1 AMI score. The figure reports coefficients from a RK regressions starting with a placebo threshold of 0.9 and ending at a placebo threshold of 0.98. To estimate these placebo coefficients, I use data points for hospitals not penalized by the HRRP on either side of the placebo thresholds. Zero out of the 33 coefficient estimates to the left of the true kink threshold are statistically significant. This indicates that nowhere to the left of the HRRP policy kink do I begin to see declines in readmissions due to the HRRP.

The evidence is also consistent when I apply the same test to the total charges for the inpatient stay or 30-day mortality for AMI patients. In Appendix Figures 3b and 3c, there is no evidence that hospitals to the left of the penalty threshold have raised spending on AMI patients or decreased 30–day mortality. All reported coefficients in the figures are statistically insignificant.

Overall, while not definitive, the evidence presented in this section suggests that hospitals that were not penalized largely did not respond to the HRRP. This is plausible and in line with the evidence of large persistence in readmission rates across years, and the high likelihood that the probability of being penalized in round 2 is strongly correlated with being penalized in round 1. Therefore, the RK estimates arguably reflect mainly the total program effect, and not the relative effect of hospitals penalized to those not penalized.

\textsuperscript{25}See Ganong and Jger (2017) for a test specific to the regression kink design.
The same test is applied to the panel of hospitals penalized for HF and PN. One concern is that the RK estimates for HF and PN are attenuated to zero, because hospitals to the left of the threshold are also responding. I show in Appendix Figures 4 that there is no evidence of a kink to the left of the HRRP threshold for these two conditions.

The above test used only hospitals far to the left of the true policy threshold i.e unpenalized hospitals. Another placebo inference test that is carried out relies on both penalized and unpenalized hospitals and randomly assigns the threshold to different values both to the right and left of the true policy threshold. This test is similar to the random inference procedure proposed by Ganong and Jger (2014). Here, I attempt to see how the magnitude of the kink estimate changes as I assign the placebo threshold to points very close to the true threshold. Appendix Figure 5a shows the coefficients from this test on the AMI Round 2 Excess Readmission Scores. In appendix figure 5a, I show the change in slope at placebo locations which are close to but to the right of the true threshold (1.01 to 1.06) as well as placebo locations which are close to but to the left of the true threshold (0.98 to 0.999). The point estimate recovered from the actual policy threshold (at 1.0) is well below the distribution of all other placebo estimates, reinforcing the view that I am detecting a true effect of the HRRP on reductions in readmissions. Note however, that this permutation test shows significant kink values within a close proximity of the true policy threshold. I show in appendix figure 5a that the t−statistic is maximized at the actual HRRP kink location only, rather than the other placebo kink locations. The fact that placebo thresholds extremely close to the HRRP threshold are statistically significant is mainly due to overlapping data points used to estimate the slope of each line in the RK. This issue of overlapping data was raised by (Card et al. 2016).

Similarly, I execute the same test on the round 2 excess readmission ratio for hospitals in the HF and PN panels (appendix figure 5b and 5c). Across both figures, no placebo estimates are significant and the estimate at the true HRRP threshold is indistinguishable from the other placebo estimates just to the right or just to the left of the true HRRP threshold. This confirms the lack of a response from hospitals penalized for HF and PN.

6.4 The impact of the HRRP on the Hospital Resource Use for HRRP Conditions

Given the evidence of a negative impact of the HRRP penalties on the round 2 readmission ratio and readmissions, at least for AMI, I now investigate the potential mechanisms that could have produced these lower readmission rates. The theoretical model predicted that the penalty would cause hospitals to provide more services (improve the quality of care) to patients with an illness that is part of the HRRP.

I begin by presenting estimates on the on total charges, charges for radiology, labs and pharmacy, and length of stay for the period from August 2011 to August 2013. Table 7 presents the reduced form results (equation 9) for AMI, HF and PN.

There are few statistically significant or economically meaningful estimates in Table
For the AMI sample, estimates indicate that the HRRP penalty is associated with an increase in total charges and laboratory charges. For hospitals that were not penalized, the round 1 excess readmission ratio is associated with a decrease in total charges; a 0.1 unit increase in the readmission ratio is associated with a $5801 (17%) decrease in total charges and a $1386 (24%) decrease in laboratory charges. In contrast, for hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a $7430 (20%) increase in total charges and a $2190 (40%) increase in laboratory charges. Figures 15a and 15b plot the predicted slope for total and laboratory charges in AMI hospitals. Note that the figures reflect the noticeable kink at the threshold. A hospital that is just penalized (an increase of 1 unit in the excess ratio is equal to 0.01 increase in excess readmission ratio), moves from having a score of 1 to a score of 1.01. This hospital would have $743 higher total charges and $219 higher labs for an AMI inpatient.

For hospitals in the HF or PN samples, I find no evidence of an effect of the HRRP on total charges, laboratory, pharmacy, or radiology charges. These estimates are shown in Panel A and Panel C of Table 7. For example, the reduced form interaction term coefficient on total charges for hospitals in the HF panel is $19 and the average total charge for HF is $22,082 (0.08%). The magnitude of the coefficient is therefore negligible.

The last outcome related to resource use is length of stay. Column 5 of Table 7 shows estimates for length of stay. For hospitals in the AMI sample, that were not penalized, the round 1 excess readmission ratio is associated with a decrease in length of stay; a 0.1 unit increase in the readmission ratio is associated with a 0.15 days (3%) decrease in length of stay. In contrast, for hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a 0.4 days (8%) increase in length of stay. The estimate is marginally significant (p-value 0.12). Note here that is unlikely that hospitals increase length of stay by 0.4 of a day.

For hospitals in the HF or PN samples, I find no evidence of an increase in length of stay. These estimates are shown in Panel A and Panel C. For HF hospitals (Panel A), and all estimates are small, not economically important and not statistically significant.

So far, I have presented estimates of the HRRP on resource use in the period from August 2011 to August 2013 (Table 7). This post HRRP period begins with the announcement of the round 1 score and ends with the announcement of the round 2 score. The evidence indicated that AMI hospitals reduced readmissions, and have increased total charges and laboratory charges.

It is worth noting that only 11 months of the three-year period used to calculate the round 2 excess readmission ratio and round 2 penalties were subsequent to August 2011 (when the first penalties were announced). If penalized hospitals were able to reduce their round 2 readmissions, they must have employed these mechanisms in the first 11 months subsequent to August 2011. To assess this hypothesis, I present estimates on resource use in the first 11 month post the penalty announcement.

Tables 8 presents estimates of the effect of the HRRP on resource use for the first 11 month period post the round 1 score announcement for AMI hospitals. Estimates
in Table 8 indicate that total charges and lab charges were affected by the HRRP in the first 11 month post the HRRP announcement. The coefficients on the interactions between the round 1 excess ratio and the penalty indicator are positive and significant (0.10 level). For hospitals that were penalized, a 0.1 unit increase in the readmission ratio is associated with a $7010 greater total charge. Similarly, a 0.1 unit increase in the excess readmission ratio had an impact of $2251 higher lab charges among penalized hospitals.

6.5 The impact of the HRRP on Mortality and Discharge Status for the HRRP conditions

I next examine mortality and destination of discharge. Estimates related to these outcomes are presented in Table 9. Columns 1-3 of Table 9 shows the estimates for 30-, 60- and 90- day mortality. For hospitals in the AMI samples, estimates associated with the interaction between the round 1 excess ratio and penalty indicator are negative and small for 30, 60 and 90-day mortality. For example, a 0.1 unit increase in the round 1 readmission ratio for AMI sample is associated with a 0.003 (3%) decrease in 30 day mortality. In contrast, for hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a 0.005 (5%) decrease in 30 day mortality.

For hospitals in the HF or PN samples, I find no evidence of a decrease in mortality. These estimates are shown in Panel A and Panel C. For HF hospitals (Panel A), the reduced form interaction term coefficient for 30-day mortality is 0.0003. For PN hospitals (Panel C), the reduced form interaction term coefficient for 30-day mortality is 0.0009. Neither estimate is significant at 5% levels and are both negligible in magnitude.

Table 9 also present estimates for the discharge destination. This outcome is relevant because of the possibility that hospitals respond to the HRRP by working with post-acute care facilities. In Table 9, I present the reduced form regression kink coefficients for the percentage of patients discharged to skilled nursing facilities and the percentage of patients discharged with home care services. For hospitals penalized for AMI (panel B), there is no evidence of an increase in the share of patients discharged to skilled nursing facilities or home care. Hospitals penalized for HF or PN also do not appear to have discharged significantly more patients to skilled nursing facilities or home care.

6.6 The impact of the HRRP on Patient Characteristics for HRRP Conditions

While altering resource use is one way of decreasing readmissions, hospitals could also attempt to alter the characteristics of patients admitted. CMS risk adjusts for

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26Inpatient hospital mortality is not presented here. However, the reduced form kink estimate is also close to zero and statistically insignificant.
a patient’s severity in the readmission score calculation, however it does not account for a patient’s socio-economic status or unobserved complications. One unintended consequence of the HRRP would be if penalized hospitals began selectively admitting patients based on their probability of a readmission. Hospitals could decrease the number of high-risk patients admitted to the hospital. This would appear as a decline in the frequency of minorities, older, and marginally sicker patients admitted with the HRRP conditions. Table 10, presents estimates for patients age, gender, race, and severity (measured by percentage assigned multiple complications DRG). Across AMI, HF and PN samples, I find no evidence of selection with respect to patient characteristics. Estimates of the interaction terms are fairly small and statistically insignificant for 11 of the 12 estimates. The only significant coefficient on percentage black in the HF panel (where no reduction in readmission was observed).

Secondly, hospitals could also “nominally” alter the characteristics of the patients admitted, causing some patients to appear sicker at baseline in order to reduce the risk-adjusted readmission rates. This would appear as an increase in the frequency of patients coded to have any of the specific clinical comorbidities included in the HRRP risk adjustment. I estimate the HRRP effects on the frequency of comorbidities included in the risk-adjustment for HRRP patients and find no evidence of an increase in coding of comorbidities specific to the HRRP27.

### 6.7 The Impact of the HRRP for non-HRRP Conditions

As noted earlier, hospitals may shift resources away from conditions that are not a part of the HRRP penalty. Using the same set of dependent variables used to analyze the HRRP conditions, I estimate the impact of the penalty for patients admitted for Medicare conditions outside the HRRP. I examined the 10 most common conditions (besides the HRRP conditions), which account for 30% of all Medicare inpatients.

