

Medicare Payment Reform and Hospital Costs: Evidence from the Prospective Payment System and the Treatment of Cardiac Disease

Daeho Kim*
Brown University

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Abstract

Medicare's Prospective Payment System (PPS) reform in 1983 tied hospital payments to the national average cost of each medical technology with the expectation of reducing health care costs. I show that an unintended consequence of PPS was to generate financial incentives for hospitals to expand treatments that had average costs greater than marginal costs due to sizable fixed investments – i.e., the Medicare payment would be greater than the treatment cost at the margin. In the context of cardiac treatments, coronary artery bypass graft (CABG) surgery has a greater average-to-marginal cost ratio than angioplasty, whose ratio is greater than drug therapy's. I document that the PPS reform induced a profit margin that was five times higher for CABG than for angioplasty. I derive a simple model that allows each treatment's effectiveness to vary by patient illness severity. The model predicts that hospitals, in response to PPS, will expand CABG use by treating patients for whom angioplasty is more cost-effective in order to exploit the greater economies of scale. To identify the impact of PPS on cardiac procedures, I exploit the discontinuity in Medicare eligibility at the age of 65. Utilizing data from *before-and-after* the PPS reform, I find a discontinuous change in CABG use at age-65 after the reform that implies an increase of 50 to 60 percent. Nearly all of the increase is driven by a composition change in the patients who receive CABG, with treatment expanded to patients who are observably healthier (i.e., fewer grafts or no comorbidity). Possible competing hypotheses do *not* exhibit changes at the age-65 threshold (e.g., disease incidence, insurance rates). The increased CABG use was not cost effective – the lower bound estimate of the cost per quality-adjusted life year was over one million dollars. The average cost payments of PPS provided incentives for hospitals to expand the use of technologies that have high fixed costs; an expansion that increased health care costs with possibly little health benefits.

Keywords: Medicare, Prospective Payment System, Hospitals, Financial Incentives, Economies of Scale, Cardiac Treatments

JEL Codes: H51, I11, I18, L51

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1 Introduction

The continuing rise in health care costs has been the major concern of public health policy in the United States during the past four decades. Health care spending has increased from 5 percent of GDP in 1960 to 18 percent in 2009 (CMS, 2011). Much of this increase has been attributed to changes in medical technology (Weisbrod, 1991; Newhouse, 1992; Cutler and McClellan, 1998). Responding to this concern, policymakers have focused on developing reimbursement mechanisms that encourage more efficient uses of medical technology (i.e., reducing the use of costly medical technology with little health benefits) and thus contain rising costs. The Medicare Prospective Payment System (PPS), introduced in 1983, is the most prominent reform reflecting this approach.

Under PPS, unlike the full-cost reimbursement,¹ hospitals receive a pre-determined fixed reimbursement for the use of each medical technology.² The fixed reimbursement rates are tied to the national average cost of each medical technology. If a hospital can keep its cost below the reimbursement rate (national average cost), it earns a profit; if its cost exceeds the reimbursement rate, it suffers a loss.³ Therefore, the PPS has been generally expected to reduce the use of expensive medical technologies because hospitals would bear the full additional costs above the fixed reimbursement rate (Butler et al., 1985; Sloan et al., 1988; Lave, 1989; Weisbrod, 1991).

The PPS may, however, induce perverse incentives when the average cost of medical technology decreases with more use (i.e., due to sizable fixed investments). When average cost decreases as use (output) increases, marginal cost falls below average cost such that the PPS reimbursement rate (national average cost) is greater than the marginal cost of medical technology. Thus, the average cost payments of PPS can induce hospitals to expand the use of medical technologies that have high fixed costs by exploiting economies of scale. This distinctive reimbursement scheme of PPS, along with the cost structure of medical technology, could potentially lead to overuse of costly medical technologies.

This paper answers two related questions: 1) how do hospitals respond to the average cost payment of PPS as opposed to the full-cost reimbursement in their use of medical technologies? 2) to the extent that the average cost payment of PPS does induce changes in the use of medical technologies, do patients benefit? The answers to these questions have important implications for how to structure reimbursement schemes so that they promote efficient health care delivery without compromising patients' health benefits.

¹Under the full-cost reimbursement (often called the cost-based reimbursement) prior to PPS, hospitals received essentially their full costs for treating Medicare patients, and thus they had few incentive to reduce costs by efficient uses of medical technology.

²Indeed, the PPS reimburses a fixed amount per hospital discharge assigned to one of the diagnosis-related groups (DRGs). Many of medical technologies used for treating patients are, however, tied to specific DRGs and in turn to specific payment rates. McClellan (1997) documents that over 40 percent of DRGs are tied to surgical procedures.

³Shleifer (1985) points out that the PPS resembles "yardstick competition," in which hospitals are financially rewarded or penalized based on their cost-reduction performance relative to the average (yardstick).

I focus on two major cardiac procedures – coronary artery bypass graft (CABG) surgery and angioplasty. Cardiac procedures are well-suited for studying the impact of PPS for several reasons. First, the two procedures differ greatly in their fixed costs and in turn average-to-marginal cost ratios. This creates differential incentives for hospitals to exploit economies of scale under PPS. Indeed, I document that the PPS reform induced a profit margin that was five times higher for CABG than for angioplasty. Second, the two procedures are medically substitutable for moderately-ill patients for whom hospitals have some discretion over the treatment. Third, more than half of the patients undergoing the two procedures are covered by Medicare so that one would expect hospitals to respond to the reimbursement scheme of PPS.

To better understand hospitals' responses to PPS in their use of cardiac treatments, I derive a simple model that allows each treatment's effectiveness to vary by patient illness severity, while also incorporating the different cost structure of each procedure. This framework provides the following testable predictions: in response to PPS i) hospitals will increase the use of CABG that has a greater average-to-marginal cost ratio than angioplasty; ii) high CABG-volume hospitals prior to PPS will increase CABG use after PPS more than low CABG-volume hospitals, and; iii) hospitals will expand CABG use by treating relatively healthier patients for whom angioplasty is more cost-effective in order to exploit the greater economies of scale.

The empirical challenge to identifying the impact of PPS arises from the nationwide scope of PPS, which makes it difficult to obtain a reliable control group (Salkever, 2000). To address this, I use a regression discontinuity (RD) design exploiting the discontinuity in Medicare eligibility at the age of 65, and comparing outcomes before and after the PPS reform at the age-65 threshold. Since the PPS applied only to the Medicare population, patients aged 65 and over were affected by the PPS rules while (most of) their counterparts under age 65 were not directly affected.⁴ More importantly, I estimate the *change* in the outcome at the age-65 threshold before and after the PPS reform. Thus, as long as other factors that might affect the outcomes do not change discontinuously at the age-65 threshold before and after PPS, this *pre-post RD* design allows causal interpretation of the estimates.

Consistent with the predictions of a model, I find a discontinuous change in CABG use at age-65 after the PPS reform that implies an increase of 50 to 60 percent. However, I find no discontinuous change in angioplasty use at the age-65 threshold. Moreover, I find that high CABG-volume hospitals (that had performed 200 or more CABGs annually prior to PPS) increased CABG use by 95 percent, discontinuously for 65-year-old patients after the PPS reform. I find no discontinuous change in CABG use at the age-65 threshold among low CABG-volume hospitals.

⁴When the PPS was implemented in 1983, the age was not an unique criteria for Medicare eligibility. Since 1972, Medicare has also covered people under age 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD). Therefore, I use information on the source of insurance coverage (Medicare, Medicaid, or private) for those under age 65 from the National Hospital Discharge Survey (NHDS) data to identify the non-elderly Medicare beneficiaries.

In addition, I find that nearly all of the increase in CABG use is driven by a composition change in the patients who receive CABG: hospitals expanded CABG use by treating patients who are observably healthier (i.e., fewer grafts or no comorbidity). The increase in CABG use for these moderately-ill patients explains 85% of the overall increase in CABG use from 1982 to 1988, despite the fact that angioplasty was readily available and medically substitutable for these patients at a lower cost.⁵ I consider a number of possible competing hypotheses (i.e., heart disease prevalence rates, hospital insurance rates, and hospital entries into the provision of CABG) and show that they do *not* exhibit changes at the age-65 threshold before and after the PPS reform.

Finally, I show that the increased CABG use was not cost-effective, partly due to the increase in CABG use for relatively healthier patients described above. First, I find no discontinuous reduction in ischemic heart disease mortality at age-65 before and after the PPS reform. Second, I show that the lower bound estimate of the cost per quality-adjusted life year (QALY) due to the increased CABG use between 1982 and 1986 was over \$1 million; from 1982 to 1988, it was over \$1.7 million.⁶

Thus, the main results of this paper suggest that financial incentives induced by the average cost payments of PPS led to the expansion of costly medical technologies with possibly little health benefits even when more cost-effective technologies were readily available and medically substitutable. The results may therefore provide one of the explanations for the continuing rise in health care costs, despite the efforts of policymakers to contain them.

The paper is organized as follows. Section 2 provides a brief background on the PPS and cardiac procedures. Section 3 lays out a simple model for hospital responses to PPS. Section 4 outlines an empirical strategy. Section 5 describes data. Section 6 presents empirical results, and Section 7 concludes.

2 Background

2.1 Medicare Prospective Payment System

Despite the significant impacts of Medicare on health improvements among the elderly soon after its introduction (Chay et al., 2010), the full-cost reimbursement of Medicare had been criticized for inducing the overuse of medical technologies, and thus escalating health care costs (Russell,

⁵It is noteworthy that the medical literature subscribes to the view that angioplasty is medically more effective than (or at least as effective as) CABG for moderately-ill patients (Yusuf et al., 1994; Rosen et al., 1995; Bypass Angioplasty Revascularization Investigation (BARI) Investigators, 1996; Hlatky et al., 1997; Hannan et al., 1999).

⁶The commonly accepted thresholds for cost-effectiveness of medical technology is \$20,000 to \$100,000 per year of life saved (Laupacis et al., 1993).

1977; Office of Technology Assessment, 1984).⁷ Under the full-cost reimbursement prior to PPS, hospitals essentially received their full costs incurred for treating Medicare patients.⁸ Hospitals therefore had few incentives to reduce costs via efficient uses of medical technology – i.e., reducing the use of costly technologies with little health benefits.

In response to this concern, Medicare changed for the first time its hospital inpatient reimbursement policy from the full-cost reimbursement to the Prospective Payment System (PPS) in October 1983.⁹ This new reimbursement policy pays hospitals a fixed amount for each discharge of Medicare patient, regardless of actual costs incurred. Each discharge of Medicare patient is classified as one of 468 diagnosis-related groups (DRGs).¹⁰ Since each medical technology (e.g., surgical procedure) used for treating Medicare patients is assigned to a specific DRG, hospitals essentially receive a fixed reimbursement for the use of each medical technology.¹¹

More importantly, under PPS the reimbursement rates are tied to the national average cost of each medical technology assigned to a particular DRG. The actual formulas used for setting a fixed reimbursement rate are highly complex, with various adjustments for indirect medical education costs, the disproportionate share of indigent patients, and outlier costs among others. I thus explain a simplified version to highlight the average cost payment scheme of PPS. The reimbursement rate for each DRG d is given by¹²

$$R_{d,h} = DRG\ weight_d \times S \times (1 + Adjust_h),$$

where h indicates a hospital, $DRG\ weight_d$ reflects the relative costliness of each DRG compared to all DRGs, S is the standardized reimbursement amount, and $Adjust_h$ is the hospital-specific adjustment.¹³ The DRG weights, the most important part of reimbursement, are derived from the national average costs of each DRG:

$$DRG\ weight_d = \frac{\overline{AC}_d}{\overline{AC}},$$

where \overline{AC}_d is the national average cost of a particular DRG and \overline{AC} is the national average cost

⁷Also, the previous research has documented that the full-cost reimbursement in general enforced excessive incentives for health care providers to use more expensive technologies (Greenberg and Derzon, 1981; Weisbrod, 1991; Cutler and McClellan, 1996; Fuchs, 2004).

⁸The actual formula used under the full-cost reimbursement is well demonstrated in Danzon (1980) and Danzon (1982).

⁹Four states (i.e., MA, NY, NJ, and MD) were exempted from the PPS. Also, exempted were psychiatric hospitals, rehabilitation hospitals, children’s hospitals, and long-term hospitals.

¹⁰DRGs are mutually exclusive diagnostic classifications of Medicare patients primarily based on their clinical conditions such as diagnoses at admission, comorbidities, complications, and the presence of surgical procedures.

¹¹McClellan (1997) documents that over 40 percent of DRGs are assigned to specific surgical procedures.

¹²This simplified version is based on Cutler (1995), McClellan (1997), and Cutler and McClellan (1998).

