The Intended and Unintended Consequences of the Hospital Readmission Reduction Program

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Abstract

Pay for performance (P4P) is increasingly being used as a tool to improve the cost effectiveness of healthcare. However, evidence on the efficacy of P4P remains mixed. The Hospital Readmission Reduction Program (HRRP) is a prominent 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 obtain estimates of the effect of the HRRP on readmissions and potential mechanisms that hospitals may use to reduce readmissions, such as spending on inpatient care, discharge destination and patient selection. I also examine the effect of the HRRP on mortality. Estimates indicate that hospitals penalized for excess heart attack (AMI) readmissions decreased AMI readmissions by 30% and increased spending on AMI patients by 40%. This additional care had no impact on mortality. Interestingly, I find that hospitals penalized for AMI readmissions increased the quantity of care for patients with diagnoses not targeted by the HRRP. Thus the P4P incentives of the HRRP did not cause hospitals to reallocate resources away from non-targeted conditions. Hospitals penalized for excess readmissions for pneumonia or heart failure did not appear to respond to the HRRP incentives.

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1 Introduction

In 2010, the Hospital Readmissions Reduction Program (HRRP) was established as part of the Affordable Care Act. The HRRP is a pay− for− performance (P4P) program that 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.

For the first round of the HRRP (FY 2013), the penalty was capped at one percent of Medicare payments with the cap increasing to two and three percent in each subsequent year (Rau, 2013). Notably, payment reductions apply to every Medicare patient −not just for those who are readmitted. In 2013, 2,214 hospitals were penalized and the penalties amounted to approximately $125,000 per hospital, on average, and $280 million total. For hospitals that were close to the maximum, the penalty was approximately $2 million per hospital (Rau, 2012).

The penalty associated with the HRRP 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, according to the American Hospital Association(American Hospital Association, 2014), hospital profit margins are approximately four percent and twenty percent of hospitals have negative margins. 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 cuts in Medicare payments of approximately the same size as those imposed by the HRRP[1]. 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 on targeted HRRP patients and "shortchange" other patients. Studies of other pay for performance policies have found evidence to support this get what you pay for hypothesis(Lo Sasso and Helmchen, 2010; Bardach et al. 2013; Rosenthal et al. 2004; Young et al. 2007).

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 assessment of the HRRP[2]. Given the limited study and the saliency of the HRRP, and the potential consequences of P4P programs, my research makes a significant contribution to both theory and policy. 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 targeted by the HRRP and conditions that are not a part of the HRRP. In short, I present evidence on whether the HRRP pay −for− performance program was successful in achieving its intended goals, and whether there were unintended consequences of the program, if there were consequences, the mechanisms that possibly explain those effects.

To accomplish these goals, I use a quasi−experimental research design−the regression kink (RK) and high-quality administrative data from Medicare. The RK has the

[1]See, White & Wu (2013); Shen & Wu (2013); White & Yee (2013); Seshamani et al. (2006); Peasah et al. (2013).

[2]See Zuckerman et al. (2016), Gupta (2016), Carey and Lin (2015), Mellor, Daly and Smith (2016) and Desai et al. (2016).

potential to yield estimates of the causal effects of the HRRP, and I provide considerable evidence of the validity of the 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 expenditures (care) on AMI patients that was also found. Moreover, the increase in expenditures in response to the HRRP penalty is larger among hospitals with a high Medicare share who are have a larger incentive to respond. 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 related to AMI.

2 Previous Research

There are only 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 the start of 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.

A few studies used quasi−experimental designs to study the HRRP. 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, non-target conditions may also be affected by HRRP because of a reallocation of resources from non-targeted to targeted conditions, or because hospitals make systematic changes that affect several 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. Gupta (2016) 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, which had a low probability of being penalized, to hospitals that had high readmission rates prior to the HRRP, which had a high probability of being penalized. Gupta (2016) 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. The difference-in-differences approach of Gupta (2016) and Mellor et al. (2016) are subject to the concern that hospitals with different levels of readmission in the baseline period will have different trends in outcomes, as these hospitals differ along many dimensions such as teaching status and share of poor and minority patients.

In sum, there is limited research on the HRRP and results from these prior stud-

ies are mixed. I contribute to this literature by conducting a national study of the effects of the HRRP on readmissions, the process of care, and mortality for conditions within the HRRP and outside the HRRP. No prior study has examined whether the HRRP has examined inpatient spending, which is an important potential mechanism, and whether there were spillover effects on non−HRRP conditions. The use of the regression kink (RK) design is novel in this context and it is known for its strength in terms of internal validity. The RK has several important advantages. First, the RK allows me to examine the conditions outside the HRRP, since the RK does not rely on the outside conditions as a counterfactual. Secondly, in contrast to studies using condition−specific or time variation in the penalty, the RK design holds any variation over time in penalized and unpenalized hospitals constant. 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 Bonuses (HVBP) that may confound difference-in-differences estimates. The RK is unaffected by these coincident policies[3].

3 Conceptual Model

There is considerable evidence that hospitals respond to financial incentives. 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 (Dafny 2005; Seshamani, Schwartz and Volpp 2006; Peasah et al. 2013)[4].

[3]I test whether hospitals on either side of the HRRP threshold vary in their HVBP bonuses and find no differential slope in HVBP penalties/bonuses on either side of the HRRP threshold.

[4]However, the evidence is not uniform. For example, Ryan et al. (2014) studied the Premier Hospital Quality Incentive Demonstration (HQID), which paid bonuses to high-performing hospitals in the mid-2000s, and found small to no effects of bonuses on the quality of care. One problem confronting Ryan et al. (2014) was that it did not have the power to detect small to moderate effects.

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 be focused on 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 profits (π) 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. 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 penalty (a lower fixed payment, $\alpha R_i, 0 < \alpha < 1$) on a hospital 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:

$$
\begin{aligned}
U^1 &= U^1[\pi^1, f(Q^1)], \qquad Q^1 = N_1{}^1 q_1{}^1 + N_2{}^1 q_2{}^1 \\
U^2 &= U^2[\pi^2, f(Q^2)], \qquad Q^2 = N_1{}^2 q_1{}^2 + N_2{}^2 q_2{}^2 \\
U &= U^1 + U^2
\end{aligned} \tag{1}
$$

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.

Profits of the firm are given by:

$$
\begin{aligned}
\pi^1 &= N_1(R_1 - c_1 {q_1}^1) + N_2(R_2 - c_2 {q_2}^1) \\
\pi^2 &= \rho({q_1}^1)\{N_1(\alpha R_1 - c_1 {q_1}^2) + N_2(\alpha R_2 - c_2 {q_2}^2)\} + \\
&\quad [1 - \rho({q_1}^1)]\{N_1(R_1 - c_1 {q_1}^2) + N_2(R_2 - c_2 {q_2}^2)\}
\end{aligned} \tag{2}
$$

In period 2 there is a probability that the hospital will be penalized (ρ) and that probability depends on the quantity of services provided for patients with illness type 1 in period 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. The costs of treating each type of patient (e.g., $c_1 {q_1}^1$) increase with greater use of services.

I assume that the hospital can influence readmission rates and thus the probability of being penalized by using more services to treat type 1 patients ($\frac{\partial \rho}{\partial q_1} < 0$). 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 αR_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. 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:

$$\frac{\partial U^1}{\partial Q^1}\frac{\partial Q^1}{\partial {q_1}^1} + \frac{\partial U^2}{\partial \pi^2}\frac{\partial \rho}{\partial {q_1}^1}[N_1(\alpha R_1 - R_1) + N_2(\alpha R_2 - R_2)] = N_1 c_1 \frac{\partial U^1}{\partial \pi^1}$$
$$\frac{\partial U^1}{\partial Q^2}\frac{\partial Q^2}{\partial {q_2}^1} = N_2 c_2 \frac{\partial U^1}{\partial \pi^1} \tag{3}$$

The equations in 3 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., $\frac{\partial U^1}{\partial Q^1}\frac{\partial Q^1}{\partial {q_1}^1}$) plus the increase in profits in period $t = 2$ due to the decreased probability of being penalized, $(\frac{\partial U^2}{\partial \pi^2}\frac{\partial \rho}{\partial {q_1}^1}[N_1(\alpha R_1 - R_1) + N_2(\alpha R_2 - R_2)])$, is equal to the marginal cost, which is equal to the utility costs of the additional service $(N_1 c_1 \frac{\partial U^1}{\partial \pi^1})$. Note that only the top equation in (3), 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 $t = 2$. Also, 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 reducing the probability of being penalized.

In the absence of the HRRP penalty, the choices of the hospital would be:

$$\frac{\partial U^1}{\partial Q^1}\frac{\partial Q^1}{\partial {q_1}^1} = N_1 c_1 \frac{\partial U^1}{\partial \pi^1}$$
$$\frac{\partial U^1}{\partial Q^2}\frac{\partial Q^2}{\partial {q_2}^1} = N_2 c_2 \frac{\partial U^1}{\partial \pi^1} \tag{4}$$

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.

The first−order conditions in (3) also illustrate that the cost of reducing the HRRP

penalties is lower the smaller the number of HRRP targeted patients. Since the HRRP targets only patients of type 1 (N_1), as N_1 rises the marginal cost of avoiding the penalty increases by relatively more than the marginal benefit. This is due to :

$$\frac{\partial U^2}{\partial \pi^2}\frac{\partial \rho}{\partial {q_1}^1}(\alpha R_1 - R_1) < c_1 \frac{\partial U^1}{\partial \pi^1} \tag{5}$$

This would imply that it is potentially more difficult to reduce readmissions for targeted conditions with a large number of admissions than targeted conditions with a lower number of admissions. Thus, hospitals penalized, or expected to be penalized, for conditions that represent a relatively small large share of admissions can focus care on a few number of patients to avoid the penalty and 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. In addition, HRRP conditions that are less prevalent, such as AMI, are conditions for which it is more likely to see a response.

To summarize, this simple model shows that a hospital, when choosing the amount of services to provide, will take into consideration the effect of providing more services in current period to a patient on future revenues. Greater provision of services will lower the probability of readmission, the size of the HRRP penalty and the probability of being penalized in the future, which raises future revenues. Because the HRRP penalty only considers readmissions for certain types of patients (e.g., type 1 illness), this forward-looking behavior only applies to those illnesses. Thus, the penalty causes the hospital to provide more services (improve the quality of care) to patients with an illness that is part of the readmission. This is exactly the intent of the HRRP− to increase the quality of care and reduce readmissions. An unintended consequence, however, may be that the hospital provides fewer services for conditions that are not considered as part of the HRRP penalty. Which is a possibility I investigate directly[5].

[5]The theoretical model I propose assumes substitution of resources away from conditions not targeted by the HRRP. However, other models such as Glazer and McGuire (2002) assume that there is a common level of quality across patients. In such a model, the HRRP penalty may result in the increase in the quantity and/or quality of care for non-HRRP patients.

The simple model above implies that all hospitals will respond to the HRRP penalty because ($\frac{\partial \rho}{\partial q^1} < 0$) and all firms can reduce the probability of being penalized. This 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. Hospitals above that readmissions threshold, which presumably depends on the quantity of services provided to patients with illness type 1, as described earlier, are likely to respond. Hospitals far below the readmissions threshold of being penalized are unlikely to respond. In general, whether a hospital responds to the HRRP depends on two conditions: how much randomness is associated with the probability of being penalized and the hospitals ability to influence readmissions and the probability of being penalized. Therefore, even if ($\frac{\partial \rho}{\partial q^1} < 0$) the firm may not respond to the HRRP if there is no chance of being penalized.

The uncertainty of the probability of being penalized can be formalized. Following the HRRP rule, the probability of being penalized is a function of the quantity of readmissions in period 1(τ_1), which I assume depends on the quantity of service provided to patients with illness type 1 in period 1, and a random component[6]. Specifically, I assume that the probability of being penalized is the following:

$$\rho = Pr[\tau_1({q_1}^1) - e > k], \qquad e \sim N(o, \sigma^2)$$

$$\rho = F[\tau_1({q_1}^1) - k] \tag{6}$$

$$\frac{\partial \rho}{\partial q^1} = \frac{\partial F}{\partial q^1} < 0$$

In equation (6), k is the threshold of readmissions that determine whether a hospital

[6]The Excess Readmission Ratio (readmission score) 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 hospitals performance with its observed case mix and a hospitals 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 hospitals case mix and the average hospital effect, it is also a rate per 100 discharges. The ratio of predicted to expected readmissions produces the readmission score. A hospital with a score greater than 1 is penalized and the penalty is a linear function of the readmission score. A hospital with a score of 0.999 is close to the penalty but unpenalized. The probability of this hospital receiving a penalty in the next round is not zero but positive.

is penalized and F is the cumulative normal distribution. Hospitals know the value of k, for example, because they know the rule that CMS uses to calculate predicted readmissions, or because it is a period after the first round of penalties when k was revealed to hospitals. 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 (6). First,the probability of being penalized depends on the productivity of spending ($\frac{\partial \rho}{\partial q^1}$) on readmissions. Second,the smaller is 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. Thus, firms will be less likely to respond when there is a large variance. The variance of the random component may differ by hospital.

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 (large $\frac{\partial \rho}{\partial q^1}$). Similarly, a hospital that was penalized may not respond if they have little ability to influence the probability of being penalized ($\frac{\partial \rho}{\partial q^1}$ close to zero or a very large variance of e). I therefore also test whether hospitals that came close to being penalized responded to the HRRP.

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). I provide evidence below to show that hospitals did not anticipate being penalized. To obtain the estimates

of interest, I utilize a regression kink (RK) design.

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[7]. 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 in a linear fashion. 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 RK design assumes that hospitals on either side of the excess readmission threshold (1.0) are likely to be quite similar and that a hospital with an excess readmission ratio equal to or just below 1.0 is arguably a good comparison hospital for a hospital with an excess readmission ratio just greater than 1.0. It is therefore possible to exploit the "kink" in the penalty formula to identify the causal effect of the readmission penalties on outcomes such as inpatient spending and mortality. The fundamental assumption is that hospitals on either side of the excess readmission threshold of 1.0 are as good as randomly assigned.