Tables 11 present the reduced form estimates for total charges in conditions outside the HRRP. For the HF sample (panel A), estimates suggest little spillover effects of the HRRP penalty on the process of care for conditions outside the HRRP. In the AMI subsample (Panel B), however, there is considerable evidence that the HRRP penalty resulted in an increase in total charges for conditions outside the HRRP. Column 2 of Table 11 shows the estimates for total charges for patients with Cardiac Arrhythmia in hospitals penalized for AMI. For hospitals in the AMI sample, that were not penalized, the round 1 excess readmission ratio is associated with a decrease in total charges; a 0.1 unit increase in the readmission ratio is associated with a $3504 (15%) decrease in total charges. In contrast, for hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a $4950 (21%) increase in total charges. The estimate is significant at 5% levels28. Out of the 10 conditions studies, five estimates of the interaction between the round 1 AMI excess ratio and penalty indicator are

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27 Since there is over 32 clinical comorbidities per condition, this evidence is not presented here, but available upon request.

28 I also find increases in laboratory charges for the exact conditions outside the HRRP that report rising total charges. This is consistent with hospitals raising both the quantity of labs -which therefore raises both total and lab charges.
statistically significant at 5% levels and all 10 coefficients indicate higher charges outside the HRRP conditions in hospitals penalized for AMI\textsuperscript{29}. I also combined the 10 medical conditions for which estimates are reported in Table 11 and estimated a single regression. When assessed jointly, I find that for hospitals that were not penalized, a 0.1 increase in the excess readmission ratio was associated with a $6000 increase in total charges. For hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a $10800 increase in total charges and the estimate is significant at 5% levels.

In the PN subsample, only 1 out of the 10 interaction terms is statistically significant at 5% levels. Column 7 in panel C, shows the effect of the HRRP on total charges for bone disease patients in hospitals penalized for PN. For hospitals that were not penalized, the round 1 excess readmission ratio is associated with a decrease in total charges; a 0.1 unit increase in the readmission ratio is associated with a $1997 (10\%) decrease in total charges. In contrast, for hospitals that were penalized, a 0.1 increase in the excess readmission ratio was associated with a $6357 (34\%) increase in total charges.

Table 12 presents the reduced form kink estimates for 30-day mortality in conditions outside the HRRP. Estimates suggest no mortality gains outside the HRRP conditions.

6.8 The Effect of the HRRP in Low vs High Medicare Share Hospitals

I present estimates of the effect of the HRRP on total charges, readmission scores and mortality (the three main estimates) for AMI patients after allowing the slope at the threshold to differ for hospitals with a high vs low Medicare share of patients. The median percentage of Medicare patients from all hospital inpatient discharges is 45\%. Recall that the conceptual model did not predict a higher response for hospitals with a higher Medicare share of patients, unless hospitals provide Medicare and non-Medicare patients with an equal level of care. In that case, when a hospital raises the quantity of care for AMI Medicare patients, it must also do so for AMI non-Medicare patients. However, only care provided to AMI Medicare patients reduces the probability of the HRRP penalty. It is therefore less costly for hospitals with a high share of Medicare patients to respond to the HRRP.

Table 13 presents the coefficients for the interaction of the HRRP threshold and the Excess Readmission Ratio for AMI, and the interaction the HRRP threshold, the Excess Readmission Ratio for AMI, and whether a hospital has a high share of Medicare patients at baseline(FY2010). The evidence in Table 13 indicates that where an effect due to the HRRP was identified (total charges, lab charges and readmissions), there is no differential response by Medicare share. The interaction of the Medicare share indicator with the RK coefficient is insignificant for all reported outcomes. In addition, the RK estimates are similar in magnitude to previously reported estimates (which did

\textsuperscript{29}In Appendix Table 7 I present evidence of the validity of the research design for these outcomes. There is no evidence of a change in the slope at the threshold in the pre-treatment period for any of the 10 diagnosis.
not include the Medicare share interaction term). The lack of a differential response by Medicare share indicates that hospitals potentially treat Medicare and non−Medicare patients admitted for the same diagnosis with varying intensity of care. This is inline with evidence presented in Card et al. (2007) and Doyle (2006).

6.9 Statistical Significance after Correcting for Multiple Hypothesis Testing

The analysis presented so far is a thorough and extensive evaluation of the effect of the HRRP on readmissions and detailed inpatient spending and care outcomes. Such comprehensive assessment is useful for advising policy. However, mechanically the more statistical tests I perform, the more likely I am to reject the null hypothesis when it is true (i.e. false positives). One established method to protect from this, is to correct the alpha level when performing multiple tests. Making the alpha level more stringent (i.e., smaller). In Appendix Table 10, I control for the false discovery rate by preforming the Holm−Bonferroni procedure among estimates. Here I define three families of statistical tests. Using this method, I still maintain that AMI patients in hospitals penalized for AMI received higher spending on lab tests (lab charges), and had lower readmission scores in the post HRRP period (2 years post the HRRP i.e round 3). I also maintain that in these hospitals, some conditions outside the HRRP had statistically significant increases in spending (specifically, Renal Failure, Psychosis and Stroke). Overall, the evidence indicates strongly that hospitals penalized for AMI increased the quantity of care, reduced readmissions and that there was positive spillover effects on non-HRRP targeted patients.

6.10 Sensitivity Analyses

In this section, I present evidence to bolster the findings related to the AMI sample indicating that the HRRP had a significant effect on resource use and readmission rate of affected hospitals. These tests include using different bandwidth and polynomial order for RK and dropping baseline covariates. I also discuss whether there is a possibility of mean reversion.

Appendix Table 11, presents the estimates for charges and labs as I vary the choice of bandwidth. Columns 1 - 3 present the reduced form kink estimates for the AMI total charges estimates in the AMI subsample. The estimate from the model with the largest bandwidth (including all hospitals in the AMI panel) indicates an effect of $6,650 (17%) dollar increase in charges for a 0.1 increase in the excess ratio for penalized hospitals. The estimates from the model with the smallest bandwidth (including hospitals with only a score between 0.9 and 1.1) indicates an effect of $7,430 (21%) for a 0.1 increase in the excess ratio for penalized hospitals.

In Appendix Table 12, I present RK estimates using a linear specification with and without covariates and Rk estimates obtained using a quadratic estimates. Estimates without the inclusion of covariates are comparable to the main estimates in magnitude,
although estimates form the model with baseline covariates have smaller standard errors. In the quadratic regression, the squared term is insignificant.

A final concern is whether readmission rates reverse to the mean from year to year. As pointed out earlier, readmissions are highly correlated from year to year (0.8) and the Excess readmission scores are extremely persistent (0.92). This is consistent with the fact that the Excess Readmission Scores are calculated based on 3–years of hospital readmission rates. The lack of any mean reversion was also pointed out by Mellor, Daly and Smith (2016) in their analysis of readmission rates in penalized vs unpenalized hospitals over time.

7 Conclusion

The evidence presented indicates that hospitals penalized for AMI have responded to the incentives of the HRRP. Specifically, estimates indicate that hospitals that received close to the maximum penalty for AMI, increased total spending on AMI patients by 20% ($7430) and laboratory tests by 40% ($2190) compared to hospitals at the threshold. These hospitals attained a 30% decline in their excess readmissions score and a 15 percent decline in risk–unadjusted readmissions (2.5 percentage points) in the subsequent round. In addition, extending the analysis period indicated that the round 1 penalty had persistent effects on AMI total spending and laboratory tests that grew in magnitude. This additional care however, had no impact on mortality.

The estimates of the effect of the HRRP on total charges in AMI penalized hospitals are plausible. A typical hospital with an excess readmission ratio of 1.1 in round 1 and who received the maximum penalty admitted 90 AMI patients a year and these readmissions determine the HRRP penalty. Estimates above indicate that in response to the HRRP penalty, spending on AMI patients in this typical hospital increased by $7430. Thus, the total cost of avoiding the HRRP penalty is $668,700 (90 times $7430). The benefit from reducing readmissions is the extra revenue as a result of increasing the intensity of care for those 90 AMI patients and reducing the likelihood of a penalty. A typical hospital with an excess readmission ratio of 1.1 in round 1 would have an expected penalty in round 2 of 1.2 percent (cap was 2% in round 2). This hospital has total Medicare revenue of $80 million. Thus, the benefit of reducing readmissions is $960,000. This simple calculation illustrates that it is indeed plausible for hospitals to increase charges per patient by the estimated amount ($7430) to avoid the HRRP penalty. Note too, that charges overstate the actual dollar value of costs incurred, so, the cost–benefit calculation understates the gain from responding.

I find no evidence that the HRRP affected readmissions or the process of care for hospitals penalized for Heart Failure or Pneumonia. One explanation for the absence of a response for HF and PN is that these conditions include a larger number of patients relative to AMI. Hospitals on average care for 250 HF Medicare inpatients and 300 PN Medicare inpatients a year, relative to 80 AMI Medicare inpatients. In line with the conceptual model, as the number of patients in the targeted condition rises, the marginal cost of reducing the penalty increases by relatively more than the marginal benefit. This intuitive result is fundamental to the discussion on the relative incentive
to reduce readmissions across diagnosis and how pay for performance programs such as the HRRP can be optimized to reflect this differential cost of responding to the program’s incentives.

Across all 3 subsamples (AMI, HF and PN), there is no evidence of an increase in disposition to SNF facilities or home care. While a popular hypothesis is that hospitals would use outpatient care such as SNF care to reduce readmissions, there is no empirical evidence that the penalties led to a higher disposition to SNFs.

Another hypothesis that is rejected, is that penalized hospitals substitute resources out of conditions not in the HRRP and into conditions in the HRRP. Interestingly, I find evidence that the penalized hospitals increased the quantity of care for patients with diagnoses outside the HRRP conditions. I find that in hospitals penalized for AMI, patients in these hospitals diagnosed for cardiac arrhythmia, pulmonary edema, kidney infections, renal failure, strokes and psychosis also experience higher quantity of care (higher charges and labs) and no significant mortality gains. These findings provide evidence for a model of shared costs and common quality across diagnoses. Hospitals may adopt general treatment style that they apply to their patient populations. Evidence of spillovers in treatment style has been shown in the inpatient hospital setting by Feder, Hadley, and Zuckerman (1987) and by Dafny (2005), and in the physician setting by Glied and Zivin (2002). It is worth noting that for the only condition where I find evidence of increased care AMI I also find evidence of increased care in AMI penalized hospitals in non-target conditions. Precisely, I find that both total charges and lab charges have increased in 5 of the 10 non-target conditions.