¹³The hospital-specific adjustment factors are, for example, indirect medical education costs, the disproportionate share of indigent patients, and outlier costs. Note that these adjustment factors do not vary across DRGs.

of all DRGs. For example, the DRG weights for CABG and angioplasty in 1988 were 5.5415 and 1.8911, respectively. This indicates that the use of CABG was more costly than angioplasty.¹⁴

The standardized reimbursement amount S , which converts the DRG weight into a dollar amount, is set equal to the national average cost of all DRGs (\overline{AC}).¹⁵ Since most of the variation in the reimbursement rate is due to DRG weights,¹⁶ the reimbursement rate for each DRG is essentially equal to the national average cost of each DRG:

$$R_{d,h} = \left(\frac{\overline{AC}_d}{\overline{AC}} \right) \overline{AC} \times (1 + Adjust_h) \approx \overline{AC}_d. \quad (1)$$

This represents the reimbursement scheme of PPS: the average cost payments. Thus, hospitals receive a fixed reimbursement (national average cost) for the use of each medical technology (assigned to a particular DRG) under PPS.

Most previous studies on the impact of PPS have focused on its general feature of reimbursement method (a fixed reimbursement rate), which leads to the expectation that the PPS would reduce the use of expensive medical technologies because hospitals would bear the full additional costs above the fixed reimbursement rate (Butler et al., 1985; Sloan et al., 1988; Lave, 1989; Weisbrod, 1991).¹⁷ However, the distinctive reimbursement scheme of PPS (the average cost payment) has received little attention. When the average cost decreases with more use of medical technology (i.e., due to large fixed investments), marginal cost falls below average cost such that the PPS reimbursement rate (national average cost) is greater than the marginal cost. Thus, the average cost payments under PPS can induce perverse incentives for hospitals to expand the use of medical technologies that have high fixed costs by exploiting economies of scale.

2.2 Cardiac Procedures Used for Treating Ischemic Heart Disease

The treatment of ischemic heart disease (IHD) involves one of (or sometimes multiple) treatment paths such as drug therapy, cardiac catheterization, angioplasty, or CABG. A drug therapy (i.e., aspirin, beta-blockers, and thrombolytics) is the least invasive treatment. A cardiac catheterization

¹⁴Indeed, the two DRG weights were assigned to CABG: 5.5415 for “CABG with catheterization” (DRG 106) and 4.2858 for “CABG without catheterization” (DRG 107) to reflect the costliness of catheterization. Angioplasty (DRG 112) was initially classified as DRG 108 (with a weight of 4.3756) which includes more intensive procedures than angioplasty. After recognizing that angioplasty was over-reimbursed, Medicare moved angioplasty into DRG 112 from 1986 (*Federal Register*, September, 1985).

¹⁵Standardization means the removal of the effects of certain variations (e.g., area-specific wage differences and case mix differences among hospitals) from the hospital cost data.

¹⁶For example, the DRG weights ranged from 0.1309 to 11.9225 in 1988. Also, the within-DRG variation in reimbursement rates across hospitals was not high (Cutler and McClellan, 1998; Cutler, 1998).

¹⁷As an exception, Acemoglu and Finkelstein (2008) emphasize the “partial cost reimbursement” feature of PPS – i.e., hospitals’ capital expenditures are fully reimbursed while labor expenses are covered by fixed price. Accordingly, they focus on changes in the relative factor prices (between capital and labor) faced by hospitals and find that the PPS is associated with an increase in the adoption of new technologies at the extensive margin.

is a diagnostic procedure that inserts a thin tube (catheter) into the coronary vessels of the heart to detect occluded area.

If the catheterization detects significant blockages in the arteries, two major cardiac procedures can be used to treat those blockages: CABG and angioplasty.¹⁸ First, CABG was introduced in 1968 (Favaloro, 1968) and rapidly diffused as the standard treatment for patients with ischemic heart disease. It is highly invasive open-heart surgical procedure that bypasses occluded area in the coronary arteries using leg veins or internal mammary artery. Second, angioplasty is the more recent technology, introduced in 1978 (Grüntzig, 1978). It is the less invasive procedure that inserts a balloon-attached catheter into the occluded arteries and inflated the balloon to restore blood flow without opening the chest.¹⁹

The two cardiac procedures, CABG and angioplasty, are well-suited for studying the impact of PPS for several reasons. First, the two procedures differ greatly in their fixed costs. To start providing CABG, a hospital needs to invest in operating room, Intensive Care Unit (ICU), heart-lung machine²⁰, laboratory, and specialized staff. Huckman (2006) finds that the fixed cost of CABG was \$14.1 million on average, while \$2.7 million for angioplasty. This implies that under PPS hospitals have differential incentives to exploit economies of scale. Indeed, I document that the profit margin for CABG was \$5,971 compared to \$1,002 for angioplasty under PPS (Table 1). Second, for moderately-ill patients, the two procedures are medically substitutable (Hillis and Rutherford, 1994; Bypass Angioplasty Revascularization Investigation (BARI) Investigators, 1996; Hlatky et al., 1997; Hannan et al., 1999).²¹ Thus, hospitals have some discretion over the treatment for those patients. Third, more than half of the patients who undergo either one of the two procedures are covered by Medicare, and thus one would expect hospitals to respond to the reimbursement scheme of PPS.²²

3 A Model of Hospital Responses

To better understand hospitals' responses to the average cost payments of PPS in their use of cardiac procedures, I derive a simple model that has three key features. First, the patients are

¹⁸Also known as Percutaneous Transluminal Coronary Angioplasty (PTCA).

¹⁹Recently, angioplasty with a stent (a small wire mesh tube) is used more frequently than balloon-tipped angioplasty because a stent is more effective to avoid restenosis (i.e., reoccurrence of blockage). The PPS pays higher reimbursement for angioplasty with a stent than for balloon angioplasty.

²⁰The heart-lung machine does the work of heart and lungs while the heart is temporarily stopped during the course of CABG procedure.

²¹Cutler and Huckman (2003) show the substitutability between CABG and angioplasty for the general population during the late 1990s.

²²Using the National Hospital Discharge Survey (NHDS) data, I note that about 51 percent of patients undergoing either one of the two procedures were covered by Medicare prior to PPS (i.e., 1982-1983). This proportion was increased to 65 percent in 1988-1989.

heterogeneous in their illness severity and the medical benefit from each cardiac procedure depends on their illness severity. Second, I assume that the hospital cares about its profit as well as patients' benefit as its objective. Also, the hospital is assumed to have better information on patients' illness severity and medical benefit from each cardiac procedure, thereby deciding benchmark severity levels above or below which it provides more or less intensive cardiac procedures. Finally, the change in Medicare reimbursement policy from full-cost reimbursement to PPS induces the hospital to face the trade-off between its profit and patients' benefit.

3.1 The patients

Medicare patients with ischemic heart disease can receive one of the three cardiac treatments, $j \in \{H, L, 0\}$, in the hospital. I denote H as highly intensive treatment (CABG), L as less intensive one (angioplasty), and 0 as non-invasive treatment (drug therapy).

Patients are heterogeneous in their illness severity, $s \in [0, \bar{s}]$, assumed to be uniformly distributed. Severity zero is normalized as the least level of illness severity. The number of patients given s is assumed to be unity and thus the total number of patients treated in the hospital is \bar{s} . And the number of patients undergoing each treatment in the hospital are denoted by $q^H(s)$, $q^L(s)$ and $q^0(s)$ respectively. Patients' medical benefit from each treatment, depending on their illness severity, are denoted by $b^H(s)$, $b^L(s)$ and $b^0(s)$ respectively. The relative benefits of CABG to angioplasty, and angioplasty to drug therapy are assumed to increase with the level of severity: $\frac{\partial b^H(s)}{\partial s} > \frac{\partial b^L(s)}{\partial s} > \frac{\partial b^0(s)}{\partial s} \geq 0$.²³ For simplicity, I assume that the benefit from drug therapy is same across severity levels, $\frac{\partial b^0(s)}{\partial s} = 0$. Also, the least severe patients get more benefit from drug therapy than angioplasty and even more than CABG, $b^0(0) > b^L(0) > b^H(0)$; and any treatment is beneficial, $b^j(s) > 0$. For the illustrative purpose of a model, I use the following simple forms of benefit functions²⁴

$$b^0 = \alpha^0, \quad b^L(s) = \alpha^L + \beta^L s, \quad b^H(s) = \alpha^H + \beta^H s, \quad (2)$$

where $\alpha^0 > \alpha^L > \alpha^H > 0$ and $\beta^H > \beta^L > 0$. I also assume that one procedure does not dominate all others across severity levels such that $\alpha^0 < \alpha^L + \beta^L \bar{s} < \alpha^H + \beta^H \bar{s}$ (Appendix Figure 1 depicts the above benefit functions). The hospital has better information on patients' illness severity and medical benefit of each treatment than patients do. Due to this asymmetry of information (or lack of information), patients are assumed to passively rely on the treatment decision by the hospital.

²³It has been acknowledged in the medical literature that the comparative medical benefit of CABG to angioplasty had been confined to severely-ill patients as opposed to moderately-ill patients (Yusuf et al., 1994; Rosen et al., 1995; Bypass Angioplasty Revascularization Investigation (BARI) Investigators, 1996; Hlatky et al., 1997; Hannan et al., 1999).

²⁴Boadway et al. (2004), Siciliani (2006), and Hafsteinsdottir and Siciliani (2010) use the similar benefit functions.

3.2 The hospital

I assume that the hospital has an objective function which includes its profit (π) and patients' benefit (B) as arguments (Ellis and McGuire, 1986, 1990; Ellis, 1998):²⁵

$$U = U(\pi, B). \quad (3)$$

The profit from all three cardiac treatments provided is given by $\pi = \sum_j R(q^j) - \sum_j TC^j(q^j)$, where $R(q^j)$ is the Medicare reimbursement and $TC^j(q^j)$ is the total cost of each treatment. With better information on patients' illness severity and medical benefit of each treatment, the hospital chooses the benchmark levels of severity, s^L and $s^H (> s^L)$ in ways that: the hospital provides CABG to severely-ill patients ($s \geq s^H$); angioplasty to moderately-ill patients ($s^L \leq s \leq s^H$), and; drug therapy to less-ill patients ($s \leq s^L$).²⁶ Since, s is uniformly distributed and the number of patients given s is assumed to be unity, the number of patients given each cardiac treatment j is defined by $q^H(s^H) = \bar{s} - s^H$, $q^L(s^H, s^L) = s^H - s^L$, and $q^0(s^L) = s^L = \bar{s} - q^H - q^L$.²⁷ Given benchmark values of s^H and s^L , the patients' benefit is given by²⁸

$$B(s^H, s^L) = \alpha^H \bar{s} + \frac{1}{2} \beta^H \bar{s}^2 + (\alpha^L - \alpha^H) s^H - \frac{1}{2} (\beta^H - \beta^L) (s^H)^2 + (\alpha^0 - \alpha^L) s^L - \frac{1}{2} \beta^L (s^L)^2. \quad (4)$$

3.3 Medicare Reimbursements

Prior to PPS, Medicare reimbursed the hospital based on the full-cost reimbursement, whereby the hospital received the full cost of each cardiac treatment used for Medicare patients:

$$R(q^j) = TC(q^j).$$

This implies that the hospital breaks even prior to PPS. Under PPS, however, the hospital receives a fixed payment for each cardiac treatment:

$$R(q^j) = \overline{AC}^j \cdot q^j,$$

where \overline{AC}^j is the national average cost of each cardiac treatment j .

²⁵I assume that both hospital managers and physicians are cooperatively involved in the decision on medical treatments for patients. The hospital can influence the physician's decision by providing lucrative compensation, preferred operating room scheduling, and the composition of surgical staff (McClellan, 1996; Huckman, 2003; Cutler et al., 2010). They are also assumed to share the same interests (hospital's profit and patients' benefit).

²⁶In other words, the hospital chooses benchmark values of (s^L, s^H) such that:

(1) $b^H(s) > b^L(s) > b^0(s), \forall s \in (s^H, \bar{s}]$; (2) $b^L(s) > \max\{b^H(s), b^L(s)\}, \forall s \in (s^L, s^H)$;
(3) $b^0(s) > b^L(s) > b^H(s), \forall s \in [\underline{s}, s^L)$; (4) $b^H(s^H) = b^L(s^H)$ and $b^L(s^L) = b^0(s^L)$.

²⁷Note that the use of CABG (q^H) increases if s^H becomes smaller – i.e. the hospital provides CABG to the most severely-ill patient first, and less severely-ill patient, and so on (see Appendix Figure 1).