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 linearly with the excess readmission ratio starting at zero 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

[7]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

the excess readmission ratio on outcome Y, for example, inpatient spending, in relation to the change in the effect (slope) of the excess readmission ratio on the size of the penalty (treatment). Thus, unlike the RD approach, hospitals away from the "kink" contribute to the estimate because of the centrality of the slope and identifying the point at which the slope changes in the RK design. 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, as does the incentive to respond, and it is this changing incentive that identifies the slope.

The interpretation of the estimates from the regression kink design depends on which hospitals respond, or if any hospital responds. As the conceptual model indicates, hospitals respond to the expected penalty, which is unmeasured.

In this paper, I assume that the expected penalty of the hospital is equal to the actual penalty received in round 1. So, I compare hospitals that were penalized to hospitals that were not penalized exploiting the kinked nature of the penalty. This is a reasonable assumption because there is substantial persistence in readmissions over time within hospitals. In Appendix Table 1, I report coefficients from a regression of readmissions rates in round 1 of the HRRP (the last exogenous 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, indicating persistence in readmission rates over time. However, conceptually as noted earlier, hospitals that were not, but close to, being penalized may respond if there is some uncertainty as to whether they will be penalized in the future, although the incentive for these hospitals to respond is small because the penalty is very small at the threshold and grows linearly with the excess readmission ratio. I test for this possibility explicitly, by assessing whether there is a change in the slope to the left of the HRRP penalty threshold. I report results below, but note here that there is no evidence that this is the case.

One complication in applying the RK design is that the readmissions penalty is a function of the excess readmission ratio for three conditions: 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[8]. 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

[8]Including controls for the excess readmission ratio for the two other conditions eg:(HF and PN in the AMI sample) does not alter estimates.

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. 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. For example, as noted earlier, the incentive to respond is larger when there are relatively fewer patients and the number (share) of patients differ by HRRP conditions. Stratifying the sample as I do, allows me test if hospitals selectively respond to reducing readmissions across AMI, HF and PN.

Figure 1 shows the actual relationship between the readmission penalty and the excess readmission ratio for hospitals in the first round of the HRRP that were penalized only because of excess readmissions for Heart Failure (HF). The points in Figure 1 are derived from a regression analysis in which the dependent variable is the readmission penalty (in percent) and the independent variables are the excess readmission ratio for HF and an interaction between the excess readmission ratio and a dummy variable indicating that the excess readmission ratio is greater than 1.0 (see equation 7 below). The plot in Figure 1 shows that the readmission penalty is zero below the excess readmission ratio threshold of 1.0. After that threshold, the readmission penalty increases linearly with the excess readmission ratio reaching a maximum of one percent. Figures 2 and 3 show analogous relationships for the other two conditions and both reflect the "sharp" regression kink feature.

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

$$(7)\quad \text{PENALTY}_{jt+1} = b_0 + b_1\text{EXCESS\_RATIO}_{jt} + b_2(\text{EXCESS\_RATIO}_{jt}{}^{*}\text{ABOVE}_{jt}) + \varepsilon_{jt}$$

$$(8)\quad \text{OUTCOME}_{jt+1} = a_0 + a_1\text{EXCESS\_RATIO}_{jt} + a_2(\text{EXCESS\_RATIO}_{jt}{}^{*}\text{ABOVE}_{jt}) + u_{jt}$$

$$(9)\qquad \text{OUTCOME}_{jt+1} = \gamma_0 + \gamma_1\text{EXCESS\_RATIO}_{jt} + \gamma_2\text{PENALITY}_{jt} + \nu_{jt}$$

In equation (7), 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 (7) and verifies that the regression mimics the penalty formula; estimates show that the coefficient on the excess readmission ratio ("b_1") is virtually zero, which is expected because the penalty is zero prior to the excess readmission threshold.

In equation (8), 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 ("$_2$") 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 (9) 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 (9) from estimates in equation (7).

Equations (7) through (9) are illustrative, although not far from the actual regressions I estimate. I add baseline covariates to equations (7) through (9) 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.

Table 1 presents the first− stage estimates from regression models (equation 7) 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 treatment at the threshold, but a change in slope (kink)[9]. 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.

[9]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.

Estimates in Table 1 indicate that for hospital penalized for HF or PN excess readmissions, reducing the excess readmission ratio by 0.01 (1 unit) yields a 0.05 percent increase in revenue and all hospitals along the positively sloped line face this incentive. In the case of AMI penalized hospitals, a 0.01 (1 unit) reduction in the excess readmissions ratio, yields a 0.03 percent increase in revenue. This difference in slope estimates reflects the differential weights CMS assigns to AMI, HF and PN readmissions in calculating the penalty. Therefore, these estimates suggests that the benefit of reducing HF and PN readmissions is higher than the benefit of reducing AMI readmissions.

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 in the association between inpatient spending and the excess readmission ratio at the threshold, then this is evidence that the HRRP had an effect.

4.1 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 its 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[10]. 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 1.0 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 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)[11].

[10]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, childrens, 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.

[11]These exemptions however did not exclude the majority of hospitals that treat most AMI, HF and PN conditions85% of AMI Medicare inpatient admissions were treated in hospitals that were 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.

4.2 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 (8) 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 a research design.

Table 2 shows the estimates from equation (8) on mortality, total charges, length of stay and discharge destination 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 analysisif 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 Figures 4 and 5, 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[12].

In Table 3 I present estimates from another "placebo" analysis, but on patient characteristics in the prior period. I examine patients age, sex, race and the percentage

[12]Table 2 provides the coefficient estimates for the regression in equation (7) for all three HRRP conditions (AMI, HF and PN). Graphically, all three conditions follow the same pattern shown in the AMI graphs in Figures $4-8$.

of patients assigned DRGs that indicate multiple complications.In Figures $6-8$, I illustrate these results graphically. In Figure 6, I present the relationship between the excess readmissions ratio and the percentage of black patients in the pre-treatment period. Similarly, in Figures 7 and 8, 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)[13] , 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 2 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 1, I find no evidence that hospitals responded pre-emptively to avoid the penalty for hospitals in the AMI panel[14]. I formally test the continuity and smoothness of the distribution of hospitals at the readmissions penalty threshold for all 3 conditions (Appendix Table 3) following Card et al. (2012) using various sized bins. The evidence indicates no manipulation by hospitals at the threshold,

[13]DSH Percent = (Medicare SSI Days / Total Medicare Days) + (Medicaid, Non-Medicare Days / Total Patient Days)

[14]The Heart Failure (HF) and Pneumonia (PN) panels follow the exact pattern shown for AMI.

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.

5 Results

5.1 The impact of the HRRP on readmissions

The first set of results I present are for readmissions, which are measured using CMS calculations. I examine whether the HRRP penalty in round 1 affected the round 2 excess readmission ratio. Table 4 presents the reduced form (equation 8) 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[15].

In Table 4, 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 2 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

[15]The results presented in table 4 use only hospitals with an excess ratio between 0.9 and 1.1 (75% of the entire distribution). 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 4.

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 9a illustrates this result and it is clear from figure 9a 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 4. 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 ratioe. Overall, estimates in the top panel of Table 4 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 4 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 9b illustrates the marked and significant change in the slope for the AMI round 2 excess readmission ratio. The estimates in table 4 suggest that the HRRP caused penalized hospitals to reduce readmissions for AMI.

The bottom panel of Table 4 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 readmissions for pneumonia (see figure 9c)[16].

5.2 Interpreting Estimates

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. If evidence indicates that hospitals that were not penalized did not respond, then the differences in outcomes between hospitals that were and were not penalized represent the response of only hospitals that were penalized, or what may be considered the total program effect.

A test for whether hospitals to the left of the penalty threshold responded is motivated by randomization inference procedure that produces a distribution of placebo estimates in regions without a policy kink. Simply, I alter the excess readmission threshold a large number of times and re-estimate the model to construct a distribution of estimates. Appendix Figure 2a shows the distribution of RK estimates for the relationship between the round 2 AMI score and the round 1 AMI score. Using the linear RK specification, I estimate changes in slope at placebo kink points to the left of the threshold. It is evident from the figure that the reduced form coefficient estimates peak, are most negative, at 1 and that further away from the threshold the estimates fluctuate around zero. In addition, the estimate at the true kink threshold of 1, falls in the 98th percentile of the distribution of placebo RK estimates. Two other similar figures for HF and PN are shown in Appendix figures 2b and 2c. There the estimates are all scattered around zero and there is no differential kink at the true policy thresh-

[16]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.

old of 1 or before it. This is also consistent with the evidence in Table 4, where the HRRP had no statistically significant effect on the round 2 excess readmission ratio for hospitals penalized for HF or PN .

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 given the large persistence in readmissions and the high likelihood that the probability of being penalized is strongly correlated with being penalized. Therefore, estimates in the previous table arguably reflect mainly the total program effect, and not the relative effect of hospitals penalized to those not penalized.

5.3 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, 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 hospital 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 5 presents the reduced form results (equation 8) for AMI, HF and PN.

There are few statistically significant or economically meaningful estimates in Table 5. 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. Figure 10-a and 10-b 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 5. 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 5 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).

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 5). 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 6 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 6 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. To better illustrate how the coefficients have changed in magnitude across the analysis periods, I plot the coefficients from the analysis on charges and labs in Figures 11a and 11b.Figure 11a shows the coefficients on total charges prior to the HRRP, the first 11 month of the HRRP, the last 3 month of the first 11 month period, and the entire round 2 period. The coefficient rises as the HRRP begins and maintains its magnitude throughout the analysis periods. Similarly, Figure 11b shows an identical analysis but for lab charges. The pattern is identical to that of total charges. Estimates in Table 6 and in Figures 11a and 11b reveal that that the HRRP had an effect on total charges and lab charges that occurred quickly and that persisted.

Finally, I 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 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 8, shows the estimates of the interaction of the penalty and the round 1 readmissions ratio for charges, discharge destination, length of stay and mortality using data from August 2011 to August 2014. The coefficients in the AMI panel on total charges and labs increase in magnitude and maintain the same sign. This indicates that the round 1 penalty had persistent effects that grew in magnitude. In the HF and PN panel, there is no indication of an increase in total charges or lab charges as the analysis period is extended to include round 2. This is consistent with the earlier evidence presented for round 1 of the HRRP.

In addition, Appendix Table 9 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 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 readmission reduction for these conditions.

5.4 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 7. Columns 1-3 of Table 7 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%s) 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[17]. Figure 11c, plots the reduced form coefficient estimates for 30−day AMI mortality across different analysis periods. The coefficient estimates fluctuate around zero and there is no clear pattern that would indicate a morality effect due to the HRRP.

For hospitals in the HF or PN samples, I find no evidence of a decrease in morality. 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 7 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 7, 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. Figure 11d, plots the reduced form estimates for the percentage of patients discharged to an SNF in the AMI sample. Each coefficient is produced from a different analysis period. There is no evidence of an increase in SNF disposition with the beginning of the HRRP period. The coefficients fluctuate around zero and remain statistically insignificant.

[17]Inpatient hospital mortality is not presented here. However, the reduced form kink estimate is also close to zero and statistically insignificant.

5.5 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 reduce readmissions by admitting less risky patients. CMS risk adjusts for a patients severity in the readmission score calculation, however it does not account for a patients socio-economic status or unobserved complications. An unintended consequence of the HRRP would be if penalized hospitals began selectively admitting patients based on their probability of a readmission. This would appear as a decline in the frequency of minorities, older, and marginally sicker patients admitted with the HRRP conditions.

Table 8, 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.

5.6 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 9 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 9 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% levels[18]. Out of the 10 conditions studies, five estimates of the interaction between the round 1 AMI excess ratio and penalty indicator are statistically significant at 5 % levels and all 10 coefficients indicate higher charges outside the HRRP conditions in hospitals penalized for AMI[19].

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 10 presents the reduced form kink estimates for 30−day mortality in conditions outside the HRRP. Estimates suggest no mortality gains outside the HRRP conditions.

[18]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.

[19]In Appendix Table 4 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.

5.7 Effect of the HRRP in Low vs High Medicare Share Hospitals

I present estimates of the effect of the HRRP on total and laboratory charges for AMI patients for two samples of hospitals stratified into a high and low Medicare share sample. The average percentage of Medicare patients from all hospital inpatient discharges is 50%. Hospitals in the low Medicare share sample have an average Medicare share of 0.4, and hospitals in the high Medicare share sample have an average Medicare share of 0.6. Since the HRRP penalizes a hospitals Medicare inpatient care bill, hospitals with a higher Medicare share of patients are more impacted by the HRRP penalties. I therefore, expect high Medicare hospitals to be more responsive to the HRRP penalties than low Medicare share hospitals.

Table 11 presents the estimates for AMI total charges and AMI lab charges (the main estimates). In the first column of Table 11, the coefficients indicate that in the low share sample, for hospitals that were not penalized, a 0.1 increase in the round 1 excess ratio is associated with a 550 decline in total charges. In contrast for hospitals that were penalized, a 0.1 increase in the excess ratio is associated with an 8220 increase in total charges. That is equivalent to a 25% increase in total charges. In the second column of Table 11, for hospitals with 50% or more Medicare inpatients, a 0.1 increase in the round 1 excess ratio is associated with a 5180 decline in total charges. In contrast for hospitals that were penalized, a 0.1 increase in the excess ratio is associated with a 9360 increase in total charges. That is equivalent to a 40% increase. Hospitals with a high Medicare share have a larger change in the slope at the HRRP threshold and they increase total charges by a relative 15% more compared to low Medicare share penalized hospitals[20] . Note, none of the estimates however in the low or high share samples are statistically significant this is partially due to the small sample size in each group.

[20]I also test whether high Medicare share hospitals penalized for HF or PN readmissions are more likely to respond and find no evidence of a relative response by medicare share for these two conditions

5.8 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.

Appendix Table 6, 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 7, 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.

6 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 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.