The results from this study suggest that the HRRP affected the process of care for AMI patients and not the two other conditions. In line with the conceptual model outlined earlier, hospitals will increase the quantity or quality of care for a given condition and respond to the HRRP, if they are able to reduce the probability of a future penalty for that given condition. The lack of response for HF and PN, could indicate that hospitals are unable to affect the readmission scores for these conditions in a cost effective manner. Further research is needed to investigate the reasons driving this selective response to the HRRP.
References


Table 1
First Stage - Estimates from Regression Kink Model for Readmission Penalty

<table>
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<th>Heart Failure</th>
<th>AMI</th>
<th>Pneumonia</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Restricted</td>
<td>Unrestricted</td>
<td>Restricted</td>
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<tr>
<td><strong>Excess Readmission Ratio</strong></td>
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<td>&lt;0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0004)</td>
<td>(0.00045)</td>
</tr>
<tr>
<td><strong>[Penalty =1] Indicator</strong></td>
<td>-.00002</td>
<td>.00006</td>
<td>-.00005</td>
</tr>
<tr>
<td></td>
<td>(.00006)</td>
<td>(.00009)</td>
<td>(.00008)</td>
</tr>
<tr>
<td><strong>Excess Readmission Ratio X [Penalty =1]</strong></td>
<td>0.05**</td>
<td>0.05**</td>
<td>0.032**</td>
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<tr>
<td></td>
<td>(0.0008)</td>
<td>(0.0009)</td>
<td>(0.00108)</td>
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<td>1106</td>
<td>657</td>
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<td>0.0005</td>
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<tr>
<td><strong>Adjusted (R²)</strong></td>
<td>(0.87)</td>
<td>(0.87)</td>
<td>(0.76)</td>
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Notes -- Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three - year performance period (June 2008-July 2011) are excluded. The unrestricted model includes an indicator for the threshold, which allows for a "jump", or intercept shift, at the threshold, and the restricted model only allows for a change in slope at the threshold. *p<0.05, ** p<0.01, ***p<0.001.
Table 2
Estimates of the Effect of the HRRP on Risk Un-Adjusted 30-Day Readmissions Prior to the HRRP Implementation
(Aug 2010 - Aug 2011)

<table>
<thead>
<tr>
<th></th>
<th>Heart Failure</th>
<th>AMI</th>
<th>Pneumonia</th>
</tr>
</thead>
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<td>0.0016</td>
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<tr>
<td></td>
<td>(0.0007)*</td>
<td>(0.0004)**</td>
<td>(0.0003)**</td>
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<tr>
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<td>0.0006</td>
<td>0.00005</td>
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<td></td>
<td>(0.0016)</td>
<td>(0.0009)</td>
<td>(0.005)</td>
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<td>881</td>
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<tr>
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<td>0.16</td>
<td>0.18</td>
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Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
### Table 3
Estimates of the Effect of the HRRP on Mortality, Discharge Destination and Charges Prior to the HRRP Implementation (FY 2010)

<table>
<thead>
<tr>
<th></th>
<th><strong>A. Heart Failure</strong></th>
<th><strong>B. AMI</strong></th>
<th><strong>C. Pneumonia</strong></th>
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<tr>
<td></td>
<td>Mortality 30 Day</td>
<td>Mortality 60 Day</td>
<td>Mortality 90 Day</td>
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<td>-0.0006 (0.001)</td>
<td>-0.004* (0.002)</td>
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<td>856</td>
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<td>Excess Ratio</td>
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<td>-0.0008 (0.0009)</td>
<td>-0.0002 (0.001)</td>
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<td>0.002 (0.002)</td>
<td>0.0005 (0.002)</td>
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<td>466</td>
</tr>
<tr>
<td>Excess Ratio</td>
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<td>0.0005 (0.0006)</td>
<td>0.0008 (0.0006)</td>
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<tr>
<td>Mean Dependent Variable</td>
<td>0.09</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>881</td>
<td>881</td>
<td>881</td>
</tr>
</tbody>
</table>

**Notes** - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
### Table 4
Estimates of the Effect of the HRRP on Patient Characteristics Prior to the HRRP Implementation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Excess Readmission Ratio</th>
<th>Portion Female</th>
<th>Portion Black</th>
<th>Percentage with Multiple Complication DRG code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Heart Failure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Readmission Ratio</td>
<td>-0.01</td>
<td>0.0005</td>
<td>0.0009</td>
<td>-0.004**</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.16</td>
<td>0.002</td>
<td>0.009*</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.87)</td>
<td>(0.002)</td>
<td>(0.004)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>78</td>
<td>0.55</td>
<td>0.1</td>
<td>0.38</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>856</td>
<td>856</td>
<td>856</td>
<td>856</td>
</tr>
<tr>
<td><strong>B. AMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Readmission Ratio</td>
<td>-0.19</td>
<td>-0.0005</td>
<td>0.001</td>
<td>-0.0006</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.0018)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.024</td>
<td>0.0017</td>
<td>-0.0019</td>
<td>0.0014</td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>78</td>
<td>0.47</td>
<td>0.07</td>
<td>0.51</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>465</td>
<td>465</td>
<td>465</td>
<td>465</td>
</tr>
<tr>
<td><strong>C. Pneumonia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Readmission Ratio</td>
<td>-0.03</td>
<td>0.0001</td>
<td>0.0016</td>
<td>-0.0015</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.0008)</td>
<td>(0.0013)</td>
<td>(0.0017)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.016</td>
<td>-0.0005</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>76</td>
<td>0.54</td>
<td>0.07</td>
<td>0.33</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>889</td>
<td>889</td>
<td>889</td>
<td>889</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio, and a control for the HVBP bonuses applied in round 1 of penalties. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
Table 5
Estimates of The Effect of the HRPP in Round 1 on The Readmission Ratio in Round 2 of the HRRP

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>Round 2 HF Excess Ratio</th>
<th>Round 2 AMI Excess Ratio</th>
<th>Round 2 PN Excess Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.008***</td>
<td>-0.005</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.005)</td>
<td>(0.0009)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.001</td>
<td>0.0007</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.01)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.02</td>
<td>-0.37</td>
<td>-0.05</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. AMI</th>
<th>Round 2 AMI Excess Ratio</th>
<th>Round 2 HF Excess Ratio</th>
<th>Round 2 PN Excess Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.007***</td>
<td>0.002**</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.0008)</td>
<td>(0.0009)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.003*</td>
<td>-0.0008</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.06</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Pneumonia</th>
<th>Round 2 PN Excess Ratio</th>
<th>Round 2 AMI Excess Ratio</th>
<th>Round 2 HF Excess Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.007***</td>
<td>0.002</td>
<td>0.0009</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.001)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.001</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.027</td>
<td>-0.06</td>
<td>-0.3</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>881</td>
<td>881</td>
<td>881</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio, and a control for the HVBP bonuses applied in round 1 of penalties. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
Table 6
Estimates of The Effect of the HRPP in Round 1 on 30-day Risk Un-adjusted Readmissions 1 and 2 Years Post the HRRP

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>Readmissions</th>
<th>Readmissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.0013</td>
<td>0.0006</td>
</tr>
<tr>
<td></td>
<td>(0.003)***</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0007</td>
<td>-0.0000015</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.0008)</td>
</tr>
<tr>
<td>Mean Dependent Variable at pretreatment year 2010</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
</tr>
</tbody>
</table>

| B. AMI | 
|------------------|--------------|
| Excess Ratio     | 0.002        | 0.0022       |
|                  | (0.0004)***  | (0.0004)***  |
| Excess Ratio X [Penalty =1] | -0.0011     | -0.0025      |
|                  | (0.0009)     | (0.001)**    |
| Mean Dependent Variable at pretreatment year 2010 | 0.16 | 0.16 |
| Number of Observations | 466 | 466 |

| C. Pneumonia | 
|------------------|--------------|
| Excess Ratio     | 0.0005       | 0.0006       |
|                  | (0.0003)     | (0.0003)     |
| Excess Ratio X [Penalty =1] | 0.001       | 0.0008      |
|                  | (0.0009)     | (0.0009)     |
| Mean Dependent Variable at pretreatment year 2010 | 0.25 | 0.25 |
| Number of Observations | 881 | 881 |

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio, and a control for the HVBP bonuses applied in round 1 of penalties. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
# Table 7
## Estimates of the Effect of the HRRP on Charges & Length of Stay Post the HRRP Implementation Round 1

<table>
<thead>
<tr>
<th></th>
<th>Total Charges</th>
<th>Radiology Charges</th>
<th>Lab Charges</th>
<th>Pharmacy Charges</th>
<th>Length of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D.</strong> Total Charges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>130.2</td>
<td>30.8</td>
<td>12.4</td>
<td>1.3</td>
<td>-0.0002</td>
</tr>
<tr>
<td></td>
<td>(177)</td>
<td>(16)</td>
<td>(43)</td>
<td>(25)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>19.9</td>
<td>-38.23</td>
<td>38.23</td>
<td>55.07</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(364)</td>
<td>(33)</td>
<td>(91)</td>
<td>(58)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Mean Dependent Variable at pretreatment year 2010</td>
<td>22082</td>
<td>1623</td>
<td>4187</td>
<td>3021</td>
<td>4.2</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
</tr>
</tbody>
</table>

| **E.** AMI |                  |                   |             |                  |               |
| Excess Ratio | -580.8*        | -15.29            | -138.6*     | 12.51            | -0.0151       |
|             | (288.0)        | (23)              | (62.38)     | (47)             | (0.01)        |
| Excess Ratio X [Penalty =1] | 1323.6*       | 78.89             | 357.5*      | -50.31           | 0.0472         |
|             | (665.9)        | (56)              | (160.5)     | (101)            | (0.03)        |
| Mean Dependent Variable at pretreatment year 2010 | 34732 | 2276 | 5661 | 4553 | 4.5 |
| Number of Observations | 466      | 466               | 466         | 466              | 466           |

| **F.** Pneumonia |                  |                   |             |                  |               |
| Excess Ratio     | 5.90           | 11.9              | 18.05       | 9.67             | 0.004         |
|                  | (158.5)        | (16)              | (35)        | (39)             | (0.009)       |
| Excess Ratio X [Penalty =1] | 459.9        | 10.71             | 46.35       | -9.93            | 0.018         |
|                  | (333.5)        | (34)              | (77)        | (79)             | (0.02)        |
| Mean Dependent Variable at pretreatment year 2010 | 23296 | 2052 | 3761 | 4518 | 4.6 |
| Number of Observations | 881   | 881               | 881         | 881              | 881           |

Notes: Each column represents a separate regression. Hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
Table 8
Estimates of the Effect of the HRRP on Charges and Length of Stay 11 month Post the HRRP Implementation

<table>
<thead>
<tr>
<th>AMI (First 11 month)</th>
<th>Total Charges</th>
<th>Radiology Charges</th>
<th>Lab Charges</th>
<th>Pharmacy Charges</th>
<th>Length of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-585.5*</td>
<td>-18.58</td>
<td>-141.4*</td>
<td>14.10</td>
<td>0.000298</td>
</tr>
<tr>
<td></td>
<td>(292.0)</td>
<td>(21.53)</td>
<td>(62.20)</td>
<td>(46.74)</td>
<td>(0.0130)</td>
</tr>
<tr>
<td>Excess Ratio X</td>
<td>1287</td>
<td>86.49</td>
<td>366.5*</td>
<td>-41.98</td>
<td>0.00975</td>
</tr>
<tr>
<td>[Penalty =1]</td>
<td>(683)</td>
<td>(53.23)</td>
<td>(162.9)</td>
<td>(108.6)</td>
<td>(0.0267)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>34732</td>
<td>2276</td>
<td>5661</td>
<td>4553</td>
<td>4.5</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. Hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
# Table 9
Estimates of the Effect of the HRRP on Mortality and Discharge Destination Post the HRRP Implementation Round 1