²⁸Note that $B(s^H, s^L) = \int_0^{s^L} b^0(s) ds + \int_{s^L}^{s^H} b^L(s) ds + \int_{s^H}^{\bar{s}} b^H(s) ds$.

3.4 Use of Cardiac Procedures Prior to PPS

The hospital's optimization problem prior to PPS is

$$\max_{s^H, s^L} U \left[\pi \left(q^H(s^H), q^L(s^H, s^L), q^0(s^L) \right), B(s^H, s^L) \right], \quad (5)$$

subject to $\bar{s} \geq s^H > s^L \geq 0$. Prior to PPS, the hospital breaks even ($\pi = 0$) and thus two first-order conditions are given by

$$B_{s^H} = 0 \quad \text{and} \quad B_{s^L} = 0.$$

These two first-order conditions imply that the hospital cares only about patients' benefit because Medicare reimburses whatever costs for treating Medicare patients. From the patients' benefit function in equation (4), the optimal values of s^H and s^L are given by $s^H = \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L}$ and $s^L = \frac{\alpha^0 - \alpha^L}{\beta^L}$, respectively. Thus, prior to PPS, the number of patients who receive CABG, angioplasty, or drug therapy are

$$q_{pre}^{H*} = \bar{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L}, \quad q_{pre}^{L*} = \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} - \frac{\alpha^0 - \alpha^L}{\beta^L}, \quad \text{and} \quad q_{pre}^{0*} = \frac{\alpha^0 - \alpha^L}{\beta^L}. \quad (6)$$

3.5 Use of Cardiac Procedures Under PPS

Under PPS, the hospital receives a fixed payment for each procedure, \overline{AC}^j (the national average cost of each procedure). Then the hospital's profit function is given by

$$\pi = \overline{AC}^H \cdot q^H(s^H) + \overline{AC}^L \cdot q^L(s^H, s^L) + \overline{AC}^0 \cdot q^0(s^L) - TC^H(q^H(s^H)) - TC^L(q^L(s^H, s^L)) - TC^0(q^0(s^L)).$$

Given objective function of (5), the hospital chooses s^H and s^L to satisfy two first-order conditions that can be simplified to be

$$B_{s^H} - (\pi_{q^H} - \pi_{q^L}) \frac{U_\pi}{U_B} = 0 \quad (7)$$

$$B_{s^L} - (\pi_{q^L} - \pi_{q^0}) \frac{U_\pi}{U_B} = 0 \quad (8)$$

The two first-order conditions imply that under PPS the hospital takes into account of relative profit margins from each treatment, $(\pi_{q^H} - \pi_{q^L})$ and $(\pi_{q^L} - \pi_{q^0})$, as well as patients marginal benefits, B_{s^H} and B_{s^L} . From equation (7), the number of patients who receive CABG is given by

$$q_{post}^{H*} = \bar{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} + \left\{ \left(\overline{AC}^H - MC^H(q^H) \right) - \left(\overline{AC}^L - MC^L(q^L) \right) \right\} \frac{U_\pi}{U_B} \frac{1}{(\beta^H - \beta^L)} \quad (9)$$

This provides intuitive implications. If the profit margin for CABG is higher than for angioplasty under PPS (the positive value in the bracket in equation (9)), then the hospital has an incentive to increase CABG use more than its pre-PPS level ($\bar{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L}$). This reflects that the hospital cares about the profit as one of its objective. However, this incentive-effect is scaled down by patients' marginal benefit from CABG relative to angioplasty ($\beta^H - \beta^L$). If the hospital increases CABG use, then it will be provided to relatively healthier patients and thus the hospital utility decreases to the extent that the increased CABG use reduces patients' marginal benefit. This reflects that the hospital cares about the patients' benefit as its another objective. Therefore, the hospital will increase CABG use up to the point where the marginal benefit of doing so (increase in profit margin) and the marginal cost (decrease in patient' marginal benefit) are balanced.

Prediction 1 *If CABG has a greater average-to-marginal cost ratio (i.e., higher fixed cost) than angioplasty, hospitals will increase the use of CABG in response to PPS:*

$$\left(\overline{AC}^H - MC^H(q^H)\right) > \left(\overline{AC}^L - MC^L(q^L)\right) \Rightarrow q_{post}^{H*} > q_{pre}^{H*}$$

As an illustration, I consider the simple cost functions of CABG and angioplasty as follows

$$TC^H(q^H) = c^H \cdot q^H + F \quad \text{and} \quad TC^L(q^L) = c^L \cdot q^L, \quad (10)$$

where c^H and c^L indicate marginal costs of CABG and angioplasty, respectively and; F is the fixed cost of CABG.²⁹ These cost functions imply that CABG exhibit higher fixed cost (i.e., greater extent of scale economies) than angioplasty.³⁰ Under PPS, Medicare reimbursements are given by $R(q^H) = \overline{AC}^H = c^H + \frac{F}{q^H}$ and $R(q^L) = \overline{AC}^L = c^L$. Therefore, $(\overline{AC}^H - MC^H(q^H)) = \frac{F}{q^H} > 0 = (\overline{AC}^L - MC^L(q^L))$. From this prediction, the following corollary is derived.

Prediction 2 (Corollary) *If the marginal cost of CABG decreases with volume, high CABG-volume hospitals prior to PPS will increase CABG use after PPS more than low CABG-volume hospitals.*

Prior to PPS, both high and low CABG-volume hospitals earned zero profits. Following PPS, however, high CABG-volume hospitals (prior to PPS) – relative to low CABG-volume hospitals – become to face higher profit margin because their marginal cost is much lower than the fixed payment given that the marginal cost of CABG is decreasing with volume.³¹ Appendix Figure 2

²⁹For simplicity, I assume that the use of angioplasty does not incur fixed costs.

³⁰Of course, it is not just the presence of large fixed costs that give rise to economies of scale. In this paper, I focus on scale economies just in terms of fixed costs.

³¹Note that the Prediction 2 compares pre- and post-PPS periods, rather than two post-PPS periods. Indeed, between two post-PPS periods, low CABG-volume hospitals may have more incentives to increase CABG use at the margin because they are on the steeper part of marginal cost curve. This dynamics of hospital responses to the reimbursement policy depending on the cost structure of medical technology will be an interesting area for future research.

illustrates the Prediction 2. Suppose that prior to PPS, a high CABG-volume hospital provided CABG at the level of q_{pre}^{high} , while a low CABG-volume hospital did so at the level of q_{pre}^{low} . Given decreasing average cost of CABG (AC line), if marginal cost is also decreasing (MC line), then the profit margin for CABG faced by a high CABG-volume hospital (the length of arrow B) is greater than that faced by a low CABG-volume hospital (the length of arrow A).

Prediction 3 (Corollary) *In response to PPS, hospitals will expand CABG use by treating relatively healthier patients for whom angioplasty is more effective in order to exploit the greater economies of scale.*

As noted in Prediction 1, given that CABG has a greater average-to-marginal cost ratio (i.e., greater extent of economies of scale) than angioplasty, hospitals will increase CABG use in response to PPS. According to patients' benefit function and the one-to-one correspondence between CABG use and benchmark value of severity ($q^H = \bar{s} - s^H$), the increase in CABG use will be observed by the expansion of CABG use to healthier patients for whom angioplasty is more effective.

Finally, the number of patients who receive angioplasty under PPS is ambiguous. From equation (8), the angioplasty use is given by

$$q_{post}^{L*} = \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} - \frac{\alpha^0 - \alpha^L}{\beta^L} + \left(\pi_{q^L} - \pi_{q^H}\right) \frac{U_\pi}{U_B} \frac{1}{(\beta^H - \beta^L)} + \left(\pi_{q^L} - \pi_{q^0}\right) \frac{U_\pi}{U_B} \frac{1}{\beta^L}.$$

Note that $\frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} - \frac{\alpha^0 - \alpha^L}{\beta^L}$ is the number of patients who received angioplasty prior to PPS. If the profit margin under PPS is greater for angioplasty (π_{q^L}) than both for CABG (π_{q^H}) and for drug therapy (π_{q^0}), then the hospital will unambiguously have an incentive to increase angioplasty use. However, if the profit margin is less for angioplasty than for CABG ($\pi_{q^L} - \pi_{q^H} < 0$), while greater for angioplasty than for drug therapy ($\pi_{q^L} - \pi_{q^0} > 0$), then there are two countervailing effects on angioplasty use. On one hand, the lower profit margin for angioplasty relative to CABG will generate disincentive for angioplasty use. On the other hand, the higher profit margin for angioplasty relative to drug therapy will counterbalance the disincentive. It also depends on patients' marginal benefit from CABG relative to angioplasty ($\beta^H - \beta^L$), compared with that from angioplasty relative to drug therapy (β^L).

4 Empirical Strategy

To identify the impact of PPS on cardiac procedures, I use a Regression Discontinuity (RD) design exploiting the discontinuity in Medicare eligibility at the age of 65, as well as comparing outcomes before and after the PPS reform at the age-65 threshold. Since the PPS applied only to Medicare patients, the cardiac procedures used for patients aged 65 and over were affected by the PPS rules

while those procedures used for patients under age 65 were not directly affected. More importantly, I estimate the *change* in the use of cardiac procedures at the age-65 threshold before and after the PPS reform. Thus, as long as other factors that might affect the use of cardiac procedures do not change discontinuously at the age-65 threshold before and after the PPS reform, this *pre-post RD design* allows causal interpretation of the estimates.

Let Y_{it} denote the outcome of interest (e.g., CABG or angioplasty discharge rate) for a person i in period t . In a given year, the relationship between the outcome variable and age takes the following form

$$Y_{it} = \alpha + f(\text{age}_{it}; \lambda) + \gamma \cdot \mathbf{1}\{\text{age}_{it} \geq 65\} + \varepsilon_{it}, \quad (11)$$

where f is an underlying function between the outcome and age with parameter vector λ (e.g., a flexible polynomial), which is continuous at age-65; $\mathbf{1}\{\cdot\}$ is an indicator function equal to one if a person is aged 65 or older; and ε_{it} is an error term reflecting the influence of all other factors. The parameter γ measures the deviation of the outcome variable from its continuous relationship with age at the age-65 threshold.

Furthermore, I apply this RD design to *before-and-after* PPS periods. Let $Post_t$ denote a dummy variable for post-PPS periods (e.g., 1986–1987). Utilizing data from before-and-after the PPS reform, I estimate the following equation

$$Y_{it} = \alpha + f(\text{age}_{it}; \lambda) + \gamma \cdot \mathbf{1}\{\text{age}_{it} \geq 65\} + \delta \cdot Post_t + f(\text{age}_{it}; \lambda) \cdot Post_t + \theta \cdot \mathbf{1}\{\text{age}_{it} \geq 65\} \cdot Post_t + \varepsilon_{it} \quad (12)$$

where δ allows for the time effects, $f(\text{age}_{it}; \lambda) \cdot Post_t$ allows the outcome-age functional relationship to change over time, and the parameter θ measures a change in age-discontinuity before-and-after the PPS reform. To identify the average treatment effect at age-65, one needs to ensure that other factors that might affect the outcome of interest do not change discontinuously at the age-65 threshold before and after PPS. This requires that

$$\begin{aligned} & \lim_{a \downarrow 65} E[\varepsilon_{it} | \text{age}_{it} = a, Post_t = 1] - \lim_{a \uparrow 65} E[\varepsilon_{it} | \text{age}_{it} = a, Post_t = 1] \\ &= \lim_{a \downarrow 65} E[\varepsilon_{it} | \text{age}_{it} = a, Post_t = 0] - \lim_{a \uparrow 65} E[\varepsilon_{it} | \text{age}_{it} = a, Post_t = 0] \end{aligned}$$

where $\lim_{a \downarrow 65}$ ($\lim_{a \uparrow 65}$) is the limit to the age of 65 from older (younger) ages. If this holds, then the comparison of the *change* in mean of Y_{it} before and after PPS on either side of the age-65 threshold yields a consistent estimate of the parameter θ in equation (12).³²

In all analyses, I use a fifth-order polynomial in age to allow the flexible functional form of f , and further divide the age 65-and-over indicator into three separate age-category indicators; 65-to-

³²I present empirical evidence that it holds for several factors such as hospital insurance rate, ischemic heart disease prevalence rate, and hospital entry into the provision of CABG in Section 6.