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

	Heart Failure		**AMI**		**Pneumonia**	
	Restricted	Unrestricted	Restricted	Unrestricted	Restricted	Unrestricted
Excess Readmission Ratio	-.0001	<0.0001	0.0001	<0.0001	-.0001	<0.0001
	(0.0003)	(0.0004)	(0.00045)	(0.0005)	(0.00049)	(0.0005)
[Penalty =1] Indicator		-.00002		.00006		-.00005
		(.00006)		(.00009)		(.00008)
Excess Readmission Ratio X [Penalty =1]	0.05**	0.05**	0.032**	0.032**	0.046**	0.046**
	(0.0008)	(0.0009)	(0.00108)	(0.0011)	(0.0011)	(0.0011)
Number of Observations	1106	1106	657	657	1112	1112
Mean dependent Variable	0.0007	0.0007	0.0005	0.0005	0.0005	0.0005
Adjusted (R^2)	(0.87)	(0.87)	(0.76)	(0.76)	(0.77)	(0.77)

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 Mortality, Discharge Destination and Charges Prior to the HRRP Implementation (FY 2010)

A. Heart Failure	**Mortality 30 Day**	**Mortality 60 Day**	**Mortality 90 Day**	**Discharged to SNF**	**Discharged to Home Care**	**Total Charges**	**Radiology Charges**	**Lab Charges**	**Pharmacy Charges**	**Length of Stay**
Excess Ratio	-0.0003	-0.0001	0.0008	0.0002	0.001	120.2	21.8	-13.7	9.1	0.005
	(0.0005)	(0.0005)	(0.0007)	(0.0009)	(0.00)	(149)	(12)	(33)	(24)	(0.01)
Excess Ratio X [Penalty =1]	-0.0006	-0.0006	-0.004*	-0.003	-0.002	-77.5	-37.2	68.3	16.9	-0.001
	(0.001)	(0.001)	(0.002)	(0.002)	(0.00)	(315)	(26)	(70)	(51)	(0.02)
Mean Dependent Variable	0.1	0.15	0.31	0.17	0.19	22082	1623	4187	3021	4.2
Number of Observations	856	856	856	856	856	856	856	856	856	856
B. AMI										
Excess Ratio	-0.0009	-0.0008	-0.0002	0.0003	0.001	-323	2.2	-97.6	36.2	0.004
	(0.0008)	(0.0009)	(0.001)	(0.001)	(0.00)	(317)	(23)	(65)	(51)	(0.02)
Excess Ratio X [Penalty =1]	0.001	0.002	0.0005	-0.0002	-0.002	710.5	24.9	258	-112.8	-0.01
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(649)	(47)	(133)	(105)	(0.03)
Mean Dependent Variable	0.09	0.14	0.17	0.18	0.13	34732	2276	5661	4553	4.5
Number of Observations	466	466	466	466	466	466	466	466	466	466
C. Pneumonia										
Excess Ratio	0.0001	0.0005	0.0008	0.0008	0.0004	10.75	16.9	16.3	-5.6	0.002
	(0.0005)	(0.0006)	(0.0006)	(0.001)	(0.0009)	(150)	(15)	(30)	(37)	(0.01)
Excess Ratio X [Penalty =1]	0.001	0.0007	0.0003	0.0003	0.0007	348	-6.1	64.3	4.0	0.03
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(324)	(32)	(65)	(81)	(0.02)
Mean Dependent Variable	0.09	0.13	0.15	0.19	0.14	23296	2052	3761	4518	4.6
Number of Observations	881	881	881	881	881	881	881	881	881	881

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 3
Estimates of the Effect of the HRRP on Patient Characteristics Prior to the HRRP Implementation

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

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 4
Estimates of The Effect of the HRPP in Round 1 on The Readmission Ratio in Round 2 of the HRRP

		Round 2 HF Excess Ratio	Round 2 AMI Excess Ratio	Round 2 Pneumonia Excess Ratio
A. Heart Failure	Excess Ratio	0.008***	-0.005	0.002*
		(0.0005)	(0.005)	(0.0009)
	Excess Ratio X [Penalty =1]	-0.001	0.0007	-0.002
		(0.001)	(0.01)	(0.002)
	Mean Dependent Variable	-0.02	-0.37	-0.05
	Number of Observations	841	841	841
		Round 2 AMI Excess Ratio	Round 2 HF Excess Ratio	Round 2 PN Excess Ratio
B. AMI	Excess Ratio	0.007***	0.002**	0.001
		(0.0008)	(0.0009)	(0.001)
	Excess Ratio X [Penalty =1]	-0.003*	-0.0008	-0.0003
		(0.001)	(0.002)	(0.003)
	Mean Dependent Variable	-0.02	-0.06	-0.06
	Number of Observations	466	466	466
		Round 2 PN Excess Ratio	Round 2 AMI Excess Ratio	Round 2 HF Excess Ratio
C. Pneumonia	Excess Ratio	0.007***	0.002	0.0009
		(0.0005)	(0.001)	(0.005)
	Excess Ratio X [Penalty =1]	-0.001	0.003	0.004
		(0.001)	(0.003)	(0.01)
	Mean Dependent Variable	-0.027	-0.06	-0.3
	Number of Observations	881	881	881

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 5

Estimates of the Effect of the HRRP on Total and Specific Service Charges Post the HRRP Implementation Round 1

A.	Total Charges	Radiology Charges	Lab Charges	Pharmacy Charges	Length of Stay
Excess Ratio	130.2	30.8	12.4	1.3	-0.0002
	(177)	(16)	(43)	(25)	(0.01)
Excess Ratio X [Penalty =1]	19.9	-38.23	38.23	55.07	0.005
	(364)	(33)	(91)	(58)	(0.02)
Mean Dependent Variable at pretreatment year 2010	22082	1623	4187	3021	4.2
Number of Observations	841	841	841	841	841
B. 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
C. 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 6
Estimates of the Effect of the HRRP on Morality, Discharge Destination, and Charges in the first 11 month post the HRRP Implementation

AMI (First 11 month)	**Mortality 30 Day**	**Mortality 60 Day**	**Mortality 90 Day**	**Discharged to SNF**	**Discharged to Home Care**	**Total Charges**	**Radiology Charges**	**Lab Charges**	**Pharmacy Charges**	**Length of Stay**
Excess Ratio	-0.0006	-0.0002	-0.0004	-0.000364	0.00135	-585.5*	-18.58	-141.4*	14.10	0.000298
	(0.0007)	(0.0009)	(0.0009)	(0.00118)	(0.00107)	(292.0)	(21.53)	(62.20)	(46.74)	(0.0130)
Excess Ratio X [Penalty =1]	0.00171	0.00110	0.0009	-0.00003	-0.0019	1287	86.49	366.5*	-41.98	0.00975
	(0.00147)	(0.00177)	(0.00191)	(0.00237)	(0.00228)	(683)	(53.23)	(162.9)	(108.6)	(0.0267)
Mean Dependent Variable	0.09	0.14	0.17	0.18	0.13	34732	2276	5661	4553	4.5
Number of Observations	466	466	466	466	466	466	466	466	466	466

Table 7

Estimates of the Effect of the HRRP on Mortality, Discharge Destination and Charges Post the HRRP Implementation Round 1

A. **Heart Failure**	**Mortality 30 Day**	**Mortality 60 Day**	**Mortality 90 Day**	**Discharged to SNF**	**Discharged to Home Care**
Excess Ratio	-0.0006	-0.0003	-0.0006	-0.0005	0.00115
	(0.0005)	(0.0006)	(0.0007)	(0.0009)	(0.00131)
Excess Ratio X [Penalty =1]	-0.0003	-0.001	-0.0014	0.0006	-0.00178
	(0.001)	(0.0013)	(0.0015)	(0.002)	(0.003)
Mean Dependent Variable at pretreatment year 2010	0.1	0.15	0.31	0.17	0.19
Number of Observations	841	841	841	841	841
B. AMI					
Excess Ratio	0.0003	0.0005	0.0006	-0.0002	0.0002
	(0.0007)	(0.0008)	(0.001)	(0.001)	(0.001)
Excess Ratio X [Penalty =1]	-0.0008	-0.001	-0.0007	0.0017	0.0005
	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
Mean Dependent Variable at pretreatment year 2010	0.09	0.14	0.17	0.18	0.13
Number of Observations	466	466	466	466	466
C. Pneumonia					
Excess Ratio	-0.00003	-0.00004	0.0002	0.001	0.001
	(0.0005)	(0.0005)	(0.0006)	(0.00)	(0.001)
Excess Ratio X [Penalty =1]	-0.00009	0.000002	0.0003	-0.0008	0.0005
	(0.0009)	(0.001)	(0.00)	(0.002)	(0.002)
Mean Dependent Variable at pretreatment year 2010	0.09	0.13	0.15	0.19	0.14
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 Patient Characteristics Post the HRRP Implementation Round 1

		Age	Portion Female	Portion Black	Percentage with Multiple Complications DRG Code
A. Heart Failure					
	Excess Ratio	0.03	0.0003	0.0005	0.004**
		(0.06)	(0.0009)	(0.002)	(0.001)
	Excess Ratio X [Penalty =1]	-0.3	0.004	0.01*	-0.004
		(0.2)	(0.002)	(0.005)	(0.003)
	Mean Dependent Variable	78	0.55	0.1	0.38
	Number of Observations	841	841	841	841
B. AMI					
	Excess Ratio	-0.02	0.002	0.0018	0.002
		(0.09)	(0.001)	(0.0017)	(0.002)
	Excess Ratio X [Penalty =1]	0.05	-0.003	-0.002	-0.003
		(0.2)	(0.002)	(0.003)	(0.003)
	Mean Dependent Variable	78	0.47	0.07	0.51
	Number of Observations	466	466	466	466
C. Pneumonia					
	Excess Ratio	-0.06	-0.0004	0.001	-0.002
		(0.06)	(0.0008)	(0.001)	(0.002)
	Excess Ratio X [Penalty =1]	0.03	0.0014	0.005	0.003
		(0.12)	(0.0016)	(0.003)	(0.004)
	Mean Dependent Variable	76	0.54	0.07	0.33
	Number of Observations	881	881	881	881

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 9

Estimates of the Effect of the HRRP on Total Charges in Conditions Excluded from the Penalty Formula Post the HRRP Implementation Round 1

A. **Heart Failure**	**COPD**	**Cardiac Arrhythmia**	**Septicemia**	**Pulmonary Edema**	**Kidney Infection**	**Renal Failure**	**Bone Disease**	**Stroke**	**Hip & Joint Replacement**	**Psychosis**
Excess Ratio	53.47	13.38	289	35.12	4.798	145.0	-109.6	13.59	7.141	210.5
	(181.5)	(135.5)	(1355)	(261.1)	(132.7)	(175.9)	(188.0)	(650.1)	(363.7)	(217.9)
Excess Ratio X [Penalty =1]	-52.29	46.71	1672	157.5	-59.20	-210.2	1119.4	2535.6	735.2	-203.7
	(388.7)	(310.2)	(3044)	(581.0)	(293.1)	(371.5)	(885.8)	(1598)	(863.8)	(459.5)
Mean Dependent Variable	24865	2109	150128	30921	19700	24816	20300	66694	56045	22909
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 10

Estimates of the Effect of the HRRP on 30 Day Mortality in Conditions Excluded from the Penalty Formula Post the HRRP Implementation Round 1

A. **Heart Failure**	**COPD**	**Cardiac Arrhythmia**	**Septicemia**	**Pulmonary Edema**	**Kidney Infection**	**Renal Failure**	**Bone Disease**	**Stroke**	**Hip & Joint Replacement**	**Psychosis**
Excess Ratio	0.0002	0.00008	-0.0018	0.003	0.0004	0.002	-0.001	0.005	0.00008	-0.003
	(0.0005)	(0.0005)	(0.003)	(0.002)	(0.0005)	(0.0008)	(0.002)	(0.003)	(0.0003)	(0.001)
Excess Ratio X [Penalty =1]	0.0001	0.000003	0.003	-0.005	-0.0007	-0.004*	0.002	-0.01	-0.0006	0.009
	(0.001)	(0.001)	(0.008)	(0.004)	(0.001)	(0.002)	(0.002)	(0.008)	(0.0006)	(0.005)
Mean Dependent Variable	0.05	0.05	0.45	0.21	0.06	0.12	0.02	0.21	0.015	0.02
B. **AMI**										
Excess Ratio	-0.001*	-0.0006	0.002	-0.004**	-0.00003	-0.0006	0.001	-0.007*	0.0001	-0.0004
	(0.0005)	(0.0004)	(0.003)	(0.001)	(0.0005)	(0.0007)	(0.001)	(0.003)	(0.0001)	(0.001)
Excess Ratio X [Penalty =1]	0.001	0.0003	0.003	0.005	-0.0007	0.0003	-0.002	0.01*	-0.0003	0.001
	(0.001)	(0.0007)	(0.006)	(0.003)	(0.00101)	(0.001)	(0.003)	(0.006)	(0.0004)	(0.003)
Mean Dependent Variable	0.05	0.05	0.47	0.21	0.05	0.11	0.02	0.19	0.015	0.01
C. **Pneumonia**										
Excess Ratio	-0.0007	-0.0004	0.0014	0.004*	0.0009	0.0003	-0.0004	0.007*	0.00004	0.0002
	(0.0005)	(0.0007)	(0.003)	(0.002)	(0.0004)	(0.001)	(0.001)	(0.003)	(0.0002)	(0.001)
Excess Ratio X [Penalty =1]	0.0012	-0.0002	0.005	-0.002	-0.002*	-0.002	0.004	-0.02**	-0.00009	0.0009
	(0.0009)	(0.001)	(0.007)	(0.004)	(0.001)	(0.002)	(0.003)	(0.006)	(0.0005)	(0.003)
Mean Dependent Variable	0.05	0.05	0.45	0.21	0.06	0.13	0.02	0.22	0.015	0.02

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 11
Regression Kink Estimates for Total Charges and Lab Charges by Medicare Share Post the HRRP
AMI Sample

A. Total Charges		**Total Charges Medicare Share <0.5**	**Total Charges Medicare Share >=0.5**	**Total Charges Entire Sample**
	Excess Readmission Ratio	-55.51	-518	-580.8*
		(260)	(403)	(288.0)
	Excess Ratio X [Penalty =1]	877	936	1323.6*
		(530)	(894)	(665.9)
	Number of Observations	251	215	466
B. Lab Charges		**Lab Charges Medicare Share <0.5**	**Lab Charges Medicare Share >=0.5**	**Lab Charges Entire Sample**
	Excess Readmission Ratio	15.20	-101	-138.6*
		(59.33)	(87)	(62.38)
	Excess Ratio X [Penalty =1]	80.74	190	357.5*
		(122)	(218)	(160.5)
	Number of Observations	251	215	466