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>-0.0006</td>
<td>-0.0003</td>
<td>-0.0006</td>
<td>-0.0005</td>
<td>0.00115</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0006)</td>
<td>(0.0007)</td>
<td>(0.0009)</td>
<td>(0.00131)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0003</td>
<td>-0.001</td>
<td>-0.0014</td>
<td>0.0006</td>
<td>-0.00178</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0013)</td>
<td>(0.0015)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable at pretreatment year 2010</td>
<td>0.1</td>
<td>0.15</td>
<td>0.31</td>
<td>0.17</td>
<td>0.19</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. AMI</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.0003</td>
<td>0.0005</td>
<td>0.0006</td>
<td>-0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.0007)</td>
<td>(0.0008)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0008</td>
<td>-0.001</td>
<td>-0.0007</td>
<td>0.0017</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable at pretreatment year 2010</td>
<td>0.09</td>
<td>0.14</td>
<td>0.17</td>
<td>0.18</td>
<td>0.13</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Pneumonia</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>-0.00003</td>
<td>-0.00004</td>
<td>0.0002</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.0006)</td>
<td>(0.00)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.00009</td>
<td>0.000002</td>
<td>0.0003</td>
<td>-0.0008</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td>(0.0009)</td>
<td>(0.001)</td>
<td>(0.00)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Mean Dependent Variable at pretreatment year 2010</td>
<td>0.09</td>
<td>0.13</td>
<td>0.15</td>
<td>0.19</td>
<td>0.14</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. Hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
Table 10
Estimates of the Effect of the HRRP on Patient Characteristics Post the HRRP Implementation Round 1

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Portion Female</th>
<th>Portion Black</th>
<th>Percentage with Multiple Complications</th>
<th>DRG Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Heart Failure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>0.03</td>
<td>0.0003</td>
<td>0.0005</td>
<td>0.004**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
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<td>0.01*</td>
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</tr>
<tr>
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<td>(0.2)</td>
<td>(0.002)</td>
<td>(0.005)</td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
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<td>0.1</td>
<td>0.38</td>
<td></td>
</tr>
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<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td></td>
</tr>
<tr>
<td><strong>B. AMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
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<td>0.002</td>
<td>0.0018</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.001)</td>
<td>(0.0017)</td>
<td>(0.002)</td>
<td></td>
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<tr>
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<td>-0.003</td>
<td>-0.002</td>
<td>-0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>78</td>
<td>0.47</td>
<td>0.07</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
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<td>466</td>
<td>466</td>
<td>466</td>
<td></td>
</tr>
<tr>
<td><strong>C. Pneumonia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-0.06</td>
<td>-0.0004</td>
<td>0.001</td>
<td>-0.002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.0008)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.03</td>
<td>0.0014</td>
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<td>0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.0016)</td>
<td>(0.003)</td>
<td>(0.004)</td>
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<tr>
<td>Mean Dependent Variable</td>
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<td>0.54</td>
<td>0.07</td>
<td>0.33</td>
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<td>881</td>
<td>881</td>
<td>881</td>
<td></td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three - year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio, and a control for the HVBP bonuses applied in round 1 of penalties. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
### Table 11
Estimates of the Effect of the HRRP on Total Charges in Conditions Excluded from the Penalty Formula Post the HRRP Implementation Round 1

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(181.5)</td>
<td>(135.5)</td>
<td>(1355)</td>
<td>(261.1)</td>
<td>(132.7)</td>
<td>(175.9)</td>
<td>(188.0)</td>
<td>(650.1)</td>
<td>(363.7)</td>
<td>(217.9)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-52.29</td>
<td>46.71</td>
<td>1672</td>
<td>157.5</td>
<td>-59.20</td>
<td>-210.2</td>
<td>1119.4</td>
<td>2535.6</td>
<td>735.2</td>
<td>-203.7</td>
</tr>
<tr>
<td></td>
<td>(388.7)</td>
<td>(310.2)</td>
<td>(3044)</td>
<td>(581.0)</td>
<td>(293.1)</td>
<td>(371.5)</td>
<td>(885.8)</td>
<td>(1598)</td>
<td>(863.8)</td>
<td>(459.5)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>24865</td>
<td>2109</td>
<td>150128</td>
<td>30921</td>
<td>19700</td>
<td>24816</td>
<td>20300</td>
<td>66694</td>
<td>56045</td>
<td>22909</td>
</tr>
</tbody>
</table>

**B. AMI**

| Excess Ratio    | -427.0 | -350.4* | -3448* | -487.3 | -364.2* | -652** | -198.4 | -1114.5 | -810.6 | -669.1* |
|                 | (232.1) | (167.6) | (1611) | (307.5) | (176.4) | (237.1) | (195.6) | (604.1) | (418.7) | (265.2) |
| Excess Ratio X [Penalty =1] | 688.0  | 844.4*  | 5461   | 1101.0 | 845.4* | 1148.1* | 470.2  | 3769**  | 1269.6  | 1442.7** |
|                 | (507.8) | (402.4) | (3331) | (671.8) | (406.9) | (533.2) | (402.0) | (1429) | (794.5) | (530.6) |
| Mean Dependent Variable | 28916  | 22733   | 163746 | 31500  | 22791  | 29834  | 20699  | 65030  | 58960   | 24836    |

**C. Pneumonia**

| Excess Ratio    | -36.05 | 4.400  | 203   | 125.8  | 6.796  | 57.37 | -199.7 | 454.5  | 212.5  | -36.74 |
|                 | (158.9) | (120.9) | (1328) | (232.3) | (114.6) | (159.2) | (157.0) | (576.0) | (318.0) | (198.6) |
| Excess Ratio X [Penalty =1] | 448.9  | 415.1  | -78   | 548.6  | 382.4  | 498.6 | 835.4* | -221.6 | 281.4  | 312.7  |
|                 | (339.2) | (266.2) | (2718) | (497.5) | (253.1) | (349.6) | (345.2) | (1190) | (726.8) | (415.2) |
| Mean Dependent Variable | 24817  | 22700  | 151942 | 31652  | 19817  | 25245 | 18656  | 64644  | 55659  | 22548  |

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.0002</td>
<td>0.00008</td>
<td>-0.0018</td>
<td>0.003</td>
<td>0.0004</td>
<td>0.002</td>
<td>-0.001</td>
<td>0.005</td>
<td>0.00008</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.0005)</td>
<td>(0.0008)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.0003)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.0001</td>
<td>0.000003</td>
<td>0.003</td>
<td>-0.005</td>
<td>-0.0007</td>
<td>-0.004*</td>
<td>0.002</td>
<td>-0.01</td>
<td>-0.0006</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.008)</td>
<td>(0.004)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.008)</td>
<td>(0.0006)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
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<td>0.05</td>
<td>0.45</td>
<td>0.21</td>
<td>0.06</td>
<td>0.12</td>
<td>0.02</td>
<td>0.21</td>
<td>0.015</td>
<td>0.02</td>
</tr>
<tr>
<td>B. AMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-0.001*</td>
<td>-0.0006</td>
<td>0.002</td>
<td>-0.004**</td>
<td>-0.0003</td>
<td>-0.0006</td>
<td>0.001</td>
<td>-0.007*</td>
<td>0.0001</td>
<td>-0.0004</td>
</tr>
<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0004)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.0005)</td>
<td>(0.0007)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.0001)</td>
<td>(0.001)</td>
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<tr>
<td>Excess Ratio X [Penalty =1]</td>
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<td>0.0003</td>
<td>0.003</td>
<td>0.005</td>
<td>-0.0007</td>
<td>0.0003</td>
<td>-0.002</td>
<td>0.01*</td>
<td>-0.0003</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0007)</td>
<td>(0.006)</td>
<td>(0.003)</td>
<td>(0.00101)</td>
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<td>(0.003)</td>
<td>(0.006)</td>
<td>(0.0004)</td>
<td>(0.003)</td>
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<tr>
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<td>0.05</td>
<td>0.05</td>
<td>0.47</td>
<td>0.21</td>
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<td>0.11</td>
<td>0.02</td>
<td>0.19</td>
<td>0.015</td>
<td>0.01</td>
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<td></td>
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<td></td>
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<td></td>
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<td>-0.0004</td>
<td>0.0014</td>
<td>0.004*</td>
<td>0.0009</td>
<td>0.0003</td>
<td>-0.0004</td>
<td>0.007*</td>
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<td>0.0002</td>
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<tr>
<td></td>
<td>(0.0005)</td>
<td>(0.0007)</td>
<td>(0.003)</td>
<td>(0.002)</td>
<td>(0.0004)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.0002)</td>
<td>(0.001)</td>
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<tr>
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<td>-0.0002</td>
<td>0.005</td>
<td>-0.002</td>
<td>-0.002*</td>
<td>-0.002</td>
<td>0.004</td>
<td>-0.02**</td>
<td>-0.00009</td>
<td>0.0009</td>
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<tr>
<td></td>
<td>(0.0009)</td>
<td>(0.001)</td>
<td>(0.007)</td>
<td>(0.004)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.006)</td>
<td>(0.0005)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
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<td>0.05</td>
<td>0.45</td>
<td>0.21</td>
<td>0.06</td>
<td>0.13</td>
<td>0.02</td>
<td>0.22</td>
<td>0.015</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Notes: Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
Table 13
Regression Kink Estimates for Charges, Readmissions and Mortality by Medicare Share Post the HRRP
AMI Sample