69, 70-to-74 and 75-to-80 to allow differential effects across age groups, if any. The final empirical specification takes on the following form

$$\begin{aligned}
Y_{it} = & \alpha + \gamma_1 \cdot T_{it}^{65} + \gamma_2 \cdot T_{it}^{70} + \gamma_3 \cdot T_{it}^{75} \\
& + \lambda_1 age_{it} + \lambda_2 age_{it}^2 + \lambda_3 age_{it}^3 + \lambda_4 age_{it}^4 + \lambda_5 age_{it}^5 + \delta \cdot Post_t \\
& + \theta_1 \cdot T_{it}^{65} \cdot Post_t + \theta_2 \cdot T_{it}^{70} \cdot Post_t + \theta_3 \cdot T_{it}^{75} \cdot Post_t + \kappa \cdot age_{it} \cdot Post_t + \varepsilon_{it},
\end{aligned} \tag{13}$$

where $T_{it}^{65} = \mathbf{1}\{65 \leq age_{it} \leq 69\}$, $T_{it}^{70} = \mathbf{1}\{70 \leq age_{it} \leq 74\}$, and $T_{it}^{75} = \mathbf{1}\{75 \leq age_{it} \leq 80\}$; $Post_t$ is an indicator for post-PPS periods. The parameters of interest are θ_1 , θ_2 , and θ_3 .

The RD design in this paper requires the Medicare eligibility to be solely determined by the single index variable, age. When the PPS was implemented in 1983, the age was not an unique criteria for Medicare eligibility. Since 1972, Medicare has also covered people under age 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD). Thus, I use information on the source of insurance coverage (Medicare, Medicaid, or private) for those under age 65 from the National Hospital Discharge Survey (NHDS) data to identify non-elderly Medicare beneficiaries.

5 Data

Primary data sources for this paper are the National Hospital Discharge Survey (NHDS), the Multiple Cause-of-Death Mortality Data, National Health Interview Survey (NHIS), and Nationwide Inpatient Sample (NIS) of Healthcare Cost and Utilization Project (HCUP).³³

5.1 The NHDS Data

I use the National Hospital Discharge Survey (NHDS) data from 1979 to 1991 to estimate the impact of PPS on the use of cardiac procedures. It contains information on medical records for hospital admissions and discharges with diagnosis and procedure codes based on the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes; patients' expected source of payment (e.g., Medicare, Medicaid, or private insurance) and; patients' age, gender, race, and marital status. From the NHDS, I construct age-specific CABG and angioplasty discharge rates using ICD-9-CM codes (36.1x for CABG and 36.0x for angioplasty). Also, I use the exact date of discharges in the NHDS and reorganize every individual discharge record into fiscal years, which begin in October of the preceding calendar years.³⁴

³³See the Data Appendix for details.

³⁴Medicare reimburses hospitals on a fiscal year basis – i.e., hospitals received fixed reimbursements for discharges occurred in a fiscal year under PPS. Also, the determination of PPS reimbursement rate is based on hospitals' fiscal-year cost reports. Thus, the year 1983 indicates a pre-PPS period.

For the main analysis, I exclude four states (i.e., MA, NY, NJ, and MD) that were exempted from the PPS (PPS-waiver states hereafter) because those states had their own hospital rate-setting reimbursement systems. Yet I examine PPS-waiver states as a falsification check. I also construct hospital panel data from the NHDS to examine the differential hospital responses by their CABG volume. To identify PPS-waiver states and panel hospitals, I need the restricted variables such as state and hospital identifiers. These data were accessed through the Research Data Center at the National Center for Health Statistics.

5.2 The Multiple Cause-of-Death Mortality Data

To estimate the effects of changes in the use of cardiac procedures on health outcomes, I use the Multiple Cause-of-Death Mortality Data from 1976 to 1991. The data are an annual census of deaths based on information abstracted from the standard Death Certificates and processed by the National Center for Health Statistics (NCHS). The data contain the universe of deaths with information on age at death and underlying causes as well as multiple causes of deaths according to the ICD codes. I use ICD-8 (1976-1978) and ICD-9 codes (1979 onward) of 410-414 for ischemic heart disease mortality rates.

5.3 The NHIS Data

The National Health Interview Survey (NHIS) data from 1976 to 1991 are used to estimate the effects of changes in the use of cardiac procedures on the perceived health status; to test competing hypotheses for my findings. The NHIS provides information on self-reported health status: the question asks “Would you say ___ health in general is excellent, very good, good, fair, or poor?” I use this information as one measure of health outcomes for those with ischemic heart disease. It is also used to estimate the quality of life when estimating the cost per quality-adjusted life year (QALY) due to the change in CABG use.

In addition, it contains information on health insurance coverage by types (hospital and doctor/surgeon) and by payment sources (Medicare, Medicaid, other public, and private insurance); acute and chronic health conditions (e.g., ischemic heart disease). Using this information, I construct age-specific hospital insurance rate and ischemic heart disease prevalence rate to test the *continuity* of these variables at the age-65 threshold before and after the PPS reform.

5.4 The HCUP Data

I use the Nationwide Inpatient Sample (NIS) of Healthcare Cost and Utilization Project (HCUP) data from 1988 to 1992 to estimate average costs, marginal costs, and profit margins for cardiac procedures (i.e., CABG and angioplasty). It contains clinical records (admissions and discharges)

classified by DRG codes as well as ICD-9-CM codes; total charge amounts for individual patients. It also provides information on the source of insurance coverage for individual patients (Medicare, Medicaid, and private insurance). I thus estimate average costs, marginal costs and profit margins for CABG and angioplasty performed to Medicare patients.³⁵ Although the HCUP data contains patient-level records large enough to precisely estimate costs and profit margins, one potential disadvantage for the purpose of this paper is that the HCUP contains data only from 1988. To the extent that the cost structure did not change systematically before and after 1988, however, it provides the solid estimates of cost and profits margins.³⁶

6 Empirical Results

6.1 Profit Margins for the Use of CABG and Angioplasty

Panel A of Figure 1 plots the average costs of CABG and angioplasty used for treating Medicare patients. The data come from the HCUP from 1988 to 1992. The average cost lines are estimated using the local linear regression. The average cost of CABG decreases as the number of discharges increases, which reflects economies of scale (e.g., high fixed costs) in CABG operation. In contrast, the average cost of angioplasty is much lower and likely flat over the range of number of discharges, which implies less extent of scale economies (e.g., low fixed costs) in angioplasty procedure. This suggests that CABG is more profitable than angioplasty under PPS.

To derive profit margin (PPS reimbursement rates minus marginal costs) for each procedure, I estimate the marginal costs from the following equation (Berndt, 1991; Gruber et al., 1999)

$$AC_{ht} = \alpha + \theta \cdot \ln(q_{ht}) + X'_h\beta + \mu_t + \varepsilon_{ht}, \quad (14)$$

where AC_{ht} represents average costs of CABG or angioplasty in hospital h at time t ; q_{ht} is the number of discharges with CABG or angioplasty; X_h are hospital-specific characteristics;³⁷ and μ_t is a set of year dummies. In equation (14), θ gives the difference between marginal cost and average cost. I can therefore derive the marginal cost of each procedure. Finally, the profit for each procedure is derived by subtracting the estimated marginal costs from the PPS reimbursement rate. Panel B of Figure 1 depicts the marginal costs and PPS reimbursement rates for CABG and angioplasty. It shows that the marginal cost of CABG decreases with the number of discharges,

³⁵To derive the costs from charges in the HCUP data, I multiply charge amounts by the cost-to-charge ratio of each hospital from Medicare Cost Reports (see the Data Appendix for details).

³⁶Indeed, more desirable data are the Medicare Provider Analysis and Review (MedPAR) Files which contains costs and PPS payment information when the PPS was introduced. The data request has been on process.

³⁷Included are hospital's location at four Census regions (Northeast, Midwest, South, and West), teaching status nested in urban-rural classification (rural, urban-nonteaching, urban-teaching), bed sizes, and ownership (for-profits, nonprofits, and governments) dummies.

while the marginal cost of angioplasty is likely flat and much lower than that of CABG. Two straight lines depict PPS reimbursement rates for CABG (solid line) and angioplasty (dotted line).³⁸

Table 1 shows the estimated profit margins for CABG and angioplasty. As seen in Column (4), the marginal costs of CABG and angioplasty are \$23,564 and \$9,701, respectively (in 1992 dollars). Column (5) presents the PPS reimbursements: \$29,535 for CABG and \$10,703 for angioplasty. Accordingly, Column (6) shows that the profit margin for CABG is \$5,971 compared to \$1,002 for angioplasty. Consistent with this financial attractiveness of CABG relative to angioplasty under PPS, the difference-in-differences estimates in Column (3) suggest that hospitals increase CABG use, while no changes in angioplasty.³⁹ I proceed to the more detailed analysis using pre-post RD approach in the next section.

6.2 The Impact of PPS on the Use of Cardiac Procedures

The higher profit margin for CABG than for angioplasty implies that hospitals have financial incentives to increase CABG use more than angioplasty use under PPS (Prediction 1). To test this, I estimate changes in CABG and angioplasty discharge rates at the age-65 threshold before and after the PPS reform, using pre-post RD approach. I begin with a graphical analysis.

Figure 2 plots the age profiles of changes in CABG and angioplasty discharge rates.⁴⁰ The data come from the NHDS. Panel A of Figure 2 plots the changes in CABG discharge rate by age. Prior to PPS (plotted by dotted line), there is virtually no change in CABG discharge rate at age-65. Following PPS, however, there is a noticeable increase in CABG discharge rate at the age-65 threshold. Relative to 1980-81, the CABG discharge rate increases about by 15 per 10,000 persons in 1986-87 (plotted with square-markers) and by 20 per 10,000 persons in 1988-89 (plotted with triangles). Panel B depicts the changes in angioplasty discharge rate by age. As expected, there is no change in angioplasty discharge rate before PPS (dotted line). Even after PPS, one can hardly see the discontinuous changes in angioplasty discharge rate at age-65 neither in 1986-87 (plotted with square-markers) nor in 1988-89 (plotted with triangles).

To confirm these graphical patterns, I estimate the pre-post RD model specified in (13) that includes a fifth-order polynomial in age, year effects, year effects interacted with age. In all analyses, estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time. Table 2 presents the results. The data come from the NHDS as for Figure 2. Panel A shows the impact of PPS on the use of CABG. Column (1) ensures that before PPS there is no change

³⁸PPS reimbursement rates for CABG and angioplasty are estimated using the average costs of each technology across all hospitals. These reimbursement amounts do not account for adjustments described in Section 3 – e.g., indirect medical education costs, the disproportionate share of indigent patients, and outlier costs for each hospital.

³⁹Difference-in-differences estimates are adjusted for age dummies and estimated standard errors are corrected for heteroskedasticity and clustered at the age-level.

⁴⁰PPS-waiver states are excluded because those states had their own rate-setting reimbursement system as described in Section 2. I examine those PPS-waiver states as a falsification check.

in CABG discharge rate at age-65. Importantly, Column (2) to (4) show considerable increase in CABG discharge rate at the age-65 threshold after the PPS reform, consistent with the patterns in Panel A of Figure 2. The estimates are highly significant and magnitudes are economically large. Given that the average CABG discharge rate among those aged 65 to 69 was 33 per 10,000 persons prior to PPS (Column (1) in Panel A of Table 1), the estimate of 18 per 10,000 persons (the first row of Column (2) of Table 2) shows that the PPS induced 50 percent increase in CABG use within its four years of implementation. Column (3) and (4) of Table 2 show that the increased CABG use is not transitory. For the same ages (the first rows), the use of CABG increased by 21 per 10,000 persons in 1988-89 (60 percent increase relative to pre-PPS) followed by 13 per 10,000 persons in 1990-91 (40 percent increase).⁴¹ For patients aged 70 to 74 (the second rows), the increase in CABG use is more so than for those aged 65 to 69. This result also ensures that the increased CABG use is not driven by patient’s delay of undergoing CABG until they turn to age 65. If patients do so, then they will receive CABG soon after they turn to age 65 and thus one would not expect to see the increase in CABG discharge rate for those aged 70 to 74 similar to that for those aged 65 to 69. The RD estimate for aged 70 to 74 does not support this delaying effect. Panel B of Table 2 presents the results for angioplasty use. In contrast to CABG, Column (2) to (4) show that under PPS the use of angioplasty does not change at the age-65 threshold – it decreases, if any.⁴² Again, Column (1) ensures that prior to PPS there was no change in angioplasty discharge rate at age-65.

Overall, the results provide evidence that hospitals increased CABG use of 50 to 60 percent, in response to higher profit margin for CABG than for angioplasty under PPS.