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. Panel A reports the estimates for total charges for an AMI episode of care, and panel B reports the estimates for lab charges for an AMI episode of care. In each panel, the low Medicare share column contains hospitals with less than 50% of Medicare patients across all inpatient discharges and the high Medicare share column contains hospitals with 50% or more Medicare patients across all inpatient discharges. Hospitals with less than 50 cases throughout the 3 year assessment period are excluded and hospitals with an excess readmission ratio outside the range of 0.9 to 1.1 are 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 1
Regression of Readmission Rates in Round 1 on Readmission Rates in Round 0 –
The Two Periods Prior to the HRRP

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

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 2
Estimates of the Effect of the HRRP on Hospital Characteristics Prior to the HRRP Implementation

		Medicare Share	Disproportionate Share	Number of Hospital Beds	Amount of HVBP Bonuses/Penalties in Round 1
A. Heart Failure					
	Excess Readmission Ratio	-0.34	0.055	-250	-0.00002
		(0.217)	(0.23)	(310)	(0.00003)
	Excess Ratio X [Penalty =1]	.015	0.036	25	0.00003
		(0.021)	(0.023)	(30)	(0.00006)
	Mean Dependent Variable	0.47	0.24	235	0.00003
	Number of Observations	856	856	856	856
B. AMI					0.00005
	Excess Readmission Ratio	0.015	0.21	-140	(0.00004)
		(0.206)	(0.23)	(305)	
	Excess Ratio X [Penalty =1]	-0.013	0.003	-7.4	-0.0001
		(0.021)	(0.024)	(31)	(0.00007)
	Mean Dependent Variable	0.47	0.23	233	0.00003
	Number of Observations	465	465	465	465
C. Pneumonia					
	Excess Readmission Ratio	-0.05	0.27	-71	-0.00004
		(0.18)	(0.19)	(271)	(0.00003)
	Excess Ratio X [Penalty =1]	0.006	-0.016	-1.17	0.0001
		(0.019)	(0.019)	(27)	(0.0001)
	Mean Dependent Variable	0.48	0.22	237	0.0003
	Number of Observations	889	889	889	889

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 3

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

		Number of Hospitals		
		0.1 Bin Size	**0.005 Bin Size**	**0.025 Bin Size**
A. Heart Failure	[Penalty =1] Indicator	-0.78	-5.20	-2.44
		(0.61)	(3.06)	(1.67)
	Excess Ratio X [Penalty =1]	0.19	-0.06	0.01
		(0.43)	(2.14)	(1.15)
	Mean Dependent Variable	43.5	25.3	10.7
	Number of Observations	19	40	79
B. AMI	[Penalty =1] Indicator	-3.55	-1.55	-0.28
		(4.54)	(2.16)	1.02
	Excess Ratio X [Penalty =1]	2.43	1.07	0.22
		(2.89)	(1.52)	(0.73)
	Mean Dependent Variable	23.2	11.4	5.9
	Number of Observations	19	39	76
C. Pneumonia	[Penalty =1] Indicator	-15.74	-6.959	-3.708*
		(9.62)	(3.77)	(1.72)
	Excess Ratio X [Penalty =1]	8.01	2.71	1.40
		(6.16)	(2.61)	(1.19)
	Mean Dependent Variable	45.5	22.2	11.28
	Number of Observations	19	39	79

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: $N_b = \alpha + \beta_1 [Excess\ Ratio < 0] + \gamma\ Excess\ Ratio_b\ X\ 1[Excess\ Ratio < 0] + \sum_p [\pi_p\ (Excess\ Ratio)^p] + \varepsilon_b$. Where N_b represents the number of hospitals in bin *b*, and $\rho = 2$ 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.

Appendix Table 4

Estimates of the Effect of the HRRP on Total Charges in Conditions Excluded from the Penalty Formula Prior to the HRRP Implementation Round 1

A. **Heart Failure**	**COPD**	**Cardiac Arrhythmia**	**Septicemia**	**Pulmonary Edema**	**Kidney Infection**	**Renal Failure**	**Bone Disease**	**Stroke**	**Hip & Joint Replacement**	**Psychosis**
Excess Ratio	154.6	57.57	371.1	314.2	127.8	123.0	-10.72	69.81	72.4	223.4
	(138)	(114)	(256.2)	(249.9)	(118)	(135.7)	(142)	(537)	(304)	(195.6)
Excess Ratio X [Penalty =1]	-163.2	-108.5	-673.2	-660.2	-201.6	-195.6	149.3	1987	367	-500.9
	(291)	(240)	(533.9)	(530.0)	(245)	(283.0)	(347)	(1325)	(667)	(405.4)
Mean Dependent Variable	24865	2109	150128	30921	19700	24816	20300	66694	56045	22909
B. AMI										
Excess Ratio	-196.5	-262.7	-63.06	-224.5	-225.0	-295.0	-178.6	-395	-436.8	-3.382
	(195)	(169)	(391.1)	(351.9)	(178)	(211.2)	(206)	(550)	(389.3)	(241.1)
Excess Ratio X [Penalty =1]	499.7	651.5	592.3	543.1	628.0	843.2	683.7	2115.6	799.8	137.5
	(402)	(344)	(789.2)	(724.9)	(363)	(432.8)	(426)	(1150)	(800.1)	(495.6)
Mean Dependent Variable	28916	22733	163746	31500	22791	29834	20699	65030	58960	24836
C. Pneumonia										
Excess Ratio	-67.05	-3.251	102.6	-23.34	122.8	145.2	121.3	198.3	423	80.12
	(136)	(106)	(242.6)	(237.0)	(115.6)	(134.0)	(189)	(526)	(293)	(178.7)
Excess Ratio X [Penalty =1]	463.3	420.6	194.6	742.0	89.52	50.73	-185.7	504.3	-216	269.2
	(294)	(238)	(522.3)	(514.1)	(248.3)	(289.2)	(402)	(1112)	(637)	(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.

Appendix Table 5

Estimates of the Effect of the HRRP on 30 day Mortality in Conditions Excluded from the Penalty Formula Prior to the HRRP Implementation Round 1

A. **Heart Failure**	**COPD**	**Cardiac Arrhythmia**	**Septicemia**	**Pulmonary Edema**	**Kidney Infection**	**Renal Failure**	**Bone Disease**	**Stroke**	**Hip & Joint Replacement**	**Psychosis**
Excess Ratio	-0.0002	0.0003	0.001	0.0040	-0.00026	-0.00002	-0.0015	-0.005	0.0003	-0.0003
	(0.0002)	(0.0005)	(0.001)	(0.0022)	(0.0005)	(0.0005)	(0.001)	(0.004)	(0.0003)	(0.0015)
Excess Ratio X [Penalty =1]	0.00001	-0.001	-0.003	-0.0039	0.000036	-0.0005	0.00106	0.017	-0.0012	0.0023
	(0.001)	(0.0009)	(0.002)	(0.0047)	(0.0012)	(0.001)	(0.002)	(0.01)	(0.0008)	(0.0032)
Mean Dependent Variable	0.05	0.05	0.45	0.21	0.06	0.12	0.02	0.21	0.015	0.02
B. **AMI**										
Excess Ratio	0.00025	0.0004	0.0003	-0.00106	-0.00048	-0.0003	-0.0008	-0.004	0.0003	0.000612
	(0.0003)	(0.0003)	(0.001)	(0.00182)	(0.0004)	(0.0005)	(0.001)	(0.004)	(0.0002)	(0.000712)
Excess Ratio X [Penalty =1]	-0.0003	-0.00110	0.0007	0.000003	-0.00025	-0.00005	0.001	0.006	-0.0003	-0.00138
	(0.0006)	(0.0009)	(0.002)	(0.00375)	(0.0009)	(0.0009)	(0.002)	(0.009)	(0.0004)	(0.00146)
Mean Dependent Variable	0.05	0.05	0.47	0.21	0.05	0.11	0.02	0.19	0.015	0.01
C. **Pneumonia**										
Excess Ratio	0.0003	-0.0011*	0.0013	-0.00117	-0.00028	-0.0003	0.00172	-0.0019	.0004	-0.00193
	(0.0003)	(0.0004)	(0.001)	(0.00211)	(0.0004)	(0.0004)	(0.0009)	(0.004)	(0.0005)	(0.00140)
Excess Ratio X [Penalty =1]	-0.0013	0.0012	-0.0014	0.00641	0.00091	0.0008	-0.004	0.0005	-.0005	0.00423
	(0.0008)	(0.0011)	(0.002)	(0.00459)	(0.001)	(0.0009)	(0.002)	(0.008)	(0.0012)	(0.00299)
Mean Dependent Variable	0.05	0.05	0.45	0.21	0.06	0.13	0.02	0.22	0.015	0.02

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 6
Robustness of the AMI Estimates on Total Charges and Lab Charges to Varying Bandwidth

	Total Charges			Lab Charges		
AMI	**0.5 to 2.5**	**0.8 to 1.2**	**0.9 to 1.1**	**0.5 to 2.5**	**0.8 to 1.2**	**0.9 to 1.1**
Excess Ratio	-327	-736*	-580.8*	-57	107	-138.6*
	(180.5)	(336)	(288.0)	(35)	(49)	(62.38)
Excess Ratio X [Penalty =1]	983*	1347	1323.6*	189*	303	357.5*
	(416)	(733)	(665.9)	(85)	(126)	(160.5)
Mean Dependent Variable	37,367	37,278	34,732	6,041	6,082	5,661
Number of Observations	657	552	466	657	552	466

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.

Appendix Table 7
Robustness of the Estimates to not including Covariates and Choice of Polynomial Order

	Total Charges			Lab Charges		
AMI	**Linear Covariates**	**Linear No Covariates**	**Quadratic No Covariates**	**Linear Covariates**	**Linear No Covariates**	**Quadratic No Covariates**
Excess Ratio	-580.8*	-420.0	-336.2	-138.6*	-94.30	-104.6
	(288.0)	(315.4)	(1256.1)	(62.38)	(66.17)	(266.3)
Excess Ratio X [Penalty =1]	1323.6*	1200.0	998.8	357.5*	317.3	329.4
	(665.9)	(743.6)	(2446.6)	(160.5)	(171.1)	(518.7)
Excess Ratio Squared			4.337			-1.772
			(119.1)			(25.65)
Mean Dependent Variable	34732	34732	34732	5661	5661	5661
Number of Observations	466	466	466	466	466	466

Notes - 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 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.

Appendix Table 8

Estimates of the Effect of the HRRP on Mortality, Discharge Destination and Charges Post the HRRP Implementation (Aug 2011 – Aug 2014)

A. **Heart Failure**	**Mortality 30 Day**	**Mortality 60 Day**	**Mortality 90 Day**	**Discharged to SNF**	**Discharged to Home Care**	**Total Charges**	**Radiology Charges**	**Lab Charges**	**Pharmacy Charges**	**Length of Stay**
Excess Ratio	-0.00001	0.0006	0.0001	-0.00008	0.002	65.87	21.98	10.73	-10.92	-0.002
	(0.0005)	(0.0006)	(0.0007)	(0.0009)	(0.001)	(176.9)	(16.11)	(43.85)	(26.68)	(0.01)
Excess Ratio X [Penalty =1]	-0.001	-0.003*	-0.002	-0.0004	-0.00114	149.8	-30.19	36.53	73.75	0.02
	(0.001)	(0.001)	(0.002)	(0.002)	(0.00267)	(366.2)	(33.76)	(91.04)	(59.95)	(0.02)
Mean Dependent Variable	0.1	0.15	0.31	0.17	0.19	22082	1623	4187	3021	4.2
Number of Observations	841	841	841	841	841	841	841	841	841	841
B. AMI										
Excess Ratio	0.00116	0.001	0.0008	-0.0002	0.001	-695.1*	-25.25	-152.8*	-22.47	-0.015
	(0.0007)	(0.0008)	(0.0008)	(0.001)	(0.001)	(304.2)	(23.42)	(62.57)	(46.70)	(0.01)
Excess Ratio X [Penalty =1]	-0.002	-0.002	-0.001	0.001	-0.002	1548.1*	105.9	377.2*	20.09	0.04
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(704.2)	(58.41)	(163.9)	(105.3)	(0.03)
Mean Dependent Variable	0.09	0.14	0.17	0.18	0.13	34732	2276	5661	4553	4.5
Number of Observations	466	466	466	466	466	466	466	466	466	466
C. Pneumonia										
Excess Ratio	0.0004	0.0005	0.0006	0.001	0.001	66.41	14.69	31.46	16.77	0.004
	(0.0005)	(0.0005)	(0.0006)	(0.0009)	(0.001)	(162.2)	(16.69)	(34.87)	(39.35)	(0.01)
Excess Ratio X [Penalty =1]	-0.0005	-0.0001	0.0004	0.0001	-0.0001	256.0	2.098	-3.013	-47.03	0.01
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(352.1)	(36.08)	(77.67)	(79.02)	(0.02)
Mean Dependent Variable	0.09	0.13	0.15	0.19	0.14	23296	2052	3761	4518	4.6
Number of Observations	881	881	881	881	881	881	881	881	881	881