<table>
<thead>
<tr>
<th></th>
<th>Charges</th>
<th>Readmissions</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Total Charges</td>
<td>Round 2 AMI</td>
<td>Round 3 AMI</td>
</tr>
<tr>
<td></td>
<td>Lab Charges</td>
<td>Excess Ratio</td>
<td>Excess Ratio</td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-567</td>
<td>0.007***</td>
<td>0.0064***</td>
</tr>
<tr>
<td></td>
<td>(310)</td>
<td>(0.0008)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>1416.5*</td>
<td>-0.004*</td>
<td>0.0062***</td>
</tr>
<tr>
<td></td>
<td>(698)</td>
<td>(0.0018)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1] X [High Medicare Share =1]</td>
<td>-432</td>
<td>-0.002</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(681)</td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>34732</td>
<td>-0.02</td>
<td>-0.025</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression using the sample of hospitals not penalized under the HRRP and the sample of hospitals penalized for AMI only. High Medicare Share is an indicator variable for whether Medicare patients account for more than 45% of a hospital's inpatient admissions. I use the baseline Medicare share for the FY 2010 to define high share hospitals. All regressions include DRG, race, age, gender HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
<table>
<thead>
<tr>
<th>Event Study for 30-Day Readmissions Prior to the HRRP</th>
<th>Event Study for Length of Stay Prior to the HRRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI</td>
<td>HF</td>
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<td><strong>August 2006 - August 2007</strong> X <strong>Middle Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>0.000576</td>
<td>-0.00407*</td>
</tr>
<tr>
<td>(0.00467)</td>
<td>(0.00172)</td>
</tr>
<tr>
<td><strong>August 2008 - August 2009</strong> X <strong>Middle Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>0.00664</td>
<td>0.0013</td>
</tr>
<tr>
<td>(0.00417)</td>
<td>(0.00198)</td>
</tr>
<tr>
<td><strong>August 2009 - August 2010</strong> X <strong>Middle Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>0.00973*</td>
<td>0.00344</td>
</tr>
<tr>
<td>(0.00387)</td>
<td>(0.00184)</td>
</tr>
<tr>
<td><strong>August 2006 - August 2007</strong> X <strong>High Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>-0.00304</td>
<td>-0.00999***</td>
</tr>
<tr>
<td>(0.00515)</td>
<td>(0.00186)</td>
</tr>
<tr>
<td><strong>August 2008 - August 2009</strong> X <strong>High Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>0.0140**</td>
<td>0.00463*</td>
</tr>
<tr>
<td>(0.00456)</td>
<td>(0.00217)</td>
</tr>
<tr>
<td><strong>August 2009 - August 2010</strong> X <strong>High Penalty Group</strong></td>
<td></td>
</tr>
<tr>
<td>0.0138**</td>
<td>0.00547**</td>
</tr>
<tr>
<td>(0.00425)</td>
<td>(0.00202)</td>
</tr>
</tbody>
</table>

**Number of Observations**

| 11082 | 11082 | 11082 | 11082 | 11082 | 11082 |

**adj. R-sq**

| 0.284 | 0.506 | 0.443 | 0.284 | 0.506 | 0.443 |

Notes – Appendix Table 1 presents estimates from difference in differences regressions, where I compare hospitals with no penalty (Low Penalty Group) to hospitals with 0-0.5% penalty (Middle Penalty Group) and hospitals with a penalty above 0.5% (High Penalty Group) over time prior to the HRRP implementation. So I do not include the period after August 2011, which is the beginning of the ex-post period. Columns 1 to 3, assess the parallel trends assumption for 30-day readmission rates. Columns 4 to 6 asses the parallel trends assumption for length of stay. Each regression in columns 1 to 6 uses all hospitals included in the HRRP assessment and includes hospital and time fixed effects.
## Appendix Table 2
The Association between Low SES Share or Baseline Readmission Rates and the Round 1 HRRP Penalty and the HVBP Penalties/Bonuses.

<table>
<thead>
<tr>
<th></th>
<th>HVBP Round 1</th>
<th>HVBP Round 1</th>
<th>HVBP Round 1</th>
<th>HVBP Round 1</th>
<th>HVBP Round 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of Dual Eligible Patients</td>
<td>-.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.04) ***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Share</td>
<td>.026</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic Share</td>
<td>0.129</td>
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<td></td>
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<tr>
<td></td>
<td>(0.11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Readmissions (AMI) in 2007</td>
<td>-.14</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.06) **</td>
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<td></td>
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<tr>
<td>Readmissions (HF) in 2007</td>
<td>-.59</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.12) ***</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Readmissions (PN) in 2007</td>
<td>-0.31</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.13) **</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean DV</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>2844</td>
<td>2833</td>
<td>2833</td>
<td>2832</td>
<td>2832</td>
</tr>
</tbody>
</table>

Notes: Column 1 reports the coefficient on the share of Dual Eligible, Black and Hispanic patients in a hospital from a regression of the HVBP bonus/penalty on these 3 variables. Column 2 reports the coefficient from the regression of the HVBP bonus/penalty on the 30-day AMI readmission rate in 2007 in a hospital. Columns 3 and 4 repeat the analysis in column 2, but the independent variable is 30-day readmissions for HF and PN respectively. The mean dependent variable HVBP bonus/penalty is 0.002, the median HVBP bonus/penalty is zero (since it is a budget neutral program). The analysis reveals that dual eligibility, and baseline readmissions (col 2, 3 and 4) are negatively correlated with HVBP, i.e. hospitals with higher share of Medicaid duals or readmissions are more likely to attain penalties (-ve payment adjustments) under the HVBP. Similarly, hospitals with higher baseline readmission rates and higher penalties under the HRRP in round 1 are more likely to be penalized by the HVBP as well.
### Appendix Table 3
Regression of Risk Unadjusted Readmission Rates in Round 1 on Risk Unadjusted Readmission Rates in Round 0 (Round 1 = last exogenous period and Round 0 = penultimate exogenous period)

<table>
<thead>
<tr>
<th></th>
<th>HF</th>
<th>AMI</th>
<th>PN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 0 Readmissions</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>(0.14)***</td>
<td>(0.038)***</td>
<td>(0.107)***</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.047</td>
<td>0.025</td>
<td>0.013</td>
</tr>
<tr>
<td>(0.02)</td>
<td>(0.007)***</td>
<td>(0.017)</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.21</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>

Notes – Each column represents a separate regression using the sample of hospitals not penalized under the HRRP and the sample of hospitals penalized for a specific condition (HF, AMI or PN). I bin hospitals into 21 bins by rounding the excess readmissions ratio to the second decimal (eg: 0.98, 0.99 etc), I then regress the readmission rates in round 1 of the HRRP (the last exogenous round) on the readmission rates in round 0 (the penultimate exogenous round). The model includes no other covariates. *p<0.05, **p<0.01, ***p<0.001
Appendix Table 4
Estimates of the Effect of the HRRP on Hospital Characteristics Prior to the HRRP Implementation

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>Medicare Share</th>
<th>Disproportionate Share</th>
<th>Number of Hospital Beds</th>
<th>Amount of HVBP Bonuses/Penalties in Round 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Readmission Ratio</td>
<td>-0.34</td>
<td>0.055</td>
<td>-250</td>
<td>-0.00002</td>
</tr>
<tr>
<td></td>
<td>(0.217)</td>
<td>(0.23)</td>
<td>(310)</td>
<td>(0.00003)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.015</td>
<td>0.036</td>
<td>25</td>
<td>0.00003</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.023)</td>
<td>(30)</td>
<td>(0.00006)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.47</td>
<td>0.24</td>
<td>235</td>
<td>0.00003</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>856</td>
<td>856</td>
<td>856</td>
<td>856</td>
</tr>
<tr>
<td>B. AMI</td>
<td></td>
<td></td>
<td></td>
<td>0.00005</td>
</tr>
<tr>
<td>Excess Readmission Ratio</td>
<td>0.015</td>
<td>0.21</td>
<td>-140</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.206)</td>
<td>(0.23)</td>
<td>(305)</td>
<td>(0.00004)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.013</td>
<td>0.003</td>
<td>-7.4</td>
<td>-0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.024)</td>
<td>(31)</td>
<td>(0.00007)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.47</td>
<td>0.23</td>
<td>233</td>
<td>0.00003</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>465</td>
<td>465</td>
<td>465</td>
<td>465</td>
</tr>
<tr>
<td>C. Pneumonia</td>
<td></td>
<td></td>
<td></td>
<td>0.00004</td>
</tr>
<tr>
<td>Excess Readmission Ratio</td>
<td>-0.05</td>
<td>0.27</td>
<td>-71</td>
<td>-0.00004</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.19)</td>
<td>(271)</td>
<td>(0.00003)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.006</td>
<td>-0.016</td>
<td>-1.17</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.019)</td>
<td>(27)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.48</td>
<td>0.22</td>
<td>237</td>
<td>0.0003</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>889</td>
<td>889</td>
<td>889</td>
<td>889</td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. The mean HVBP bonus is zero because the HVBP is a budget neutral program that assigns bonuses and penalties. *p<0.05, **p<0.01, ***p<0.001.
## Appendix Table 5

Testing Evidence of Manipulation around the Threshold (Round 1 Ratios) – Estimates of the Number of Hospitals per bin using The First Round HRRP Ratio

<table>
<thead>
<tr>
<th></th>
<th>Number of Hospitals</th>
<th>0.1 Bin Size</th>
<th>0.005 Bin Size</th>
<th>0.025 Bin Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. HF</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Penalty =1] Indicator</td>
<td>-0.78</td>
<td>-5.20</td>
<td>-2.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.61)</td>
<td>(3.06)</td>
<td>(1.67)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>43.50</td>
<td>25.33</td>
<td>10.71</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>19</td>
<td>40</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td><strong>B. AMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Penalty =1] Indicator</td>
<td>-3.55</td>
<td>-1.55</td>
<td>-0.28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.54)</td>
<td>(2.16)</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>23.20</td>
<td>11.40</td>
<td>5.90</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>19</td>
<td>39</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td><strong>C. PN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Penalty =1] Indicator</td>
<td>-15.74</td>
<td>-6.959</td>
<td>-3.708*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(9.62)</td>
<td>(3.77)</td>
<td>(1.72)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>45.50</td>
<td>22.20</td>
<td>11.28</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>19</td>
<td>39</td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>

**Notes** – For each panel we formally test the continuity and smoothness of the distribution of hospitals at the penalty threshold following Card et. al (2012). We collapse the data into bins and estimate: \( N_b = \alpha + \beta _1 [\text{Excess Ratio} < 0 ] + \gamma \text{Excess Ratio}_b \times 1[\text{Excess Ratio} < 0 ] + \sum_p \pi_p (\text{Excess Ratio})^p + \epsilon_b \). Where \( N_b \) represents the number of hospitals in bin \( b \), and \( p = 2 \) is chosen. We use three bin sizes of (0.1, 0.05 and 0.0025). Appendix Figure 1 display the unconditional density of the readmissions ratio, plotting the proportion of hospitals in each 0.025 size bin, up to a readmission ratio of 0.2 above the penalty threshold for AMI.
## Estimation of the Effect of the HRPP in Round 1 on The Readmission Ratio & Penalty in Round 3 of the HRRP