6.3 The Impact of PPS by Hospital’s CABG volume

A model predicts that in case of decreasing marginal cost of CABG, high CABG-volume hospitals prior to PPS will increase CABG use after PPS more than low CABG-volume hospitals (Prediction 2). To test this prediction,⁴³ I first construct a panel data using hospital identifiers in the restricted NHDS data. First, I restrict hospitals which had been maintained in the data consecutively during the time period from 1980 to 1987.⁴⁴ Second, I estimate the mean annual CABG volume for each hospital from 1980 to 1983 as pre-PPS CABG volumes.⁴⁵ Finally, I divide hospitals by two groups;

⁴¹Appendix Figure 3 confirms the stability of estimates. In the Figure, I combine years from 1980 to 1983 (pre-PPS) and similarly from 1986 to 1989 (post-PPS). Panel A of Appendix Figure 3 shows sharp discontinuity in CABG discharge rate at age-65 after PPS (1986-1989), while no change at the age-65 threshold before PPS (1980-1983). Note that the magnitude of discontinuous jump at age-65 is similar to the RD estimates in Table 2.

⁴²Panel B of Appendix Figure 3 ensures no change in angioplasty use.

⁴³The marginal cost of CABG is shown to decrease in its use (Panel B of Figure 1).

⁴⁴Unfortunately, the NHDS changed the format of hospital identifiers after 1987 so that I use data from 1980 to 1987 during which the same format of hospital identifiers had been used.

⁴⁵The NHDS provides analytical weights per discharge record based on the two-stage sampling scheme (i.e., hospital level and discharge level within a hospital), which provides hospital-discharge level weights. To estimate hospital-level CABG volumes, I therefore derive hospital-level weights (see the Data Appendix for details).

high and low CABG-volume hospitals based on their mean annual CABG volume from 1980 to 1983. To avoid arbitrariness of hospital grouping by CABG volume, I follow the guidelines of the American College of Surgeons and American College of Cardiology/American Heart Association, and classify hospitals that had performed 200 or more CABG procedures annually from 1980 to 1983 as high CABG-volume hospitals.⁴⁶

In Figure 3, Panel A shows the changes in CABG discharge rate in high CABG-volume hospitals defined above. During the pre-PPS period (plotted in dotted line), the use of CABG was not changed, as expected. Between 1980-81 and 1986-87 (plotted with square-markers), however, high CABG-volume hospitals increased CABG use discontinuously at age-65. The magnitude appears to be about 15 per 10,000 persons. Panel B of Figure 3 plots the changes in CABG discharge rate in low CABG-volume hospitals. It shows no discrete change in CABG use at the age-65 threshold neither during pre-PPS period (1980-81 to 1982-83) nor between pre- and post-PPS period (1980-81 to 1986-87), other than the trend-increase for the elderly in 1986-87.

To ensure the results of graphical analysis, I estimate the pre-post RD model with the same specification used in the previous analysis. Table 3 presents the results of the RD estimates. Panel A confirms that during the pre-PPS period (from 1980-81 to 1982-83) there is no discontinuity in CABG use at age-65 in both high and low CABG-volume hospitals except a small decrease for aged 65 to 69 in low CABG-volume hospitals. Panel B presents the RD estimates of changes in CABG discharge rate before and after the PPS reform (from 1982-83 to 1986-87). The first row of Column (2) shows that high CABG-volume hospitals increased CABG use discontinuously at age-65 by 15 per 10,000 persons. Given that the mean CABG discharge rate among those aged 65 to 69 in high CABG-volume hospitals was 16 per 10,000 persons prior to PPS (curly brackets in Column (2) of Panel B), the estimate of 15 per 10,000 implies that the PPS results in 95 percent increase in CABG use by high CABG-volume hospitals. Column (3) shows no changes in CABG use at age-65 in low CABG-volume hospitals.

Therefore, the results show that high CABG-volume hospitals prior to PPS increased CABG use after PPS, while no change in low CABG-volume hospitals.

6.4 The Effects of PPS on Patient Composition

Given the results that hospitals increased the use of CABG under PPS, a model predicts that this increased use of CABG will be observed among relatively healthier patients (Prediction 3).

To test the prediction, I examine the use of CABG by patients' illness severity. Although the NHDS does not contain direct information on severity level of patients who receive CABG, I use

⁴⁶Waldhausen et al. (1984) recommend 150 CABG procedures per year as a minimum standard and Kirklin et al. (1991) recommend a minimum of 200 to 300 CABG procedures per year. See Crawford et al. (1996) for a review of volume requirements for CABG.

the number of grafts used in CABG and the indication of comorbidity⁴⁷ as a measure of patients' illness severity. The number of grafts indicates how many grafts are used to bypass the diseased vessels, which in turn indicates patients' illness severity. Accordingly, I define the patients who receive 1) CABG with one or two grafts or; 2) CABG with three or more grafts *without* indication of comorbidity as moderately-ill patients, while the patients who receive CABG with three or more grafts *with* indication of comorbidity as severely-ill patients.

Figure 4 plots the difference in CABG discharge rate between age groups by severity level: CABG with one or two grafts (black bars); three or more grafts without indication of comorbidity (gray bars) and; three or more grafts with indication of comorbidity (white bars). In Panel A, I plot the difference in CABG discharge rate between Medicare (aged 65 to 69) and non-Medicare patients (aged 60 to 64). It suggests that CABG use for moderately-ill patients (black bars and gray bars) increased among Medicare patients more than among non-Medicare patients after PPS relative to before PPS. In Panel B, I plot the difference between two non-Medicare-patient groups (aged 60 to 64 and aged 55 to 59) to check whether the similar pattern appears among non-Medicare patients. It shows that there is no discernable difference in CABG use for moderately-ill patients among two non-Medicare-patient groups. Thus, Figure 4 suggests that the use of CABG under PPS was expanded to relatively healthier patients only among Medicare patients.

Now I turn to the pre-post RD analysis. I begin with graphical presentation. Figure 5 depicts the age profiles of changes in CABG discharge rate by patients' illness severity – i.e., moderately-ill patients (plotted as two solid lines) and severely-ill patients (plotted as dotted line). Panel A plots the change in CABG discharge rate between two pre-PPS periods (from 1980-81 to 1982-83). It shows that there is no visible change in CABG use at age-65 by patients' illness severity. Panel B depicts the changes in CABG discharge rates before (1980-81) and after (1988-89) the PPS reform. It shows that CABG use for moderately-ill patients (plotted with square-markers and triangles) increased discontinuously at the age-65 threshold. In contrast, there is no discontinuous change in CABG use for severely-ill patients at age-65 (dotted line with circles).

The RD estimates in Table 4 confirm these patterns. Panel A of Table 4, corresponding to Panel A in Figure 5, ensures that there is no changes in CABG use at age-65 prior to PPS across patients' severity levels. Panel B of Table 4 provides evidence that CABG use was expanded to relatively healthier patients following PPS. The use of CABG with one or two grafts (Column (1)) increased at age-65 by 8 per 10,000 persons and; CABG with three or more grafts without indication of comorbidity (Column (2)) increased at age-65 by 10 per 10,000 persons. However, the use of CABG with three or more grafts with indication of comorbidity (Column (3)) did not change at age-65. Combining the two estimates (the first rows in Column (1) and (2) of Panel B)

⁴⁷I measure the indication of comorbidity based on patients' diagnosis at admission – acute myocardial infarction (or heart attack), diabetes mellitus, chronic renal disease, cardiac arrhythmias, congestive heart failure, and history of previous heart surgery (see the Data Appendix for corresponding ICD-9 codes used).

yields the increase in CABG use by 18 per 10,000 persons. Compared to the increased CABG use for all patients (21 per 10,000 – first row of Column (3) in Panel A of Table 2), the magnitude of 18 per 10,000 implies that about 85% of the overall increase in CABG use from 1982 to 1988 is explained by the increased CABG use for moderately-ill patients.⁴⁸ It is noteworthy that the medical literature has subscribed to the view that angioplasty is medically more effective than (or at least as effective as) CABG for moderately-ill patients (Yusuf et al., 1994; Rosen et al., 1995; Hlatky et al., 1997; Hannan et al., 1999).

Thus, consistent with the Prediction 3, the results show that the increase in CABG use under PPS has been mostly driven by its expanded use for relatively healthier patients for whom angioplasty is more cost-effective.

6.5 Effects of Increased CABG Use on Health Outcomes

6.5.1 Ischemic Heart Disease Mortality and Perceived Health Status

I analyze two measures of health outcomes: ischemic heart disease (IHD) mortality and perceived health status of those with IHD. In terms of mortality measure, although the in-hospital CABG mortality rate can be used, it is not perfectly desirable for the purpose of this paper.⁴⁹ As the findings in the previous section show, the composition of patients who receive CABG can be changed – i.e., relatively healthier patients receive CABG. Then the in-hospital CABG mortality rate will be biased due to this composition change in patients who receive CABG.⁵⁰ The advantage of using IHD mortality rate is to be less subject to this selection bias. On the other hand, the disadvantage is that it does not provide information on the type of medical treatments the deceased received, if any. As long as other procedures (i.e., angioplasty) provided to the deceased do not change discontinuously at age-65 before and after PPS, the IHD mortality rate is the preferable measure of health outcomes resulting from CABG use.

Figure 6 plots the age profiles of changes in IHD mortality rate. The data come from Multiple Cause-of-Death Mortality Data and intercensal estimates of population from the Bureau of the Census. All years are calendar years. The overall IHD mortality rates had been appreciably

⁴⁸To further explore the increase in elective CABG use, I plot the changes in CABG discharge rate among heart attack (Acute Myocardial Infarction: AMI) patients. The CABG use for heart attack patients is urgent or emergent so that hospitals might not have as much discretion for emergent CABG use as for elective CABG use. Appendix Figure 4 shows that there is no change in CABG use at age-65 among heart attack patients. This supports the finding of the expansion of CABG use elective to healthier patients.

⁴⁹Indeed, I use the in-hospital CABG mortality rate from the NHDS data. Appendix Figure 5 suggests no changes in the in-hospital CABG mortality at age-65 before and after the PPS reform.

⁵⁰Another concern is that hospitals may transfer patients after undergoing CABG to long-term care facilities (i.e., nursing homes) because the longer stay in hospital is not proportionately reimbursed under PPS (Kosecoff et al., 1990). Sager et al. (1989) show that the increased transfer of terminally-ill patients from hospitals to nursing homes.

reduced *across ages* over time.⁵¹ Even before PPS (from 1976-77 to 1981-82; plotted with circles), the IHD mortality rate was reduced across ages. The similar time trends are shown after PPS – i.e., from 1976-77 to 1986-87 (plotted with square-markers) and to 1988-89 (plotted with triangles). Also, over time, the IHD mortality rate had been *continuously* decreased as ages get older. These patterns imply that overall medicine for treating IHD generally benefits the overall population, and more so the elderly. Relevant to the purpose of this paper, however, there is no discernable change in IHD mortality rate at the age-65 threshold, despite the substantial increase in CABG use at age-65 as evidenced above. This shows that the increase in CABG use did not seem to improve patients’ health, which supports the findings of increased use of CABG for relatively healthier patients. In fact, Heidenreich and McClellan (2001a) and Heidenreich and McClellan (2001b) show that the use of CABG contributed to only 2% of the reduction in heart attack mortality rate between 1975 and 1995, while 58% of the reduction was attributed to drug therapy (especially aspirin, beta-blockers, and thrombolytics).

Table 5 shows the estimates of discontinuity in IHD mortality rate at age-65. First, the year effects confirm overall time trends shown in Figure 6. Other than this overall time-trend reduction, Column (1) shows no change in IHD mortality at age-65. Note that the marginally significant increase in IHD mortality by 7 per 10,000 persons aged 65 to 69 does not yields mechanical reduction in IHD mortality after PPS. Column (2)-(4) reassure the graphical patterns in Figure 6. During all the post-PPS periods, the IHD mortality rate does not change at the age-65 threshold. Overall, the RD estimates in Table 5 show that the increase in CABG use did not seem to improve patients’ health.⁵²

Now I turn to another measure of health outcomes: self-reported health status among people with IHD. Figure 7 plots the age profiles of changes in percent of being in good health among those with IHD, based on the share of people with IHD reporting “excellent,” “very good,” or “good” to the question on their health in general. The data come from the NHIS. It shows that prior to PPS (plotted with hollow circles) the proportion of persons who assess their health as good is smoothly reduced as people get older. The similar pattern is shown after PPS (two solid lines with markers) yet not discontinuously at age-65. It implies that between pre- and post-PPS time periods, health status among those with IHD do not change at age-65, despite the sizable increase in CABG use at the age-65 threshold. Table 6 shows the RD estimates.⁵³ Column (2) to (4) confirm that there is no change in the perceived health status among those with IHD at age-65. Again, Column (1)

⁵¹Between 1982 and 1988, the IHD mortality rate across *all ages* decreased by 3 per 10,000 persons

⁵²Other studies (Rogers et al., 1990; Cutler, 1995) also find no impact of PPS on mortality, although they do not explore the specific medical treatments.