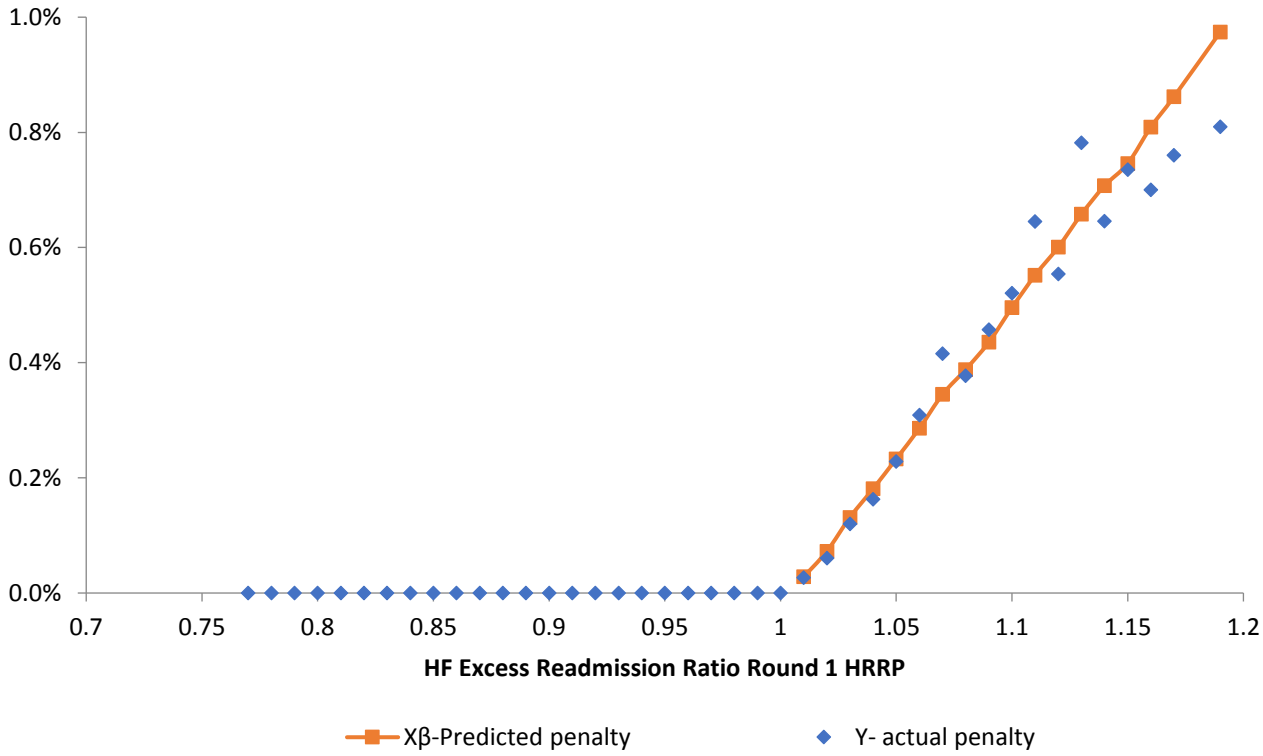
Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout 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 9
Estimates of The Effect of the HRPP in Round 1 on The Readmission Ratio & Penalty in Round 3 of the HRRP

		Round 2 HF Excess Ratio	Round 2 AMI Excess Ratio	Round 2 PN Excess Ratio
A. Heart Failure	Excess Ratio	0.006***	-0.006	0.0007
		(0.0008)	(0.005)	(0.0009)
	Excess Ratio X [Penalty =1]	-0.003	-0.001	0.0005
		(0.003)	(0.01)	(0.003)
	Mean Dependent Variable	-0.02	-0.4	-0.03
	Number of Observations	841	841	841
		Round 2 AMI Excess Ratio	Round 2 HF Excess Ratio	Round 2 PN Excess Ratio
B. AMI	Excess Ratio	0.006***	0.003*	0.0019
		(0.001)	(0.001)	(0.002)
	Excess Ratio X [Penalty =1]	-0.004	-0.0006	-0.00001
		(0.002)	(0.002)	(0.003)
	Mean Dependent Variable	-0.025	-0.05	-0.04
	Number of Observations	466	466	466
		Round 2 PN Excess Ratio	Round 2 AMI Excess Ratio	Round 2 HF Excess Ratio
C. Pneumonia	Excess Ratio	0.00461***	-0.00368	-0.000542
		(0.000904)	(0.00521)	(0.00199)
	Excess Ratio X [Penalty =1]	-0.000996	0.0193	0.00897*
		(0.00193)	(0.0110)	(0.00363)
	Mean Dependent Variable	-0.25	-0.37	-0.06
	Number of Observations	881	881	881

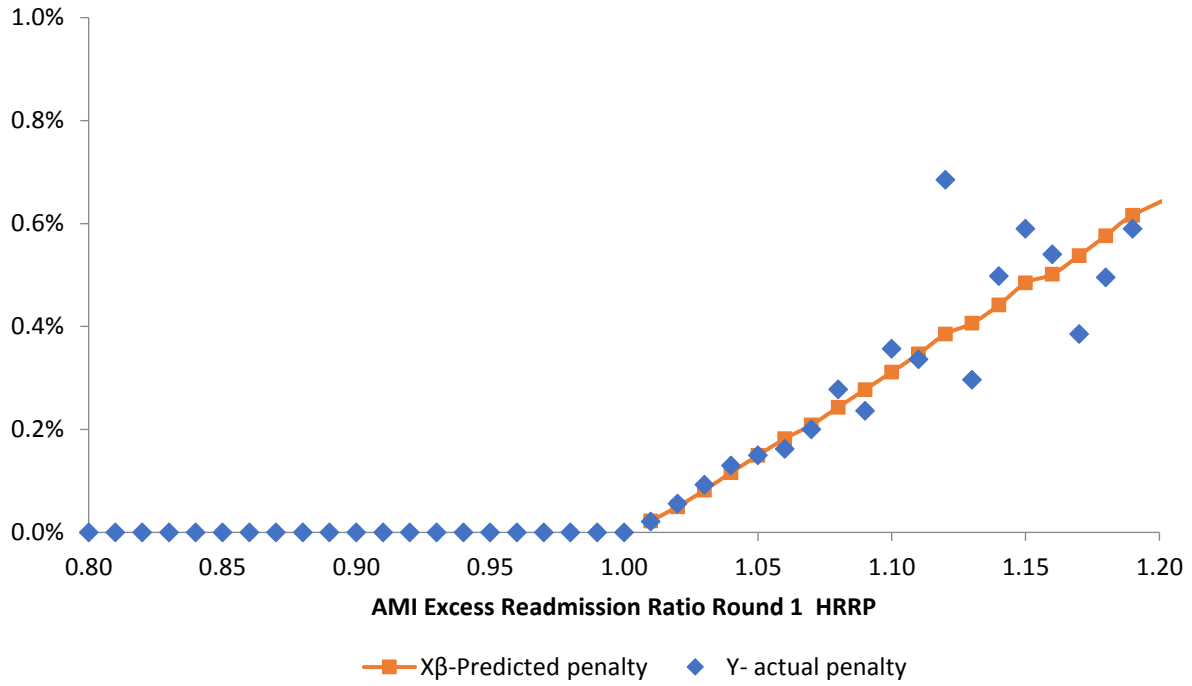
Notes - Each column represents a separate regression. For each condition (AMI, Heart Failure, Pneumonia), the sample of hospitals differs and includes hospitals that were penalized because of the condition (e.g., AMI) and hospitals who were not penalized at all. Hospitals with less than 50 cases throughout 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.

Figure 1
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.

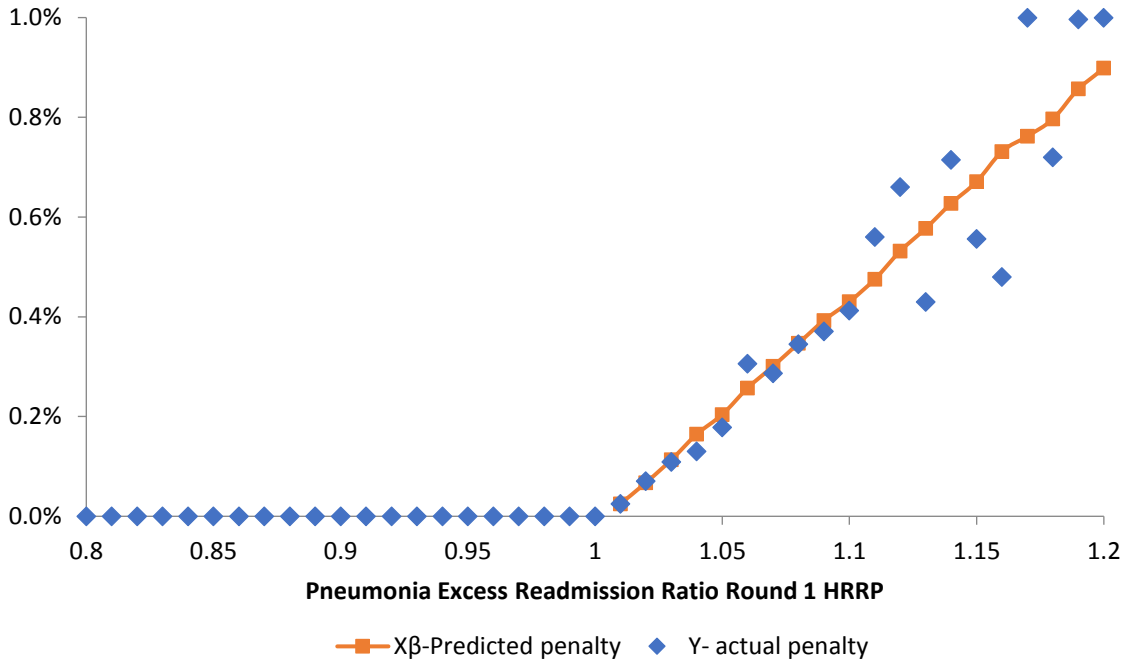
Figure 2
The Relationship between Hospital Excess Readmission Ratio for AMI and HRRP Penalty



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.

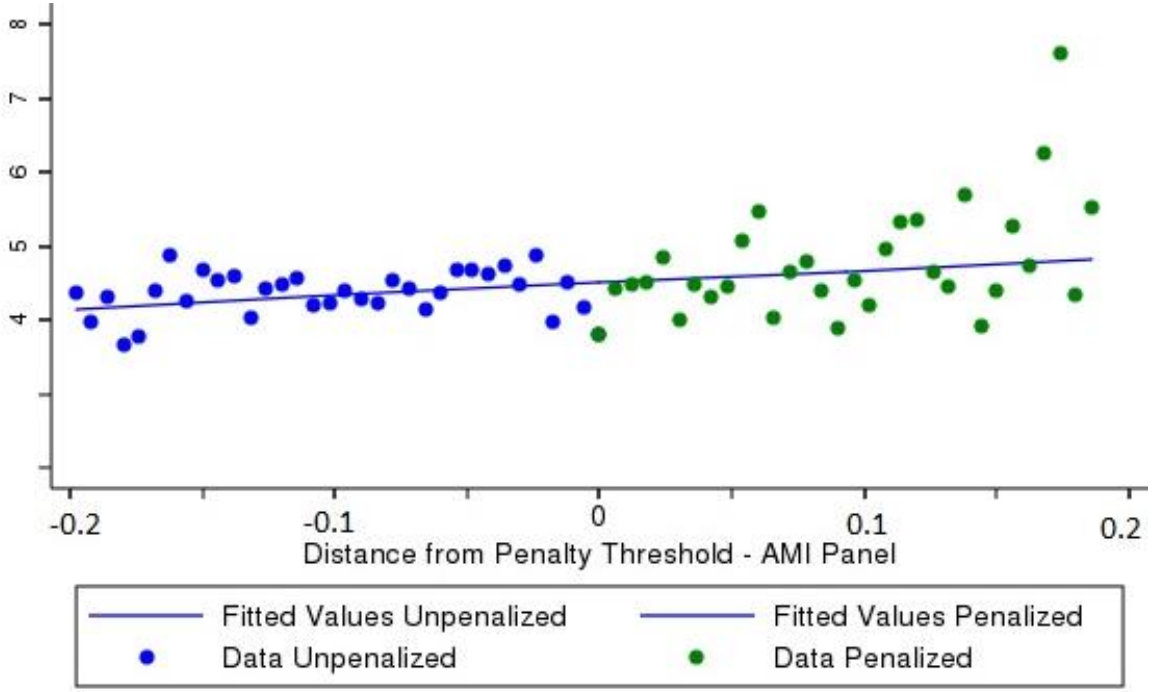
Figure 3

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.

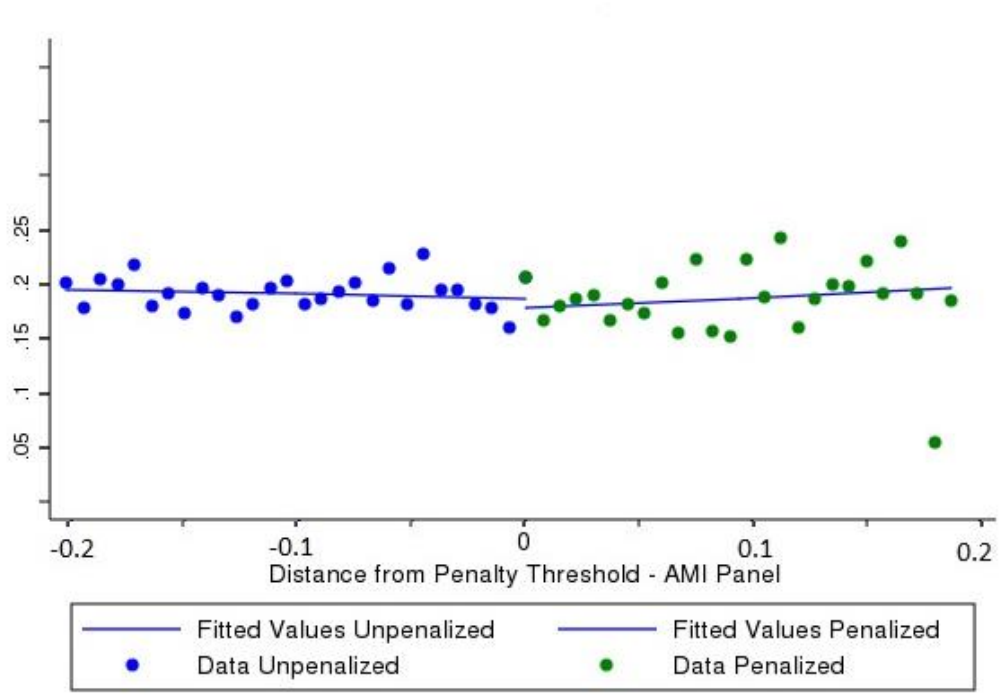
Figure 4 - AMI Length of Stay in 2010
(Period Prior to the HRRP)



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 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.