### Appendix Table 6

<table>
<thead>
<tr>
<th>Condition</th>
<th>Round 3 AMI Excess Ratio</th>
<th>Round 3 HF Excess Ratio</th>
<th>Round 3 Pneumonia Excess Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>-0.006 (0.005)</td>
<td>0.006*** (0.0008)</td>
<td>0.0007 (0.0009)</td>
</tr>
<tr>
<td>A. Heart Failure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty = 1]</td>
<td>-0.001 (0.01)</td>
<td>-0.003 (0.003)</td>
<td>0.0005 (0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.4</td>
<td>-0.02</td>
<td>-0.03</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>0.006*** (0.001)</td>
<td>0.003* (0.001)</td>
<td>0.0019 (0.002)</td>
</tr>
<tr>
<td>B. AMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty = 1]</td>
<td>-0.004 (0.002)</td>
<td>-0.0006 (0.002)</td>
<td>-0.00001 (0.003)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.025</td>
<td>-0.05</td>
<td>-0.04</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-0.00368 (0.00521)</td>
<td>-0.000542 (0.00199)</td>
<td>0.00461*** (0.000904)</td>
</tr>
<tr>
<td>C. Pneumonia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty = 1]</td>
<td>0.0193 (0.0110)</td>
<td>0.00897* (0.00363)</td>
<td>-0.000996 (0.00193)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>-0.37</td>
<td>-0.06</td>
<td>-0.25</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>881</td>
<td>881</td>
<td>881</td>
</tr>
</tbody>
</table>

**Notes:** Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include only the excess readmission ratio, an interaction of the penalty threshold and the excess readmission ratio, and a control for the HVBP bonuses applied in round 1 of penalties. Coefficient magnitudes are adjusted to show the effect of a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
### Appendix Table 7
Estimates of the Effect of the HRRP on Total Charges in Conditions Excluded from the Penalty Formula Prior to the HRRP Implementation Round 1

<table>
<thead>
<tr>
<th></th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Heart Failure</strong></td>
<td>154.6 (138)</td>
<td>57.57 (114)</td>
<td>371.1 (256.2)</td>
<td>314.2 (249.9)</td>
<td>127.8 (118)</td>
<td>123.0 (135.7)</td>
<td>-10.72 (142)</td>
<td>69.81 (537)</td>
<td>72.4 (304)</td>
<td>223.4 (195.6)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-163.2 (291)</td>
<td>-108.5 (240)</td>
<td>-673.2 (533.9)</td>
<td>-660.2 (530.0)</td>
<td>-201.6 (245)</td>
<td>-195.6 (283.0)</td>
<td>149.3 (347)</td>
<td>1987 (1325)</td>
<td>367 (667)</td>
<td>-500.9 (405.4)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>24865</td>
<td>2109</td>
<td>150128</td>
<td>30921</td>
<td>19700</td>
<td>24816</td>
<td>20300</td>
<td>66694</td>
<td>56045</td>
<td>22909</td>
</tr>
</tbody>
</table>

|                   | 499.7 (402) | 651.5 (344)        | 592.3 (789.2) | 543.1 (724.9)   | 628.0 (363)     | 843.2 (432.8) | 683.7 (426)  | 2115.6 (1150) | 799.8 (800.1)            | 137.5 (495.6) |
| **B. AMI**        | -196.5 (195) | -262.7 (169)       | -63.06 (391.1) | -224.5 (351.9)  | -225.0 (178)   | -295.0 (211.2) | -178.6 (206) | -395 (550)      | -436.8 (389.3)            | -3.382 (241.1) |
| Excess Ratio X [Penalty =1] | 463.3 (294) | 420.6 (238)        | 194.6 (522.3) | 742.0 (514.1)   | 89.52 (248.3)  | 50.73 (289.2) | -185.7 (402) | 504.3 (1112) | -216 (637)              | 269.2 (380.9) |
| Mean Dependent Variable | 28916     | 22733              | 163746       | 31500           | 22791           | 29834        | 20699        | 65030  | 58960                    | 24836     |

|                   | -67.05 (136) | -3.251 (106)       | 102.6 (242.6) | -23.34 (237.0)  | 122.8 (115.6)   | 145.2 (134.0) | 121.3 (189)  | 198.3 (526)      | 423 (293)               | 80.12 (178.7) |
| **C. Pneumonia**  | 463.3 (294) | 420.6 (238)        | 194.6 (522.3) | 742.0 (514.1)   | 89.52 (248.3)  | 50.73 (289.2) | -185.7 (402) | 504.3 (1112) | -216 (637)              | 269.2 (380.9) |
| Excess Ratio X [Penalty =1] | 463.3 (294) | 420.6 (238)        | 194.6 (522.3) | 742.0 (514.1)   | 89.52 (248.3)  | 50.73 (289.2) | -185.7 (402) | 504.3 (1112) | -216 (637)              | 269.2 (380.9) |
| Mean Dependent Variable | 24817     | 22700              | 151942       | 31652           | 19817           | 25245        | 18656        | 64644  | 55659                    | 22548     |

Notes: Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three - year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
### A. Heart Failure

<table>
<thead>
<tr>
<th>Condition</th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>-0.0002</td>
<td>0.0003</td>
<td>0.001</td>
<td>0.0040</td>
<td>-0.00026</td>
<td>-0.00002</td>
<td>-0.0015</td>
<td>-0.005</td>
<td>0.0003</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
<td>(0.0005)</td>
<td>(0.001)</td>
<td>(0.0022)</td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.001)</td>
<td>(0.004)</td>
<td>(0.0003)</td>
<td>(0.0015)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>0.000001</td>
<td>-0.001</td>
<td>-0.003</td>
<td>-0.0039</td>
<td>0.000036</td>
<td>-0.0005</td>
<td>0.00106</td>
<td>0.017</td>
<td>-0.0012</td>
<td>0.0023</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.0047)</td>
<td>(0.0012)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.01)</td>
<td>(0.0008)</td>
<td>(0.0032)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.05</td>
<td>0.05</td>
<td>0.45</td>
<td>0.21</td>
<td>0.06</td>
<td>0.12</td>
<td>0.02</td>
<td>0.21</td>
<td>0.015</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### B. AMI

<table>
<thead>
<tr>
<th>Condition</th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.00025</td>
<td>0.0004</td>
<td>0.0003</td>
<td>-0.00106</td>
<td>-0.00048</td>
<td>-0.0003</td>
<td>-0.0008</td>
<td>-0.004</td>
<td>0.0003</td>
<td>0.000612</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0003)</td>
<td>(0.001)</td>
<td>(0.00182)</td>
<td>(0.0004)</td>
<td>(0.0005)</td>
<td>(0.001)</td>
<td>(0.004)</td>
<td>(0.0002)</td>
<td>(0.000712)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0003</td>
<td>-0.00110</td>
<td>0.0007</td>
<td>0.000003</td>
<td>-0.00025</td>
<td>-0.00005</td>
<td>0.001</td>
<td>0.006</td>
<td>-0.0003</td>
<td>-0.00138</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.00375)</td>
<td>(0.0009)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.009)</td>
<td>(0.0004)</td>
<td>(0.00146)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.05</td>
<td>0.05</td>
<td>0.47</td>
<td>0.21</td>
<td>0.05</td>
<td>0.11</td>
<td>0.02</td>
<td>0.19</td>
<td>0.015</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### C. Pneumonia

<table>
<thead>
<tr>
<th>Condition</th>
<th>COPD</th>
<th>Cardiac Arrhythmia</th>
<th>Septicemia</th>
<th>Pulmonary Edema</th>
<th>Kidney Infection</th>
<th>Renal Failure</th>
<th>Bone Disease</th>
<th>Stroke</th>
<th>Hip &amp; Joint Replacement</th>
<th>Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.0003</td>
<td>-0.0011*</td>
<td>0.0013</td>
<td>-0.00117</td>
<td>-0.00028</td>
<td>-0.0003</td>
<td>0.00172</td>
<td>-0.0019</td>
<td>.0004</td>
<td>-0.00193</td>
</tr>
<tr>
<td></td>
<td>(0.0003)</td>
<td>(0.0004)</td>
<td>(0.001)</td>
<td>(0.00211)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0009)</td>
<td>(0.004)</td>
<td>(0.0005)</td>
<td>(0.00140)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0013</td>
<td>0.0012</td>
<td>-0.0014</td>
<td>0.00641</td>
<td>0.00091</td>
<td>0.0008</td>
<td>-0.004</td>
<td>0.005</td>
<td>-0.005</td>
<td>0.00423</td>
</tr>
<tr>
<td></td>
<td>(0.0008)</td>
<td>(0.0011)</td>
<td>(0.002)</td>
<td>(0.00459)</td>
<td>(0.001)</td>
<td>(0.0009)</td>
<td>(0.002)</td>
<td>(0.008)</td>
<td>(0.0012)</td>
<td>(0.00299)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.05</td>
<td>0.05</td>
<td>0.45</td>
<td>0.21</td>
<td>0.06</td>
<td>0.13</td>
<td>0.02</td>
<td>0.22</td>
<td>0.015</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Notes:** Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
## Appendix Table 9
### Estimates of the Effect of the HRRP on Mortality, Discharge Destination and Charges Post the HRRP Implementation Round 1 and Round 2

<table>
<thead>
<tr>
<th>A. Heart Failure</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
<th>Total Charges</th>
<th>Radiology Charges</th>
<th>Lab Charges</th>
<th>Pharmacy Charges</th>
<th>Pharmacy Charges</th>
<th>Length of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>-0.00001 (0.0005)</td>
<td>0.0006 (0.0006)</td>
<td>0.0001 (0.0007)</td>
<td>-0.00008 (0.0009)</td>
<td>0.002 (0.001)</td>
<td>65.87 (176.9)</td>
<td>21.98 (16.11)</td>
<td>10.73 (43.85)</td>
<td>-10.92 (26.68)</td>
<td>-0.002 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.001 (0.001)</td>
<td>-0.003* (0.001)</td>
<td>-0.002 (0.002)</td>
<td>-0.00114 (0.00267)</td>
<td>-0.00008 (0.0009)</td>
<td>149.8 (366.2)</td>
<td>-30.19 (33.76)</td>
<td>36.53 (91.04)</td>
<td>73.75 (59.95)</td>
<td>0.02 (0.02)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.1</td>
<td>0.15</td>
<td>0.31</td>
<td>0.17</td>
<td>0.19</td>
<td>22082</td>
<td>1623</td>
<td>4187</td>
<td>3021</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td>841</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. AMI</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
<th>Total Charges</th>
<th>Radiology Charges</th>
<th>Lab Charges</th>
<th>Pharmacy Charges</th>
<th>Pharmacy Charges</th>
<th>Length of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.00116 (0.0007)</td>
<td>0.001 (0.0008)</td>
<td>0.0008 (0.0008)</td>
<td>-0.0002 (0.001)</td>
<td>0.001 (0.001)</td>
<td>-695.1* (304.2)</td>
<td>-25.25 (23.42)</td>
<td>-152.8* (62.57)</td>
<td>-22.47 (46.70)</td>
<td>-0.015 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.002 (0.001)</td>
<td>-0.002 (0.002)</td>
<td>-0.001 (0.002)</td>
<td>0.001 (0.002)</td>
<td>-0.002 (0.002)</td>
<td>1548.1* (704.2)</td>
<td>105.9 (58.41)</td>
<td>377.2* (163.9)</td>
<td>20.09 (105.3)</td>
<td>0.04 (0.03)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.09</td>
<td>0.14</td>
<td>0.17</td>
<td>0.18</td>
<td>0.13</td>
<td>34732</td>
<td>2276</td>
<td>5661</td>
<td>4553</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td>466</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Pneumonia</th>
<th>Mortality 30 Day</th>
<th>Mortality 60 Day</th>
<th>Mortality 90 Day</th>
<th>Discharged to SNF</th>
<th>Discharged to Home Care</th>
<th>Total Charges</th>
<th>Radiology Charges</th>
<th>Lab Charges</th>
<th>Pharmacy Charges</th>
<th>Pharmacy Charges</th>
<th>Length of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess Ratio</td>
<td>0.0004 (0.0005)</td>
<td>0.0005 (0.0005)</td>
<td>0.0006 (0.0006)</td>
<td>0.001 (0.0009)</td>
<td>0.001 (0.001)</td>
<td>66.41 (162.2)</td>
<td>14.69 (16.69)</td>
<td>31.46 (34.87)</td>
<td>16.77 (39.35)</td>
<td>0.004 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>-0.0005 (0.001)</td>
<td>-0.0001 (0.001)</td>
<td>0.0004 (0.002)</td>
<td>0.0001 (0.002)</td>
<td>-0.0001 (0.002)</td>
<td>256.0 (352.1)</td>
<td>2.098 (36.08)</td>
<td>-3.013 (77.67)</td>
<td>-47.03 (79.02)</td>
<td>0.01 (0.02)</td>
<td></td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>0.09</td>
<td>0.13</td>
<td>0.15</td>
<td>0.19</td>
<td>0.14</td>
<td>23296</td>
<td>2052</td>
<td>3761</td>
<td>4518</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td>881</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with a excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions include DRG, race, age, gender, HVBP bonus controls. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
Appendix Table 10
Holm-Bonferroni P Value Correction