⁵³I combine years of 1982 and 1983 instead of 1981 and 1982 because the question on health status was changed in 1982 (see the Data Appendix for details). This is just to insure the consistent measure of health status at least between pre-and-post PPS periods (i.e., between 1982-83 and 1986-87). However, combining years of 1981 and 1982 as done for IHD mortality rate shows the same results (see Appendix Table 1).

shows no change in self-reported health status of those with IHD at age-65 prior to PPS. Overall, the results show that the increased CABG use did not appear to improve patients' health.

6.5.2 Cost-Effectiveness of the Increased CABG Use

To further examine the effects of increased use of CABG on health outcomes, I estimate the cost per quality adjusted life year (QALY) resulting from the increased CABG use. I first construct the life table for survivors to age 45 using age-specific IHD mortality rate, which provides the age-specific survival gains from avoiding death risk of IHD.⁵⁴ To proceed the cost-effectiveness analysis, I derive the added life years (per 10,000 persons) by single-age from the life table explained above. The corresponding figures are presented in Table 8 (the second panel).

I now turn to the estimation of quality of life for persons with IHD, the challenging part of the cost-per-QALY calculation. I use the latent variable model to estimate quality of life using information on self-reported health status from the NHIS. This method with the same data has been also used in other studies (Cutler and Richardson, 1997, 1998; Cutler et al., 2001). Suppose person i 's underlying health status is denoted by h_i^* , and is related to types of disease (d_i), demographic characteristics (X_i), and idiosyncratic error term (ε_i):

$$h_i^* = \alpha + \gamma d_i + X_i' \beta + \varepsilon_i. \quad (15)$$

I assume that self-reported health status represent h_i^* and ε_i follows the logistic distribution. Then I estimate equation (15) by ordered logit regression.⁵⁵

I report the results of this estimation, along with imputed QALY weights in Table 7. The implied QALY weights are calculated as $1 - \frac{\beta}{c_4 - c_1}$, where c_4 is the estimated value of h_i^* at which a person begins to report excellent health and c_1 is the estimated value at which he reports poor health.⁵⁶ The estimated QALY weights in Column (2) show that persons with chronic disease perceive their health status lower than those without chronic disease do. For instance, in 1982-1983 persons with IHD aged 45 to 64 perceive their health status as 66 percent of perfect health. Noteworthy is that over time (Column (4)) the perceived health status among those with chronic disease had been improved by 4 to 6 percent. However, perceived health among persons with IHD aged 65 to 69 relative to 45 to 64 was not improved between pre- and post-PPS periods (the second

⁵⁴The results are shown graphically in Appendix Figure 6. It plots the survival curve for IHD. Similar to Figure 6, it shows that the survivorship has been improved over time, but not discontinuously at age-65. Comparing two time intervals – i.e., 6 years before PPS (1976 and 1982 lines) and 6 years after PPS (1982 and 1988 lines), I note that overall survival gains appear to be larger during the pre-PPS than the post-PPS periods. This pattern implicitly suggests possibly little health benefits from the increased CABG use.

⁵⁵I include six chronic-disease dummies (i.e., circulatory disease other than IHD, respiratory disease, digestive disease, skin and musculoskeletal disease, impairments, and other chronic disease), age, age squared, indicator for ages 65-69, 70-74, and 75-80; then fully interacted with the ischemic heart disease dummy.

⁵⁶These two values are indicated as Cut 4 and Cut 1 under the “Cut points” Panel in Table 7.

row of Column (4)).⁵⁷ For the cost-per-QALY estimation, I use the imputed QALY weights from the interaction term of IHD dummy with indicator for ages of 65 to 69.

Table 8 summarizes the results so far in this section and presents the cost-per-life-year and cost-per-QALY estimates. It shows that the lower bound estimate of the cost-per-QALY due to the increased CABG use between 1982 and 1986 was over \$1 million; between 1982 and 1988, it was over \$1.7 million. Even these lower bound estimates are based on the conservative assumptions. First, I overstate survival gains from the increased CABG use. Hunink et al. (1997) show that 29% of reduction in IHD mortality rate from 1980 to 1990 was explained by both medical and surgical treatments – i.e., including not only CABG, but also angioplasty and drug therapy.⁵⁸ Nevertheless, I conservatively assume that all 29% of decline in IHD mortality from 1982 to 1988 was solely attributable to CABG use. Second, I understate the cost of increased CABG use by applying the increase in CABG use only to survivors. Also, I do not include other costs for CABG use, such as Medicare’s separate reimbursements for cardiac surgeons who perform CABG in hospitals.⁵⁹ Noticeable is that even the lower bound estimates of cost-per-QALY ratios are exceptionally higher than the commonly accepted thresholds for cost-effectiveness of medical technology: \$20,000 to \$100,000 (Laupacis et al., 1993). This is partly because of the increased CABG use for relatively healthier patients. Weinstein and Stason (1982) also show that in 1981 the cost-per-QALY of CABG was \$470,000 for one-vessel disease with mild angina compared to \$7,200 for three-vessel disease with severe angina, suggesting that the use of CABG is not effective for relatively healthier patients. In sum, the results of cost-effectiveness analysis show that the expanded CABG use resulting from the PPS increased health care expenditures with possibly little health benefits.

6.6 Competing Hypotheses

In this section, I examine a number of possible competing hypotheses that may explain my findings. Of particular hypotheses are 1) the increase in hospital insurance rate, 2) the increase in heart disease prevalence rate, and 3) the increase in hospital entry into the provision of CABG.

6.6.1 Increase in Hospital Insurance

Some researchers have argued that insurance per se could induce technological change toward cost-increasing, and away from cost-saving innovations (Feldstein, 1971; Warner, 1978; Russell, 1979;

⁵⁷Indeed, one can expect the decrease in quality of life if there is a reduction in mortality presumably because survivors might be severely-ill. The estimates (insignificant and small) indirectly support no mortality reduction at the age-65 threshold.

⁵⁸Heidenreich and McClellan (2001a,b) show that only 0.6 to 2% of the reduction in heart attack (AMI) mortality from 1975 to 1995 was attributed to the use of CABG, while 50 to 58% was due to drug therapy (aspirin, beta-blockers, and thrombolytics).

⁵⁹Medicare reimbursements for physician services (also known as Part B) had been based on full-cost reimbursement during the study period. It was changed to the PPS-like payment system in 1992 – i.e., Physician Fee Schedule.

Goddeeris, 1984). If persons under age 65 with ischemic heart disease who want to undergo CABG but cannot do so because they are uninsured or unable to cover out-of-pocket expenses under their insurance policy, then they would delay undergoing CABG until the time when they are eligible for Medicare. If so, then being covered by Medicare, regardless hospital responses, might explain the increased CABG use. I thus examine whether there is a discontinuous change in hospital insurance rate at age-65 before and after the PPS reform. Figure 8 plots the age profiles of changes in hospital insurance rate. The data come from the NHIS.⁶⁰ Not surprisingly, it shows no change in percent insured for hospital services at age-65 before and after the PPS reform. In Table 9, Panel A presents the RD estimates. Consistent with graphical patterns, Column (2) to (4) in Panel A show no discontinuous change in hospital insurance rate at the age-65 threshold before and after PPS. Column (1) ensures no discontinuous change in hospital insurance rate at age-65 before PPS.

6.6.2 Increase in Ischemic Heart Disease Prevalence

Another possible competing hypothesis is the increase in ischemic heart disease prevalence rate among aged 65 and over, which potentially leads to the increase in CABG use. To test this hypothesis, I examine changes in IHD prevalence rate before and after PPS at the age-65 threshold. In Figure 9, I plot the changes in IHD prevalence rate by age using the NHIS data. It shows no discontinuous change at age-65 throughout the periods. Panel B of Table 9 presents the RD estimates. Confirming the graphical patterns, Column (2) to (4) show no change in IHD prevalence rate at age-65 before and after PPS. Although marginally significant, the IHD prevalence rate seems to rather decrease at age-65 in 1989 relative to 1982. Column (1) ensures that the IHD prevalence rate did not change at age-65 before PPS.

6.6.3 Increase in Hospital Entry into the Provision of CABG

I consider another alternative hypothesis that the increased CABG use may simply reflect the increase in hospital entry into the provision of CABG. If so, hospitals in states *without* entry restriction will increase CABG use more than hospitals in states *with* entry restriction. I examine this hypothesis utilizing variations in the entry restriction for the provision of CABG across states.

The National Health Planning and Resources Development Act of 1974 authorized state Certificate-of-Need (CON) programs. Under these programs, hospitals that plan on capital expenditures or providing costly medical treatments such as CABG, are subject to the review and approval of the state regulatory authorities (Maryland Health Care Commission, 2000). In the

⁶⁰Before 1989, the NHIS had not regularly surveyed insurance coverage. The survey years containing insurance information during the study period are 1978, 1980, 1982, 1983, 1984, and 1986. From 1989 on, the insurance data have been collected every year.

1980s, many states repealed their CON programs.⁶¹ If some states repealed their CON programs for CABG around when the PPS was implemented, then the increase in hospital entry into the provision of CABG due to the repeal of CON program might explain the increased CABG use after the PPS reform.⁶²

To test this, I examine changes in CABG use by each state's CON status. Figure 10 plots the age profiles of changes in CABG use among states that repealed their CON programs (Panel A), along with states that maintained their CON programs (Panel B). Panel A shows that hospitals in states that repealed CON programs (free entry) do not increase the use of CABG discontinuously at age-65 following PPS (dotted with square-markers). Again, prior to PPS, there is no discontinuous change at age-65 (plotted as dotted line). Interestingly, however, Panel B shows that hospitals in states that maintained CON programs (entry restrictions) indeed increase the use of CABG after PPS (plotted with square markers) while no changes before PPS (plotted with circles).

Table 10, presenting the RD estimates, confirms no effect of hospital entry on the change in CABG use. The first columns of each panel of Table 10 replicate my baseline results from Table 2 for comparisons. Panel A shows, as expected, that there is no change in CABG use before PPS among states both with and without CON programs. Column (2) in Panel B presents no discontinuous change in CABG use at age-65 after PPS in states with free entry. In contrast, Column (3) in Panel B shows that hospitals in states with entry restrictions do increase CABG use discontinuously at age-65, following PPS. In terms of the magnitude of RD estimates in Column (3), the increased use of CABG at age-65 by 20 (per 10,000 persons) is close to the increase in CABG use in all PPS states – i.e., 21 per 10,000 persons (Column (1) in Panel B). Overall, the main results of this paper are not masked by the increase in hospital entry into the provision of CABG. Indeed, the entry restrictions seemed to increase the use of CABG presumably because hospitals could exploit economies of scale in CABG operation without threat of new entry. An investigation of the extent to which the reimbursement schemes affect hospital behavior under entry restrictions will be an interesting area for future research.

⁶¹States that repealed their cardiac CON program between 1983 and 1988 are Idaho, New Mexico, Minnesota, Utah, Arizona, Kansas, Texas, Wyoming, California, Colorado, and South Dakota (Vaughan-Sarrazin et al., 2002; Maryland Health Care Commission, 2000).

⁶²Indeed, I find suggestive evidence that there was an increase in hospital entry into the provision of CABG after the repeal of CON program. Appendix Figure 7 shows the distribution of hospitals by annual CABG volume by CON status. In states that repealed their CON program (black bars), over 60 percent of hospitals perform CABG less than 200 annually. In contrast, in states that maintained CON program (gray bars), less than 35 percent of hospitals do so. This pattern implies that new entrants in the provision of CABG share the market with incumbents, i.e., “business stealing” (Mankiw and Whinston, 1986). Moreover, Appendix Figure 8 plots the percent of patients undergoing CABG at high CABG-volume hospitals by CON status of each state. It shows that in states that repealed their CON program before 1989 (black bars), the proportion of patients undergoing CABG in high CABG-volume hospitals was reduced considerably relative to 1980 and 1982 (before the repeal of CON program). This pattern does not appear in states that maintained their CON program (gray bars). Other studies also show that the repeal of CON program induced hospital entry into the provision of CABG (Vaughan-Sarrazin et al., 2002; Cutler et al., 2010). Thus, I test the likely actual hospital entry.

6.6.4 A falsification check

I examine changes in the use of CABG and angioplasty in PPS-waiver states as a falsification check. Figure 11 plots the age profiles of changes in CABG and angioplasty discharge rates in PPS-waiver states. It shows no discontinuous change in the use of CABG and angioplasty at age-65. In Panel A of Figure 11, I note the mean increase (yet no discontinuity at age-65) for ages of 70-75 in 1988-1989. This can be partly explained by catch-up of two PPS-waiver states – i.e., Medicare PPS was in effect in Massachusetts and New York from 1986. Consistent with these graphical patterns, the RD estimates in Table 11 confirm no change in the use of CABG and angioplasty at the age-65 threshold before and after the PPS reform in PPS-waiver states.