Figure 5 – AMI 30 Day Mortality in 2010

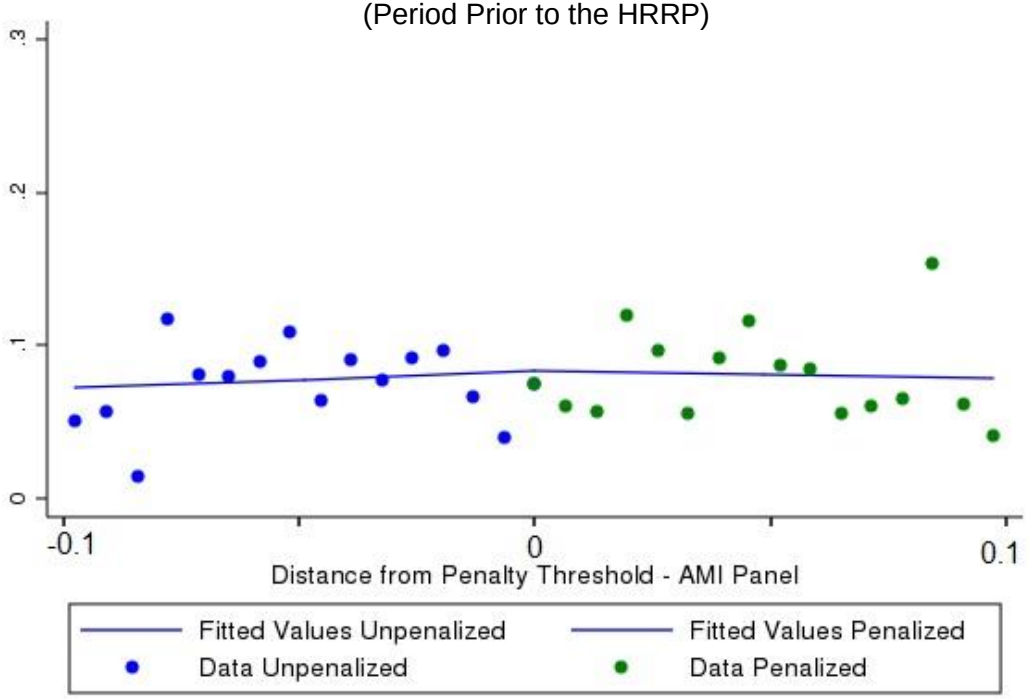
(Period Prior to the HRRP)



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 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.

Figure 6 – Percentage Black in 2010

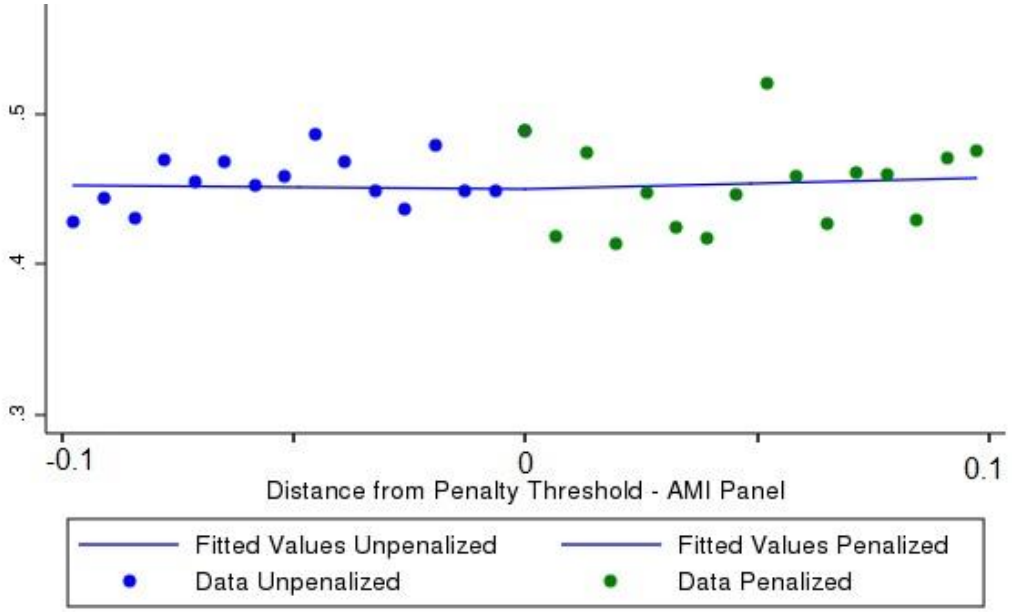
(Period Prior to the HRRP)



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 3, 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 3.

Figure 7 – Percentage of AMI patients with Multiple Complications in 2010

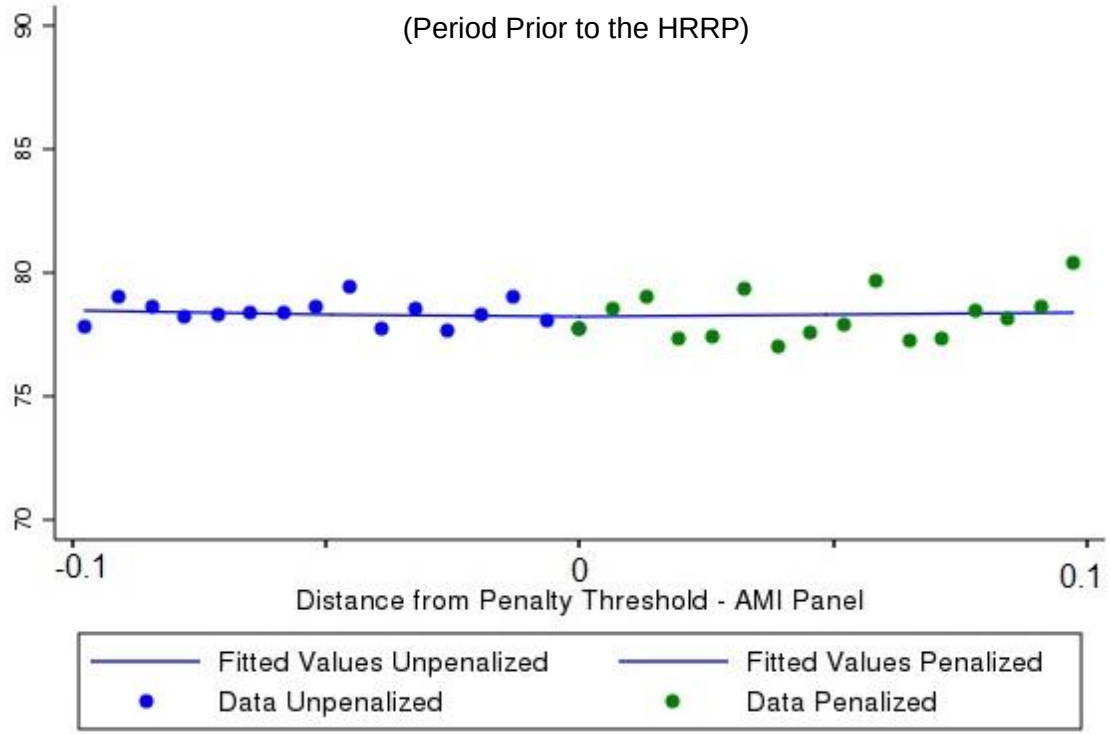
(Period Prior to the HRRP)



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 3, 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 3.

Figure 8 – AMI Average Age in 2010

(Period Prior to the HRRP)

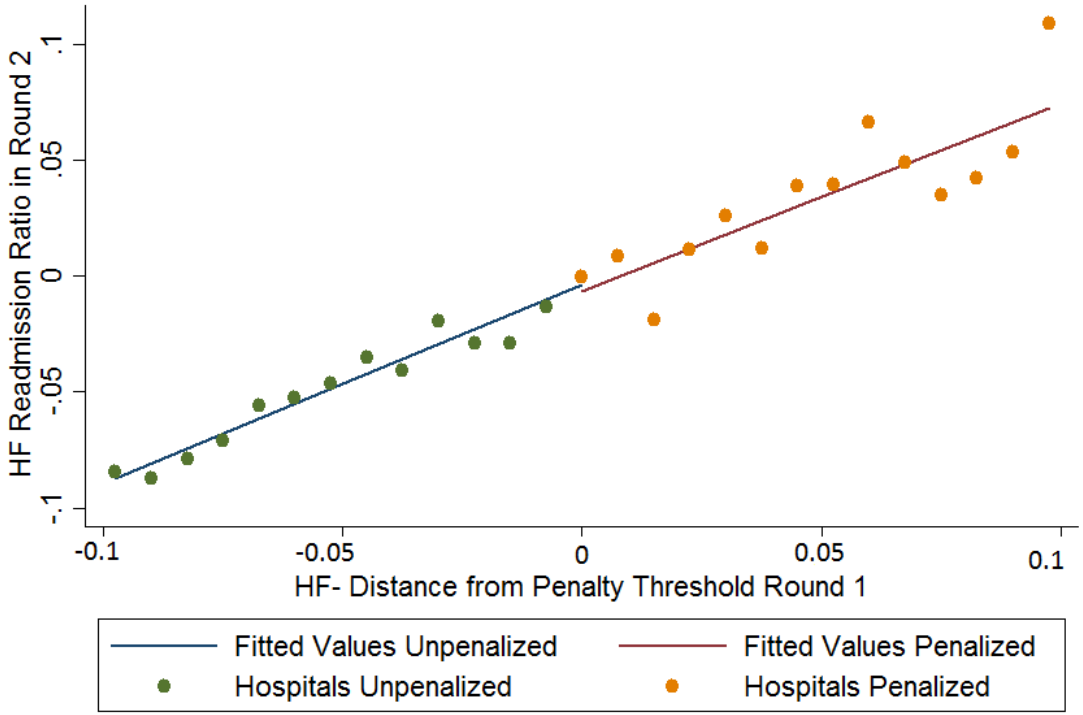


Notes – Each circle represents the age of patients admitted for an AMI inpatient episode in the AMI subsample prior to the HRRP (2010). The solid line represents age from a regression of age on the readmission excess ratio, the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls. Table 3, 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 3.

Figure 9a

The Relationship between the HF round 1 score and the

HF round 2 score

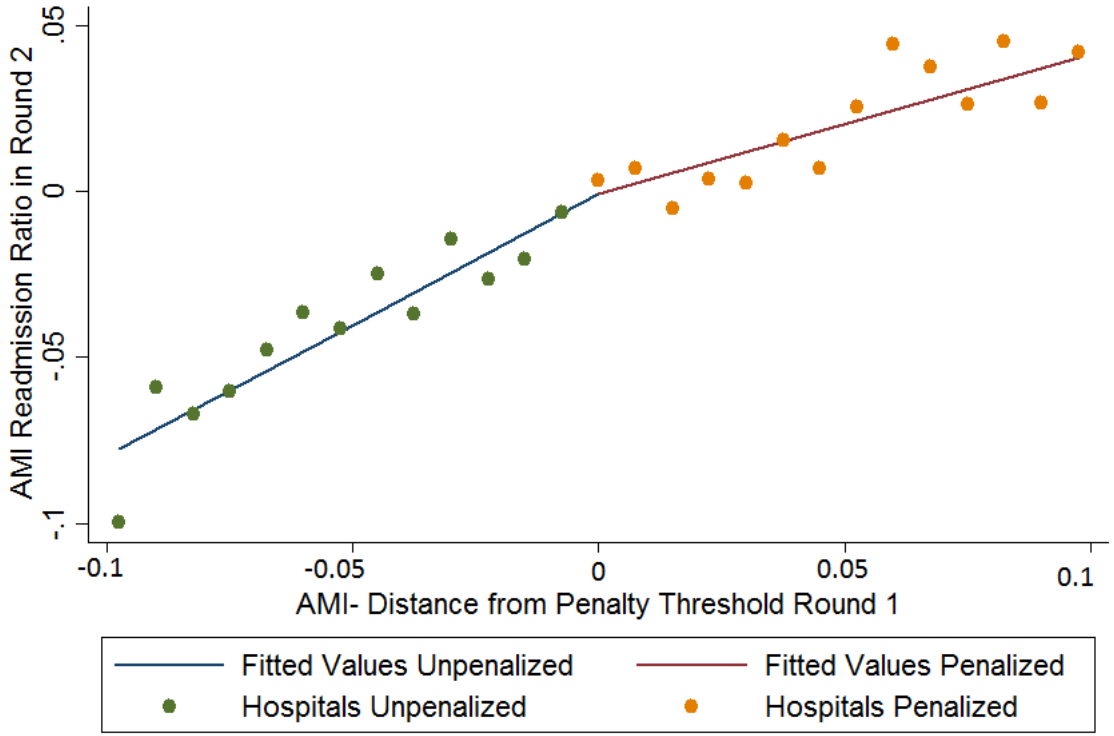


Notes – Each circle represents the round 2 score for HF readmissions in the HF subsample. The solid line represents predicted round 2 score from a regression of round 2 score on the readmission excess ratio (round 1), the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 4, shows the estimates of the exact analysis.