Panel A: AMI (Charges & Length of Stay for patients targeted by HRRP) (K=5)

<table>
<thead>
<tr>
<th></th>
<th>P-Value</th>
<th>Test</th>
<th>Inverse</th>
<th>Holm-Bonferroni P-Value (alpha=0.05)</th>
<th>Holm-Bonferroni P-Value (alpha=0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Charges</td>
<td>0.009</td>
<td>1</td>
<td>5</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Total Charges</td>
<td>0.038</td>
<td>2</td>
<td>4</td>
<td>0.0125</td>
<td>0.025</td>
</tr>
<tr>
<td>Radiology Charges</td>
<td>0.106</td>
<td>3</td>
<td>3</td>
<td>0.0166</td>
<td>0.03</td>
</tr>
<tr>
<td>Length of Stay</td>
<td>0.138</td>
<td>4</td>
<td>2</td>
<td>0.025</td>
<td>0.05</td>
</tr>
<tr>
<td>Pharmacy Charges</td>
<td>0.576</td>
<td>5</td>
<td>1</td>
<td>0.05</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Panel B: AMI (Readmissions for Patients targeted by HRRP) (k=2)

<table>
<thead>
<tr>
<th></th>
<th>P-Value</th>
<th>Test</th>
<th>Inverse</th>
<th>Holm-Bonferroni P-Value (alpha=0.05)</th>
<th>Holm-Bonferroni P-Value (alpha=0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readmission Score (Round 2)</td>
<td>0.036</td>
<td>1</td>
<td>2</td>
<td>0.025</td>
<td>0.05</td>
</tr>
<tr>
<td>Readmission Score (Round 3)</td>
<td>0.05</td>
<td>2</td>
<td>1</td>
<td>0.05</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Panel C: AMI (Charges for Patients Not Targeted by HRRP) (k=10)

<table>
<thead>
<tr>
<th></th>
<th>P-Value</th>
<th>Test</th>
<th>Inverse</th>
<th>Holm-Bonferroni P-Value (alpha=0.05)</th>
<th>Holm-Bonferroni P-Value (alpha=0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal Failure</td>
<td>0.004</td>
<td>1</td>
<td>10</td>
<td>0.005</td>
<td>0.01</td>
</tr>
<tr>
<td>Psychosis</td>
<td>0.006</td>
<td>2</td>
<td>9</td>
<td>0.0055</td>
<td>0.011</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.008</td>
<td>3</td>
<td>8</td>
<td>0.006</td>
<td>0.0125</td>
</tr>
<tr>
<td>Cardiac Arrhythmia</td>
<td>0.036</td>
<td>4</td>
<td>7</td>
<td>0.007</td>
<td>0.014</td>
</tr>
<tr>
<td>Kidney Infection</td>
<td>0.038</td>
<td>5</td>
<td>6</td>
<td>0.008</td>
<td>0.016</td>
</tr>
<tr>
<td>Pulmonary Edema</td>
<td>0.05</td>
<td>6</td>
<td>5</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Septicemia</td>
<td>0.05</td>
<td>7</td>
<td>4</td>
<td>0.0125</td>
<td>0.025</td>
</tr>
<tr>
<td>Hip and Joint Replacement</td>
<td>0.056</td>
<td>8</td>
<td>3</td>
<td>0.016</td>
<td>0.033</td>
</tr>
<tr>
<td>COPD</td>
<td>0.088</td>
<td>9</td>
<td>2</td>
<td>0.025</td>
<td>0.05</td>
</tr>
<tr>
<td>Bone Disease</td>
<td>0.12</td>
<td>10</td>
<td>1</td>
<td>0.05</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Notes: I execute the Holm-Bonferroni correction on the sample of hospitals for which I find significant effects i.e. the AMI sample of hospitals. Panel A, corrects the P-values using the Holm-Bonferroni method and assesses the significance of the estimates for the inpatient process of care (which includes inpatient spending and length of stay) for patients admitted for AMI. Similarly, Panel B assesses the significance of the estimates for readmissions for patients with an AMI diagnosis. Panel C, assess the significance of the estimates for the inpatient process of care for patients admitted for non-HRRP conditions.
## Appendix Table 11
Robustness of the AMI Estimates on Total Charges and Lab Charges to Varying Bandwidth

<table>
<thead>
<tr>
<th>AMI</th>
<th>Total Charges</th>
<th>Lab Charges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 to 2.5</td>
<td>0.8 to 1.2</td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-327</td>
<td>-736*</td>
</tr>
<tr>
<td></td>
<td>(180.5)</td>
<td>(336)</td>
</tr>
<tr>
<td>Excess Ratio X [Penalty =1]</td>
<td>983*</td>
<td>1347</td>
</tr>
<tr>
<td></td>
<td>(416)</td>
<td>(733)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>37,367</td>
<td>37,278</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>657</td>
<td>552</td>
</tr>
</tbody>
</table>

Notes: Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded. All regressions with covariates include DRG, race, age, gender, HVBP bonus controls. Quadratic regressions include a term for the Excess Ratio Squared. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, ** p<0.01, ***p<0.001.
<table>
<thead>
<tr>
<th></th>
<th>Total Charges</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Linear Covariates</td>
<td>Linear No Covariates</td>
<td>Quadratic No Covariates</td>
</tr>
<tr>
<td>Excess Ratio</td>
<td>-580.8*</td>
<td>-420.0</td>
<td>-336.2</td>
</tr>
<tr>
<td></td>
<td>(288.0)</td>
<td>(315.4)</td>
<td>(1256.1)</td>
</tr>
<tr>
<td></td>
<td>-138.6*</td>
<td>-94.30</td>
<td>-104.6</td>
</tr>
<tr>
<td></td>
<td>(62.38)</td>
<td>(66.17)</td>
<td>(266.3)</td>
</tr>
<tr>
<td>Excess Ratio X</td>
<td>1323.6*</td>
<td>1200.0</td>
<td>998.8</td>
</tr>
<tr>
<td>[Penalty =1]</td>
<td>(665.9)</td>
<td>(743.6)</td>
<td>(2446.6)</td>
</tr>
<tr>
<td></td>
<td>357.5*</td>
<td>317.3</td>
<td>329.4</td>
</tr>
<tr>
<td></td>
<td>(160.5)</td>
<td>(171.1)</td>
<td>(518.7)</td>
</tr>
<tr>
<td>Excess Ratio Squared</td>
<td>4.337</td>
<td>-</td>
<td>-1.772</td>
</tr>
<tr>
<td></td>
<td>(119.1)</td>
<td></td>
<td>(25.65)</td>
</tr>
<tr>
<td>Mean Dependent Variable</td>
<td>34732</td>
<td>34732</td>
<td>34732</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
<tr>
<td></td>
<td>5661</td>
<td>5661</td>
<td>5661</td>
</tr>
<tr>
<td></td>
<td>466</td>
<td>466</td>
<td>466</td>
</tr>
</tbody>
</table>

Notes: Hospitals with less than 50 cases throughout the three-year performance period (June 2008-July 2011) are excluded and hospitals with an excess readmission ratio outside the range, 0.9 to 1.1, are also excluded. All regressions with covariates include DRG, race, age, gender, HVBP bonus controls. Quadratic regressions include a term for the Excess Ratio Squared. Coefficient magnitudes are adjusted to show the change from a 0.01 change in the distance from the penalty threshold. *p<0.05, **p<0.01, ***p<0.001.
Notes – The figure plots the linear predicted penalty for the AMI subsample against the actual penalty assigned by CMS in round 1 of the HRRP. The entire distribution of hospitals in the AMI subsample is used (0.8 to 1.2). Hospitals on the left-hand side of 1, are unpenalized and receive a penalty of zero percent. Hospitals on the right-hand side of 1, are penalized. The penalty increases linearly and is kinked at 1. Table 1, presents the coefficients of for both the slope and the penalty indicator at the threshold. Visually there is no evidence of a “jump” at the threshold. This is also confirmed by estimated presented in table 1.
Figure 2
The Relationship between Hospital Excess Readmission Ratio for PN and HRRP Penalty

Notes – The figure plots the linear predicted penalty for the PN subsample against the actual penalty assigned by CMS in round 1 of the HRRP. The entire distribution of hospitals in the PN subsample is used (0.8 to 1.2). Hospitals on the left-hand side of 1, are unpenalized and receive a penalty of zero percent. Hospitals on the right-hand side of 1, are penalized. The penalty increases linearly and is kinked at 1. Table 1, presents the coefficients of for both the slope and the penalty indicator at the threshold. Visually there is no evidence of a “jump” at the threshold. This is also confirmed by estimated presented in table 1.
Figure 3
The Relationship between Hospital Excess Readmission Ratio for HF and HRRP Penalty