6.7 Other Procedures?

My findings show that the average cost payments of PPS provided financial incentives for hospitals to expand the use of CABG that yields high profit margin. Since financial incentives under PPS can affect more than just cardiac procedures, I examine the use of other surgical procedures under PPS. Figure 12 depicts the growth in the use of each surgical procedure between 1983 (pre-PPS) and 1987 (post-PPS) and its PPS relative reimbursement rate. It shows a strong positive association between the PPS reimbursement rate and the change in procedure use, which suggests that hospitals may have an incentive to expand the use of financially attractive medical technologies in general under PPS. One procedure that had almost the lowest reimbursement rate and decreased most is a cataract surgery (lens procedure). This implies that hospitals may have disincentives to provide cataract surgery in the inpatient settings.⁶³ Before the implementation of PPS, cataract surgery had been the most frequently performed procedure for Medicare beneficiaries. For example, cataract surgery discharge rate for those aged 65 and over was 183 (per 10,000 persons) in 1983. However, it dropped to 19 (per 10,000 persons) in 1987, fell by 90 percent.

Figure 13 plots the age profiles of the changes in cataract surgery discharge rate. In contrast to the stable and no discontinuous change at age-65 prior to PPS (plotted with circles), there was a large decline in the use of cataract surgery at age-65 after PPS (plotted with square-markers and triangles). Table 12 presents the RD estimates. It shows that following PPS (Column (2) to (4)) the use of cataract surgery decreased remarkably at age-65 even after controlling for sizable time effects. Column (1) confirms no changes in the use of cataract surgery at age-65 before PPS. Although this analysis is very preliminary, the results suggest that hospitals seemed to respond to financial (dis)incentives under PPS in their use of medical technologies in general.

⁶³Note that Medicare PPS applied only to hospital inpatient services, while hospital outpatient services had been reimbursed under the full-cost reimbursement system even after the implementation of PPS. The hospital outpatient PPS was implemented in 2000.

7 Conclusion

In this paper, I examined the impact of average cost payments of PPS on the use of cardiac treatments in hospitals, and its resulting effects on health outcomes. It has been generally expected that the average cost payments of PPS would reduce the use of expensive technologies because hospitals would bear the full additional costs above the PPS reimbursement rate. As the findings of this paper show, however, the use of costly medical technology (CABG) had been increased due to financial incentives faced by hospitals to exploit economies of scale under PPS. Furthermore, hospitals expanded CABG use by treating relatively healthier patients for whom the alternative technology (angioplasty) was readily available and medically substitutable at a lower cost. The results of this paper may therefore provide one of the explanations for the continuing rise in health care costs, despite the efforts of policymakers to contain them.

To the extent that Medicare PPS has long been considered a likely effective cost-containment strategy, the results of this paper provide important implications for how to structure provider payment systems that can enhance the efficiency of health care delivery without compromising patients' health benefits. The paper highlights the importance for policymakers, third-party payers, and health care consumers to understand 1) implicit incentives faced by providers (i.e., hospitals) under reimbursement schemes (i.e., the average cost payments) along with 2) cost structure of medical technology, both of which are key to understanding the implications of reimbursement system on the efficiency of health care delivery.

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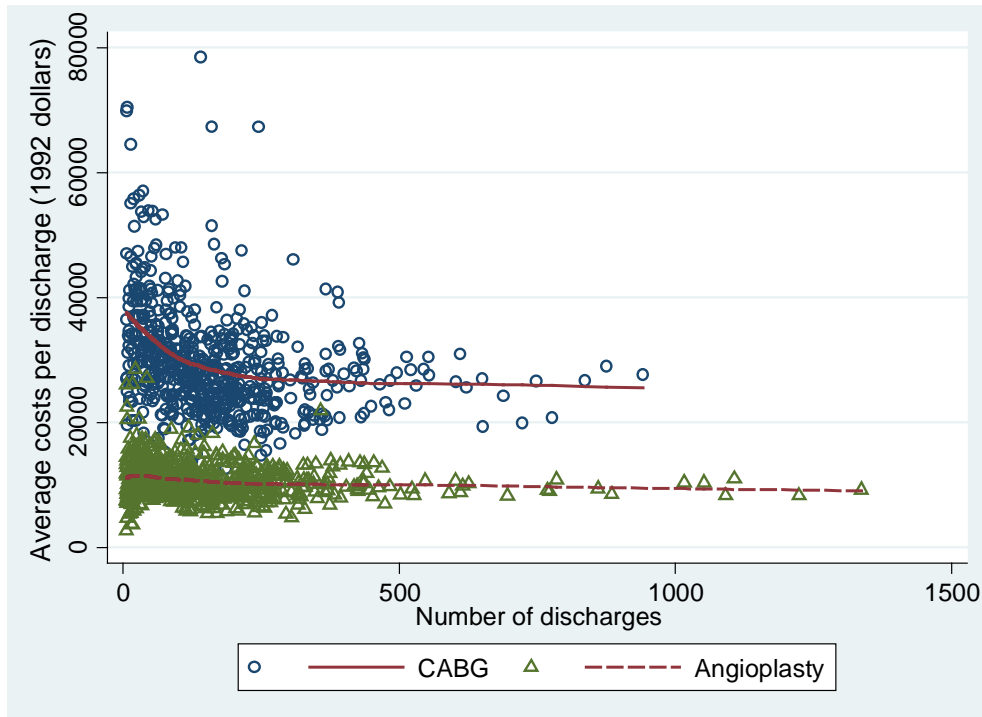
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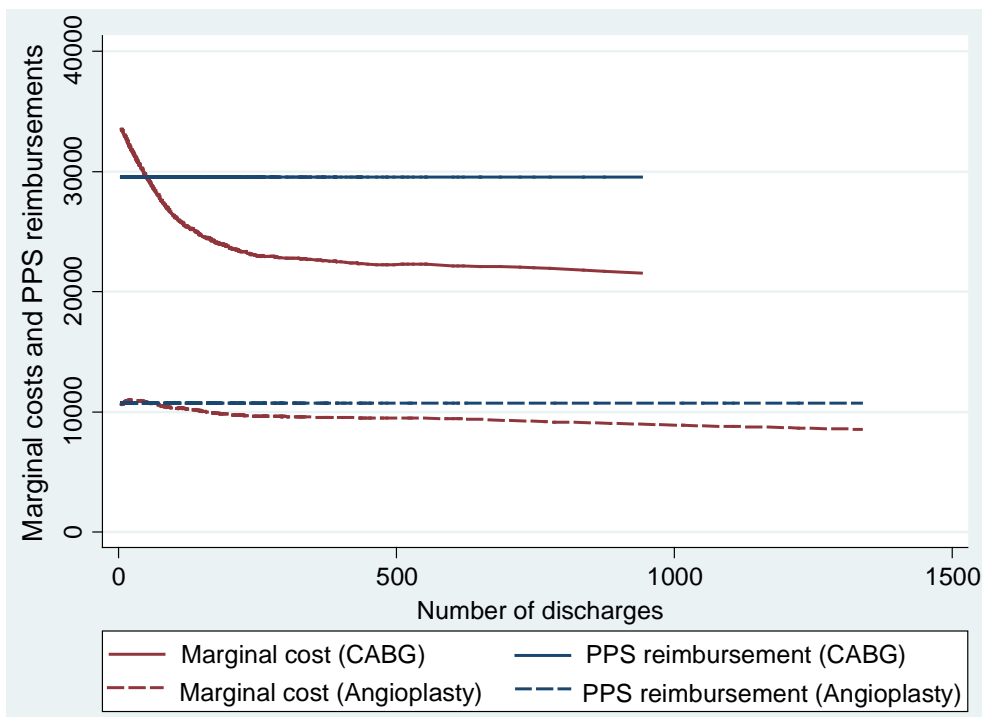
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Figure 1: Costs and PPS reimbursements for CABG and Angioplasty, ages 65 and over
 A. Average costs of CABG and Angioplasty (per discharge), 1988-1992



B. Marginal costs and PPS reimbursements of CABG and Angioplasty (per discharge), 1988-1992

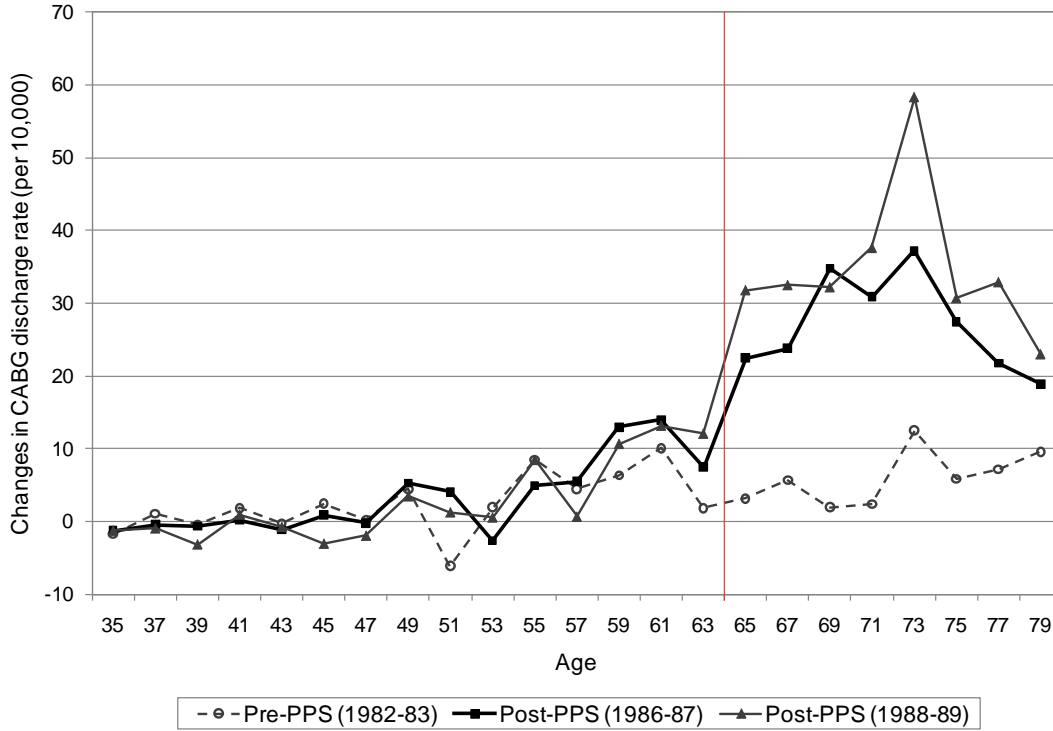


Notes: Figures include CABG and angioplasty provided to Medicare patients aged 65 or over. Any hospitals that performed five or more procedure annually are included. Average cost lines are derived from local linear regressions. Marginal cost lines come from the estimation of equation (14), controlling for hospital's locations at four Census regions (Northeast, Midwest, South, and West), teaching status nested in urban-rural classification (rural, urban-nonteaching, urban-teaching), bed sizes, and ownership (for-profits, nonprofits, and governments). DRG codes used for CABG are 106 and 107, and the code used for Angioplasty is 112.

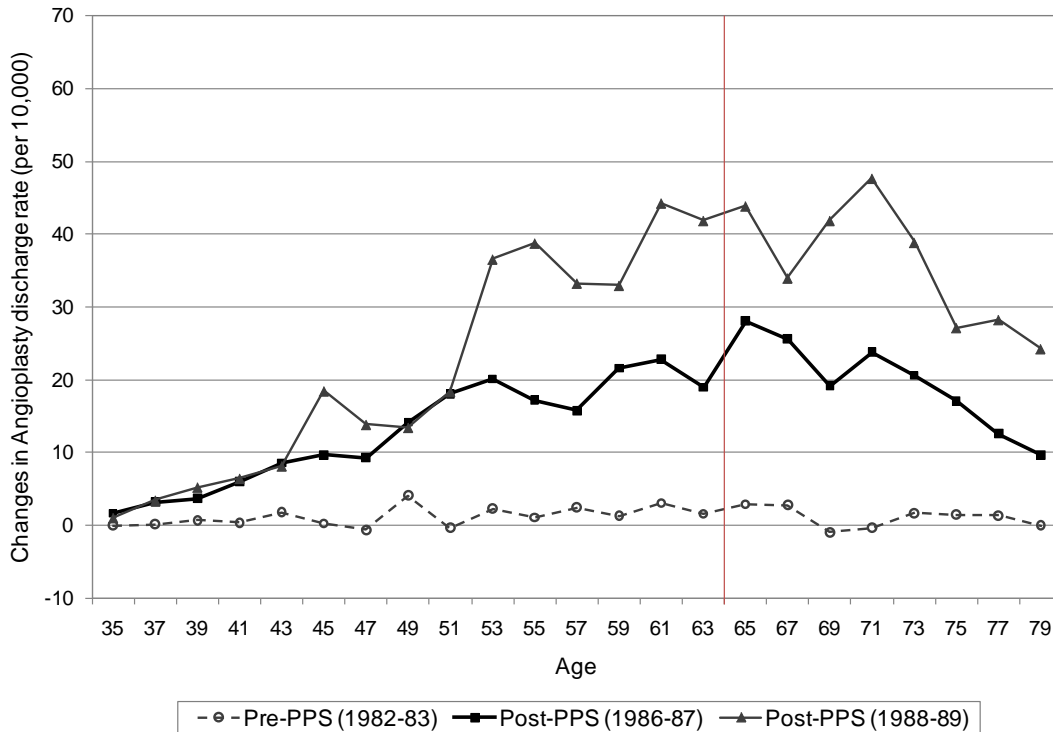
Source: Healthcare Cost and Utilization Project (HCUP) and Medicare Cost Reports.