Figure 9b

The Relationship between the AMI round 1 score and the

AMI round 2 score

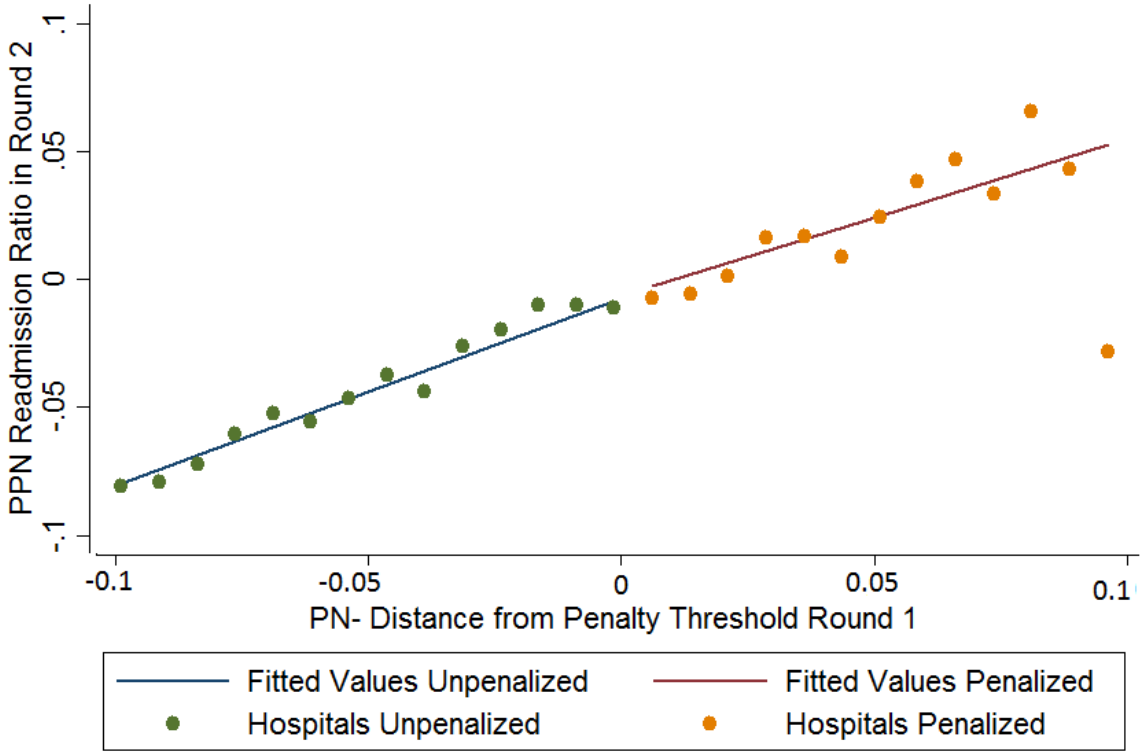


Notes – Each circle represents the round 2 score for AMI readmissions in the AMI subsample. The solid line represents predicted round 2 score from a regression of round 2 score on the readmission excess ratio(round 1) , the interaction of the excess ratio and the penalty indicator, age, race, sex and DRG controls at baseline. Table 4, shows the estimates of the exact analysis.

Figure 9C

The Relationship between the PN round 1 score and the

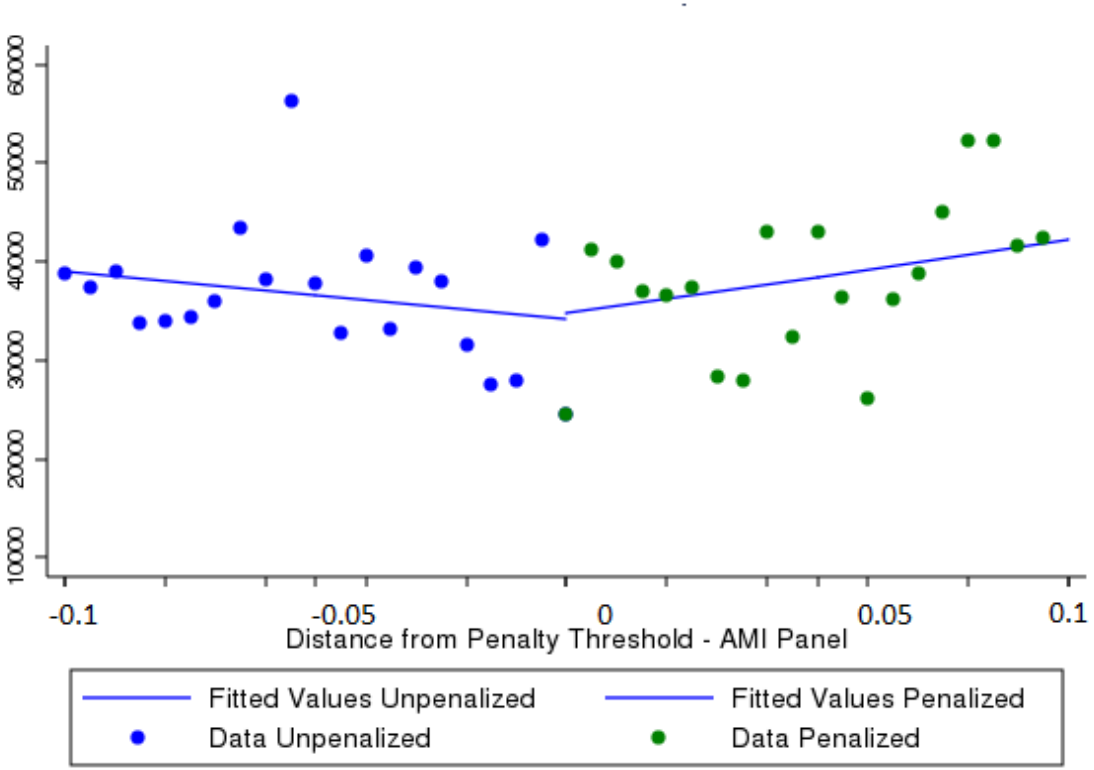
PN round 2 score



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 4, shows the estimates of the exact analysis.

Figure 10 – a

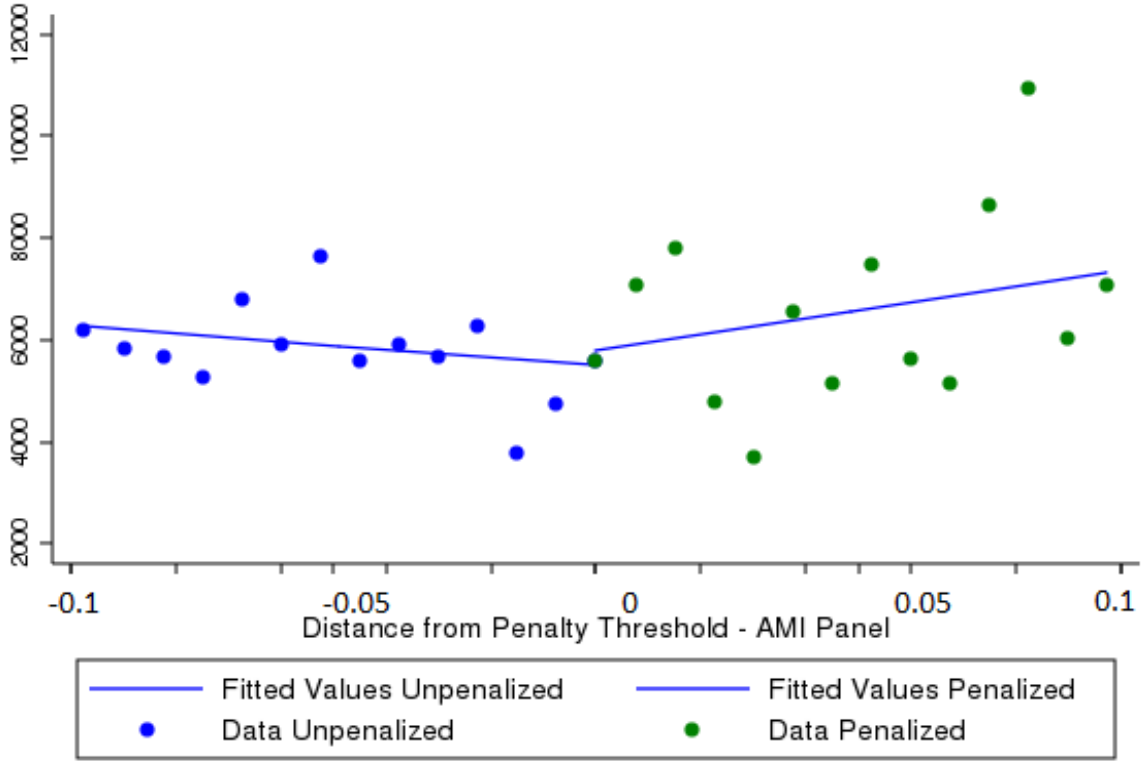
Total Charges in AMI Penalized Hospitals – Post the HRRP



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 5a, shows the estimates of the exact analysis.

Figure 10 – b

Laboratory Charges in AMI Penalized Hospitals – Post the HRRP



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 5a, shows the estimates of the exact analysis.

Figure 11 a

Reduced form Kink Estimates for Charges over time
(AMI Panel)

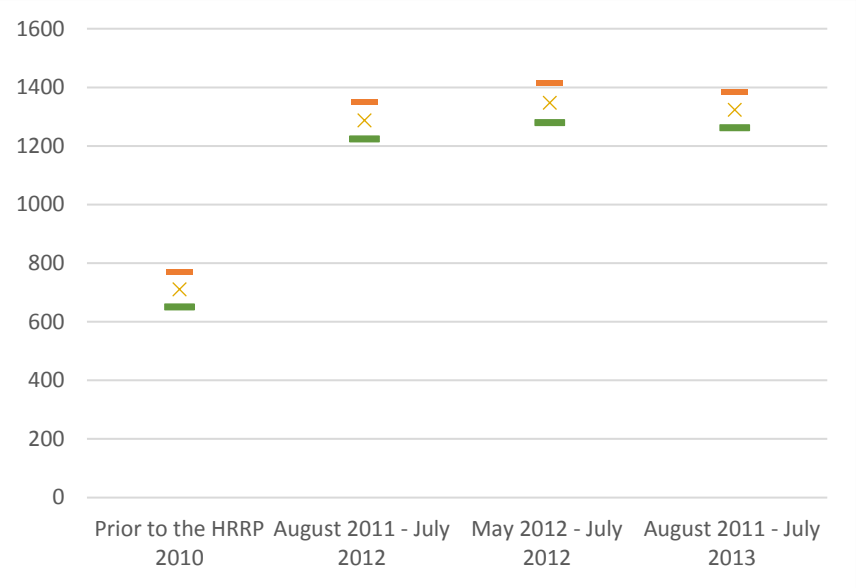
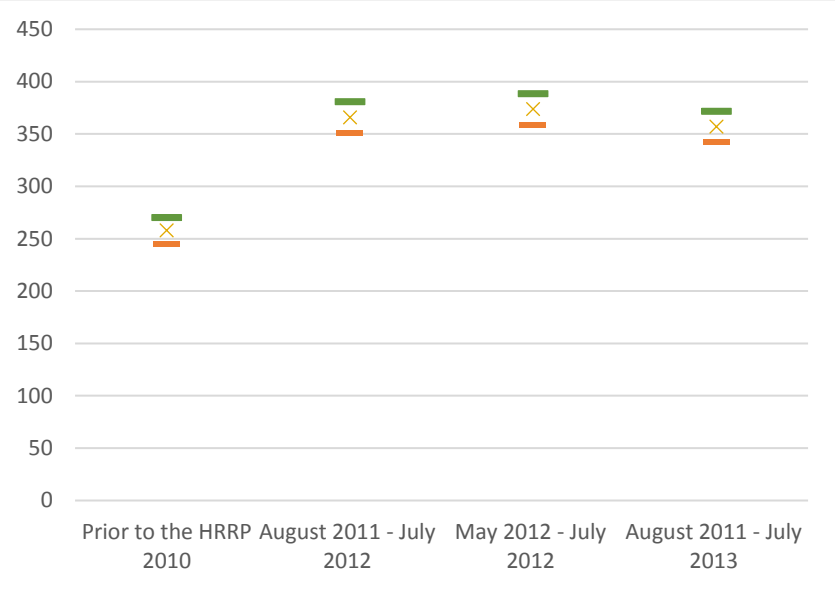


Figure 11 b

Reduced form Kink Estimates for Lab Charges over time
(AMI Panel)



Notes – panel a: plots the reduced form coefficient of the kink estimate for total charges over multiple analysis period. The first period is the period prior to the HRRP (2010), the second period is the first 11 month post the HRRP announcement, the third period is the last 3 month of the first 11-month period, and the fourth period is the entire 2 year round 1 response period. Confidence intervals are plotted as bars above and below the coefficient. The reduced form kink coefficient rises as the HRRP is announced and maintains significantly higher levels across all the ex-post analysis periods. Panel b : plots the reduced form coefficient of the kink estimate for lab charges over multiple analysis period. The first period is the period prior to the HRRP (2010), the second period is the first 11 month post the HRRP announcement, the third period is the last 3 month of the first 11-month period, and the fourth period is the entire 2 year round 1 response period. Confidence intervals are plotted as bars above and below the coefficient. The reduced form kink coefficient rises as the HRRP is announced and maintains significantly higher levels across all the ex-post analysis periods.

Figure 11 c

Reduced form Kink Estimates for SNF Discharges over time (AMI Panel)

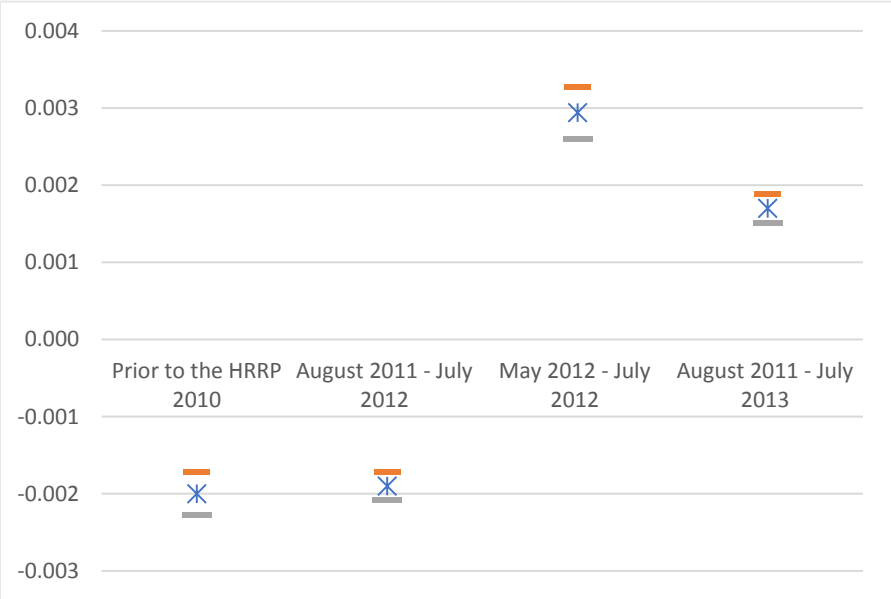
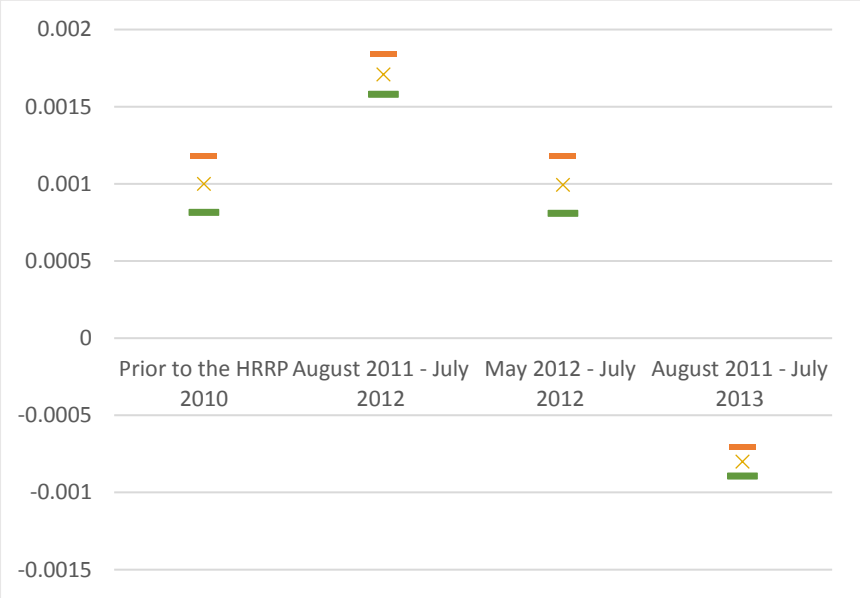