Notes – The figure plots the linear predicted penalty for the HF subsample against the actual penalty assigned by CMS in round 1 of the HRRP. The entire distribution of hospitals in the HF subsample is used (0.8 to 1.2). Hospitals on the left-hand side of 1, are unpenalized and receive a penalty of zero percent. Hospitals on the right-hand side of 1, are penalized. The penalty increases linearly and is kinked at 1. Table 1, presents the coefficients of for both the slope and the penalty indicator at the threshold. Visually there is no evidence of a "jump" at the threshold. This is also confirmed by estimated presented in table 1.
Figure 4 A, B and C – 30-Day Risk Un-Adjusted Readmissions
(Period Prior to the HRRP- August 2010 to August 2011)

Notes – Each figure presents the 30-day readmissions prior to the HRRP for the subsample that was not penalized and the subsample that was penalized for a single specific condition. Hence, in panel A, I show the hospitals not penalized for any conditions and the hospitals only penalized for HF. Panel B, shows the hospitals not penalized and only penalized for AMI. The solid line represents predicted 30-day readmissions from a regression of 30-day readmissions on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator. Hospitals within a narrow bandwidth of 0.9 to 1.1 are plotted. Table 2, shows the estimates of the exact analysis with a narrower bandwidth (0.9 to 1.1). Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above as well as table 2.
Notes – Each circle represents the length of stay for an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents predicted length of stay from a regression of length of stay on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. The entire distribution of hospitals is plotted. Table 3, shows the estimates of the exact analysis with a narrower bandwidth (0.9 to 1.1). Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above as well as table 3.
Notes – Each circle represents 30-day mortality after an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents predicted 30-day mortality from a regression of 30-day mortality on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. The entire distribution of hospitals is plotted. Table 3, shows the estimates of the exact analysis with a narrower bandwidth (0.9 to 1.1). Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above as well as table 3.
Notes – Each circle represents the percentage of black patients admitted for an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents predicted percentage black from a regression of percentage black on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. Table 4, shows the estimates of the exact analysis. Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above as well as table 4.
Figure 8 – Percentage of AMI patients with Multiple Complications in 2010
(Period Prior to the HRRP)

Notes – Each circle represents the percentage of patients with multiple complications (MCC) admitted for an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents the percentage with MCC from a regression of MCC on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. Table 4, shows the estimates of the exact analysis. Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above and table 4.
Notes – Each circle represents the age of patients admitted for an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents age from a regression of age on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. Table 4, shows the estimates of the exact analysis. Evidence of no kink at the threshold in the period immediately prior to the HRRP is presented in both the figure above and table 4.
Notes – Each circle represents the round 2 score for HF readmissions in the HF subsample. The solid line represents predicted round 2 score from a regression of round 2 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 5 shows the estimates of the exact analysis.
The Relationship between the AMI round 1 score and the AMI round 2 score (1 Year Post Period)

Notes – Each circle represents the round 2 score for AMI readmissions in the AMI subsample. The solid line represents predicted round 2 score from a regression of round 2 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 5 shows the estimates of the exact analysis.
Notes – Each circle represents the round 2 score for PN readmissions in the PN subsample. The solid line represents predicted round 2 score from a regression of round 2 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 5 shows the estimates of the exact analysis.
The Relationship between AMI round 1 Score and the AMI Round 3 Score (2 Years Post Period)

Notes – Each circle represents the round 3 score for AMI readmissions in the AMI subsample. The solid line represents predicted round 3 score from a regression of round 3 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline.
Figures 11 B & 11 C –

Relationship between HF and PN round 1 Score and HF and PN Round 3 Score

Notes – In Figure 11 B, each circle represents the round 3 score for HF readmissions in the HF subsample. The solid line represents predicted round 3 score from a regression of round 3 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. In Figure 11 C, each circle represents the round 3 score for PN readmissions in the PN subsample. The solid line represents predicted round 3 score from a regression of round 3 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline.
Figures 12 A & B
Relationship between HF round 1 Score and HF 30-day Readmissions 1 and 2 Years Post the HRRP

Notes – In each figure, each circle represents the 30-day HF readmission rate in the HF subsample in post periods. The solid line represents predicted 30-day readmission rate score from a regression of 30-day readmissions on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, and controls for the HVBP bonuses. Figure 12 A, shows the 30-day readmissions for HF patients 1 year post the implementation of the HRRP. Figure 12 B, shows the 30-day readmissions for HF patients 2 years post the implementation of the HRRP.
Figures 13 A & B

Relationship between AMI round 1 Score and AMI 30-day Readmissions 1 and 2 Years Post the HRRP

Notes – In each figure, each circle represents the 30-day AMI readmission rate in the AMI subsample in post periods. The solid line represents predicted 30-day readmission rate score from a regression of 30-day readmissions on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, and controls for the HVBP bonuses. Figure 13 A, shows the 30-day readmissions for AMI patients 1 year post the implementation of the HRRP. Figure 13 B, shows the 30-day readmissions for AMI patients 2 years post the implementation of the HRRP.
Figures 1A & B

Relationship between PN round 1 Score and PN 30-day Readmissions 1 and 2 Years Post the HRRP

Notes – In each figure, each circle represents the 30-day PN readmission rate in the PN subsample in post periods. The solid line represents predicted 30-day readmission rate score from a regression of 30-day readmissions on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, and controls for the HVBP bonuses. Figure 1A shows the 30-day readmissions for PN patients 1 year post the implementation of the HRRP. Figure 1B shows the 30-day readmissions for PN patients 2 years post the implementation of the HRRP.
Notes – Each circle represents the AMI total charges for hospitals in the AMI subsample. The solid line represents predicted total charges from a regression of total charges in the post period on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 7, shows the estimates of the exact analysis.
Notes – Each circle represents the AMI lab charges for hospitals in the AMI subsample. The solid line represents predicted lab charges from a regression of lab charges in the post period on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 7, shows the estimates of the exact analysis.
Appendix Figure 1A
The Relationship between the AMI Simulated Excess Readmission Ratio and the Actual Excess Readmission Ratio for AMI

Round 1

Notes – The figure plots the actual CMS Excess Readmission Ratio (Score) for AMI in round 1 on the simulated Excess Readmission Ratio (Score) for AMI in round 1. Visually there is evidence that the simulated score is highly correlated with the actual Excess Readmission Ratio calculated by CMS. The correlation between the simulated Excess Readmission Ratio and the actual CMS Excess Readmission Ratio is 0.92. CMS uses three datasets to calculate the Excess Readmission Ratio for each condition (the inpatient, outpatient and ER records). Since I only have access to the entire inpatient claims, I am not able to simulate the CMS Excess Readmission Ratio perfectly. However, using only one of the three datasets, I simulate an Excess Readmission Ratio that is highly correlated with that of CMS’s. For brevity, I only present the evidence for AMI here. HF and PN are also simulated with a high degree of correlation and the evidence is available upon request.
Appendix Figure 1B

The Relationship between the Round 1 AMI Simulated Excess Readmission Ratio and the Round 0 AMI Simulated Excess Readmission Ratio for AMI

Notes – The figure plots the Simulated CMS Excess Readmission Ratio (Score) for AMI in round 1 on the simulated Excess Readmission Ratio (Score) for AMI in round 0. The dots represent data points and the line represents the 45-degree line. Visually there is clear evidence that two Excess Readmission Ratios prior to the HRRP are highly correlated. The correlation is 0.98. This is to be expected since i) the Excess Readmission Ratio for each round is a 3-year assessment of risk-adjusted readmissions and ii) risk un-adjusted readmissions are also very highly correlated (see Appendix Table 1). Overall, the evidence indicates that readmissions rates are highly correlated over time. For brevity, I only present the evidence for AMI here. HF and PN are also simulated with a high degree of correlation and the evidence is available upon request.
Notes – Each circle represents the number of hospitals in each bin for hospitals in the AMI subsample in the per-HRRP period. The solid line represents predicted values from a regression of number of hospitals in each round 1 score bin on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, and the penalty indicator. Bin size of 0.025 is chosen. Appendix table 1 shows the estimates from this regression as well as the estimates from regressions where hospital scores are binned in 0.05, 0.10 bins.
Appendix Figures 3
Testing the Presence of a Kink to the Left of the HRRP Policy Threshold - AMI Sample

Notes – Appendix Figure 3A presents the estimates for the Round 2 AMI Excess Readmissions Ratio from a placebo test where I assign the threshold to be at different values to the left of the HRRP policy threshold. Each dot in Appendix Figure 3A represents a reduced form regression kink estimate from a separate regression, and the shaded area is the confidence interval of the estimate. For each regression, I only include the set of hospitals who were not penalized by the HRRP in round 1. There is no evidence of a kink prior to the actual policy threshold. Appendix Figures 3B and 3C replicate this test for Total Charges (3B) and 30-day mortality (3C).
Appendix Figures 4

Testing the Presence of a Kink to the Left of the HRRP Policy Threshold – HF and PN Sample

Notes – Appendix Figures 4A and 4B test the presence of a kink in total charges or Round excess readmission ratios at placebo thresholds to the left of the HRRP policy threshold. In each figure, each dot represents a reduced form regression kink estimate from a separate regression, and the shaded area is the confidence interval of the estimate. For each regression, I only include the set of hospitals who were not penalized by the HRRP in round 1. There is no evidence of a kink prior to the actual policy threshold. Appendix Figures 4C and 3D replicate this test for hospitals in the Pneumonia Sample.
Appendix Figures 5a.

Testing the Presence of a Kink Using Hospitals Both to the Left & Right of the HRRP Policy Threshold – AMI Sample

Notes – Appendix Figure 5a shows estimates from a placebo inference test, where I randomly assign the threshold to values close to the policy threshold but to the right and left of the true policy threshold (1.0). To estimate each coefficient, I rely on an equal bandwidth (+/- 0.1) to the right and left of the placebo threshold. For example, the threshold at 0.98 uses hospitals from 0.98 to 1.08 (right) and hospitals from 0.98 to 0.88 (left). The threshold at 1.02 uses hospital from 1.02 to 1.12 (right) and hospitals from 1.02 to 0.92 (left). The dependent variable is the Excess Readmission Ratio in Round 2 of the HRRP.
Appendix Figures 5b.
Testing the Presence of a Kink Using Hospitals Both to the Left & Right of the HRRP Policy – HF Sample

Appendix Figures 5c.
Testing the Presence of a Kink Using Hospitals Both to the Left & Right of the HRRP Policy – PN Sample

Notes – Appendix Figure 5b and 5c show estimates from a placebo inference test, where I randomly assign the threshold to values close to the policy threshold but to the right and left of the true policy threshold (1.0). To estimate each coefficient, I rely on an equal bandwidth (± 0.1) to the right and left of the placebo threshold. For example, the threshold at 0.98 uses hospitals from 0.98 to 1.08 (right) and hospitals from 0.98 to 0.88 (left). The threshold at 1.02 uses hospital from 1.02 to 1.12 (right) and hospitals from 1.02 to 0.92 (left). In Appendix Figure 5b, the dependent variable is the HF Excess Readmission Ratio in Round 2, in 5c it is the PN Excess Readmission Ratio in Round 2.