Figure 11 d

Reduced form Kink Estimates for 30-day Mortality over time (AMI Panel)

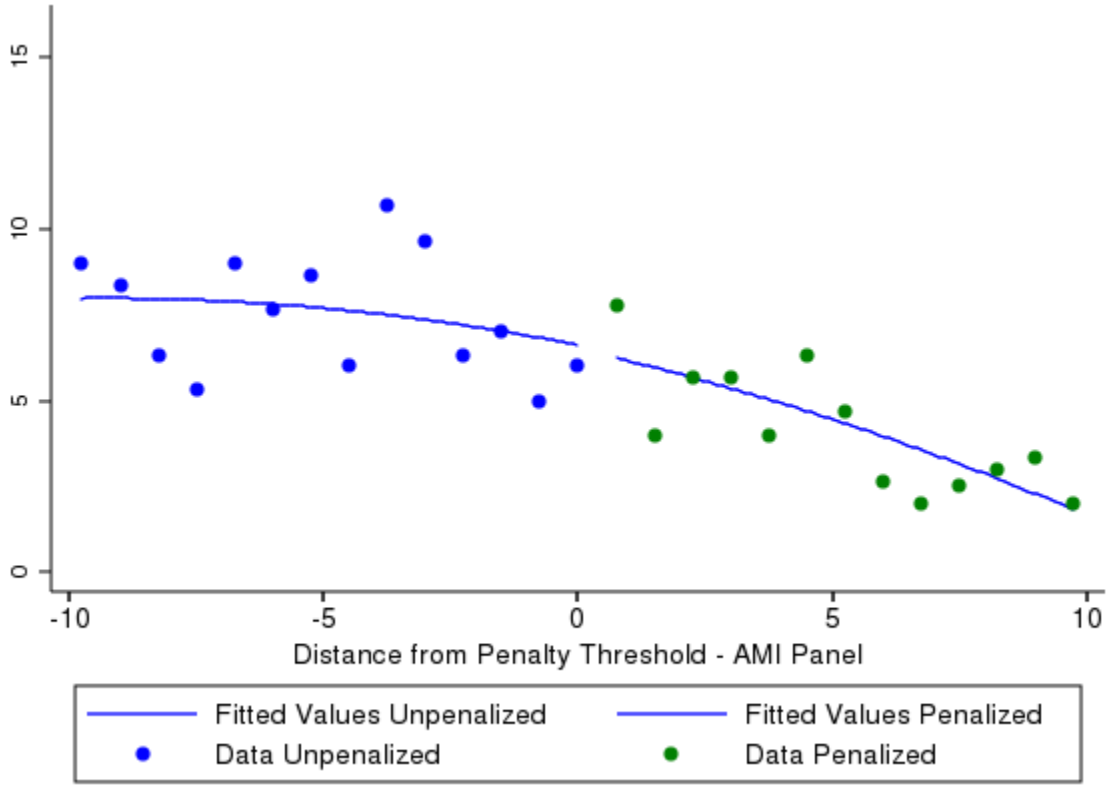


Notes – panel c: plots the reduced form coefficient of the kink estimate for SNF discharges over multiple analysis period. The first period is the period prior to the HRRP (2010), the second period is the first 11 month post the HRRP announcement, the third period is the last 3 month of the first 11-month period, and the fourth period is the entire 2 year round 1 response period. Confidence intervals are plotted as bars above and below the coefficient. The reduced form kink coefficient rises as the HRRP is announced and maintains significantly higher levels across all the ex-post analysis periods. Panel d : plots the reduced form coefficient of the kink estimate for lab charges over multiple analysis period. The first period is the period prior to the HRRP (2010), the second period is the first 11 month post the HRRP announcement, the third period is the last 3 month of the first 11-month period, and the fourth period is the entire 2 year round 1 response period. Confidence intervals are plotted as bars above and below the coefficient. The reduced form kink coefficient rises as the HRRP is announced and maintains significantly higher levels across all the ex-post analysis periods

Appendix Figure 1

Density of Hospitals at the round 1 penalty Threshold

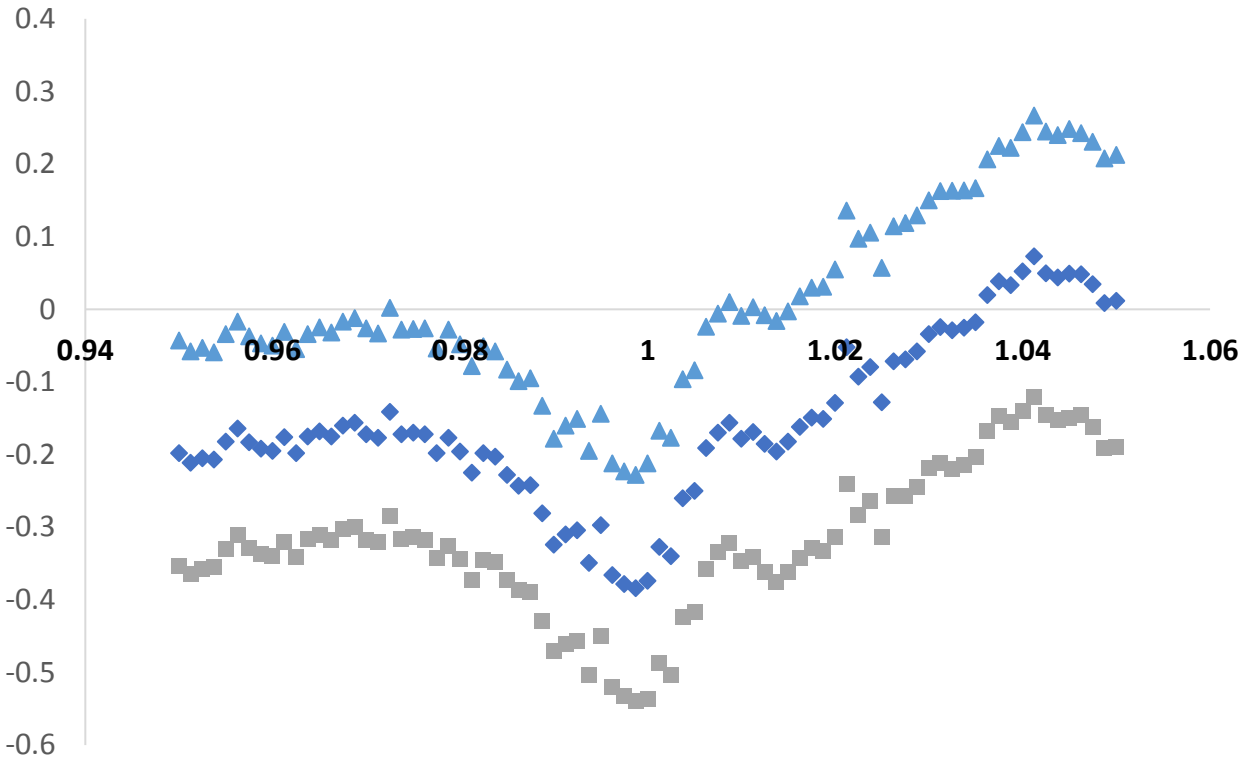
AMI Panel



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 Figure 2a

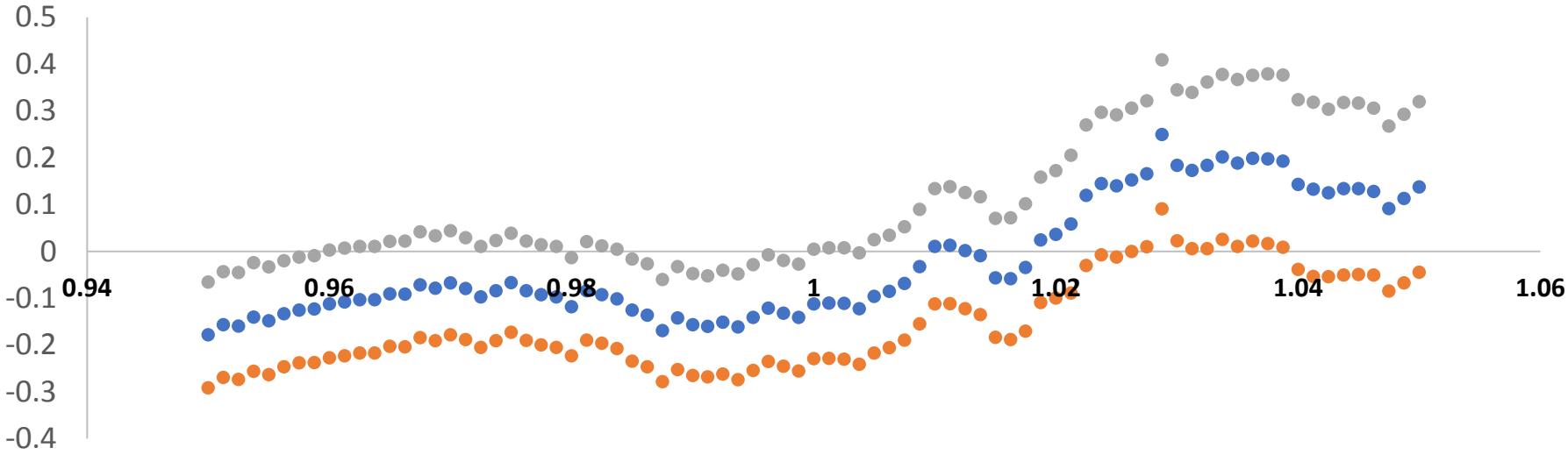
Reduced form kink coefficients for round 2 score from a permutation test using placebo kinks around the threshold – AMI Subsample



Notes – Each circle represents a reduced form coefficient estimate for the interaction of the excess readmission ratio and the penalty threshold. The top series indicates the upper 95% confidence interval, the bottom series indicates the lower 95% confidence interval. Hospitals with an excess readmissions ratio between 0.95 and 1.05 are included. I move the threshold and estimate a placebo kink estimate at each point in this distribution. Each regression is identical to the model used for the main estimates.

Appendix Figure 2b

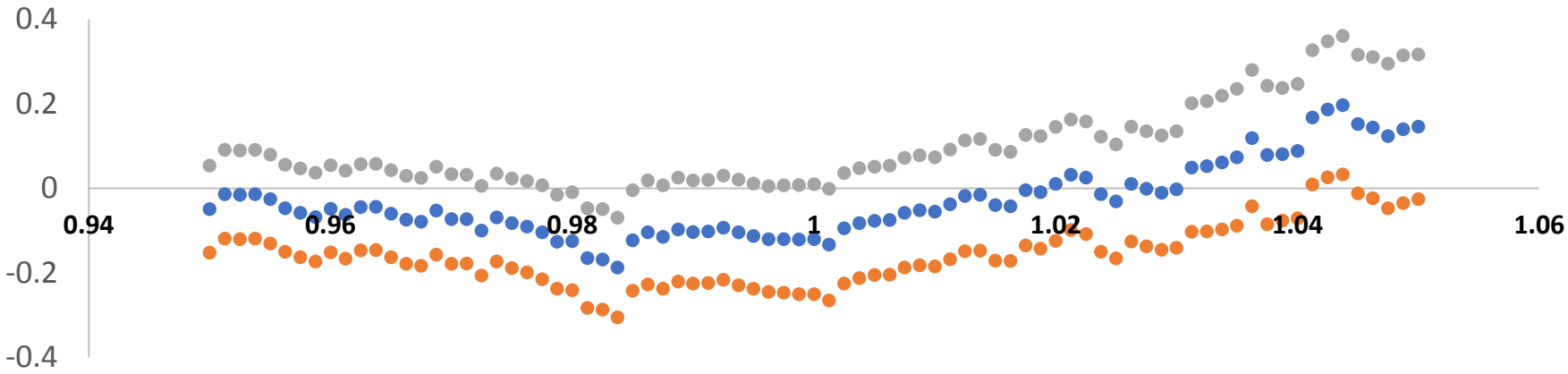
Reduced form kink coefficients for round 2 score from a permutation test using placebo kinks around the threshold – HF Subsample



Notes – Each circle represents a reduced form coefficient estimate for the interaction of the excess readmission ratio and the penalty threshold. The top series indicates the upper 95% confidence interval, the bottom series indicates the lower 95% confidence interval. Hospitals with an excess readmissions ratio between 0.95 and 1.05 are included. I move the threshold and estimate a placebo kink estimate at each point in this distribution. Each regression is identical to the model used for the main estimates.

Appendix Figure 2c

Reduced form kink coefficients for round 2 score from a permutation test using placebo kinks around the threshold – PN Subsample



Notes – Each circle represents a reduced form coefficient estimate for the interaction of the excess readmission ratio and the penalty threshold. The top series indicates the upper 95% confidence interval, the bottom series indicates the lower 95% confidence interval. Hospitals with an excess readmissions ratio between 0.95 and 1.05 are included. I move the threshold and estimate a placebo kink estimate at each point in this distribution. Each regression is identical to the model used for the main estimates.