Figure 2: Changes in hospital discharge rate, by cardiac procedure

A. Changes in CABG discharge rates relative to 1980-1981



B. Changes in Angioplasty discharge rate relative to 1980-1981

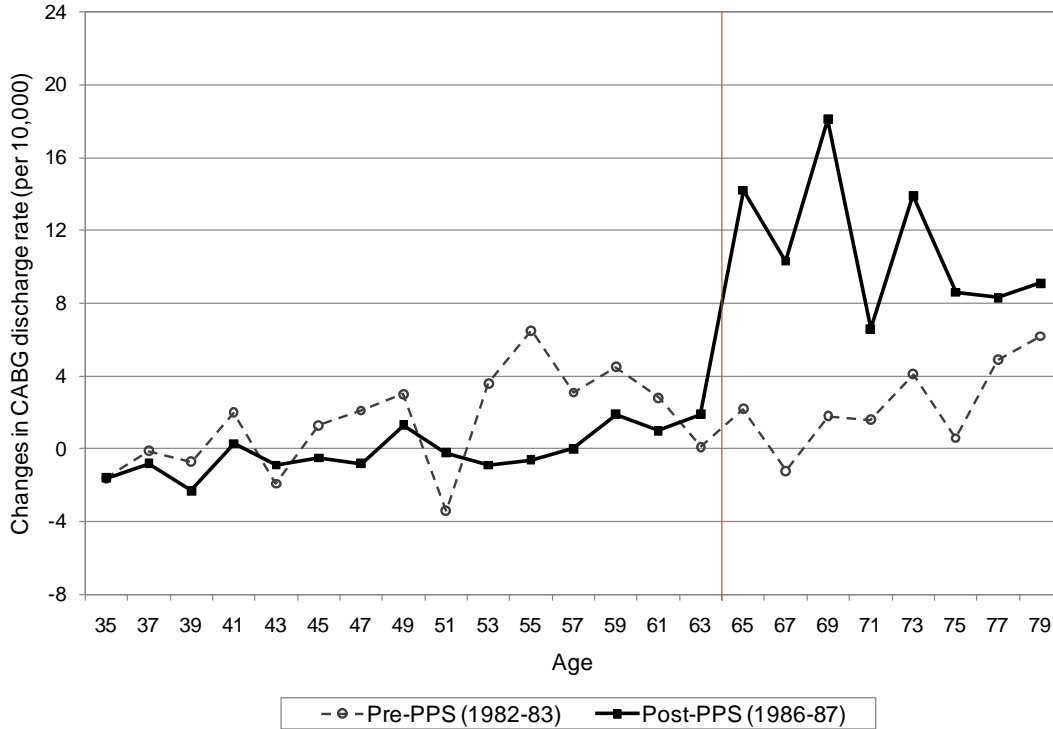


Notes: Figures exclude PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)). The ICD-9-CM codes used for CABG and Angioplasty are 36.1x and 36.0x, respectively.

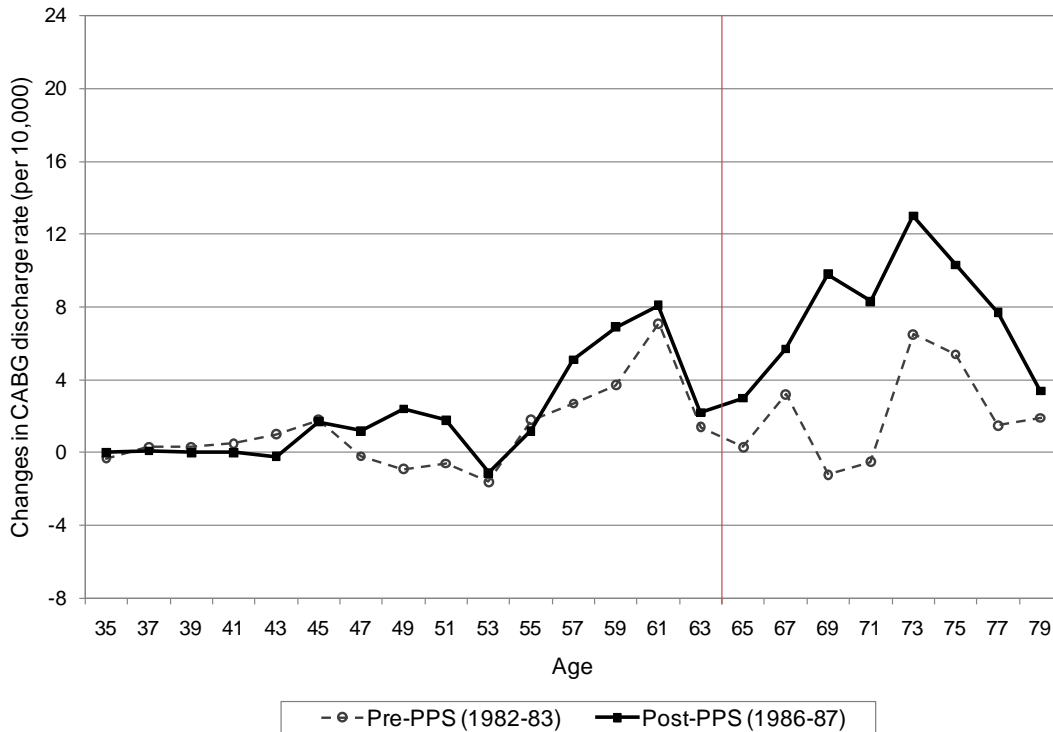
Source: National Hospital Discharge Survey

Figure 3: Changes in CABG discharge rate, by hospital CABG-volume

A. Changes in CABG discharge rate relative to 1980-1981, high CABG-volume hospitals

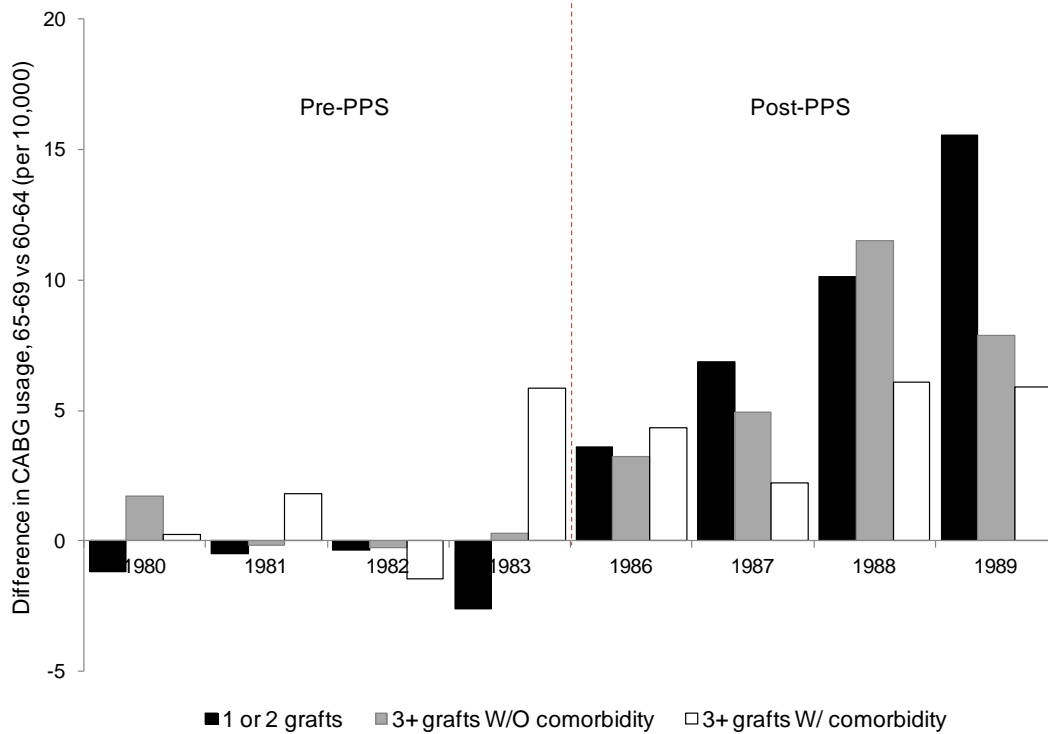


B. Changes in CABG discharge rate relative to 1980-1981, low CABG-volume hospitals

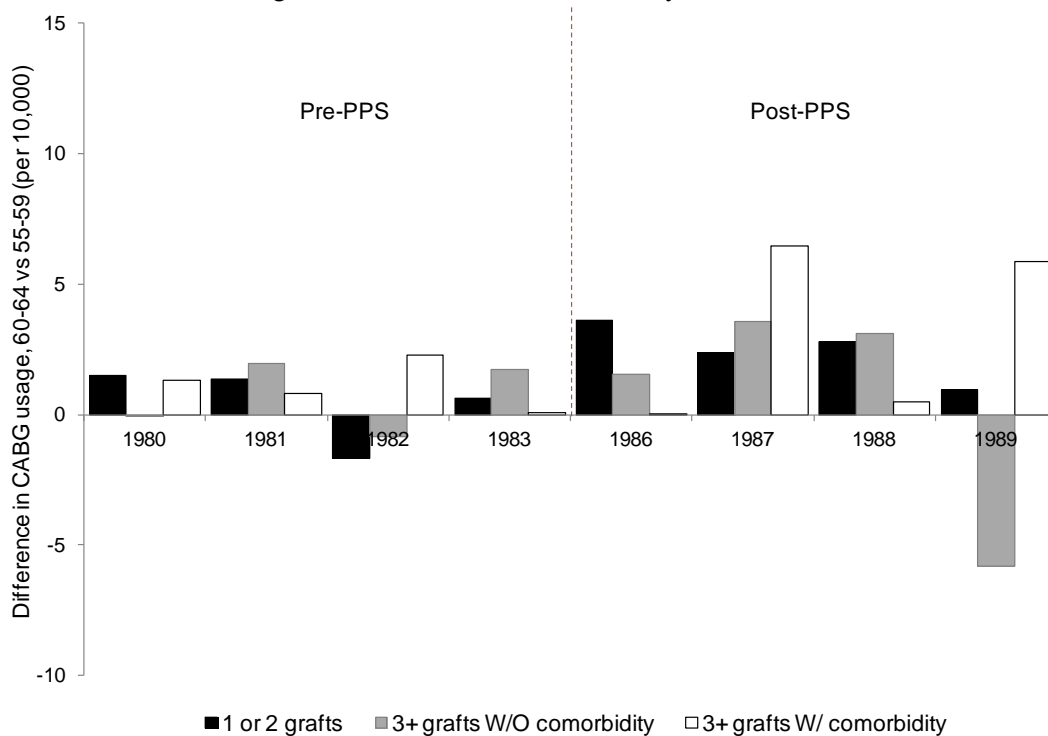


Notes: Figures exclude PPS-waiver states (MA, NY, NJ, and MD) and non-elderly Medicare beneficiaries. Hospitals that had performed 200 or more CABGs annually during 1980-82 (i.e., pre-PPS period) are categorized as high-volume hospitals. ICD-9-CM codes for CABG and Angioplasty are 36.1x and 36.0x, respectively.
 Source: National Hospital Discharge Survey

Figure 4: Difference in CABG discharge rate between age-groups, by number of grafts and comorbidity
 A. Difference in CABG discharge rate between 65-69 and 60-64 years



B. Difference in CABG discharge rate between 60-64 and 55-59 years olds

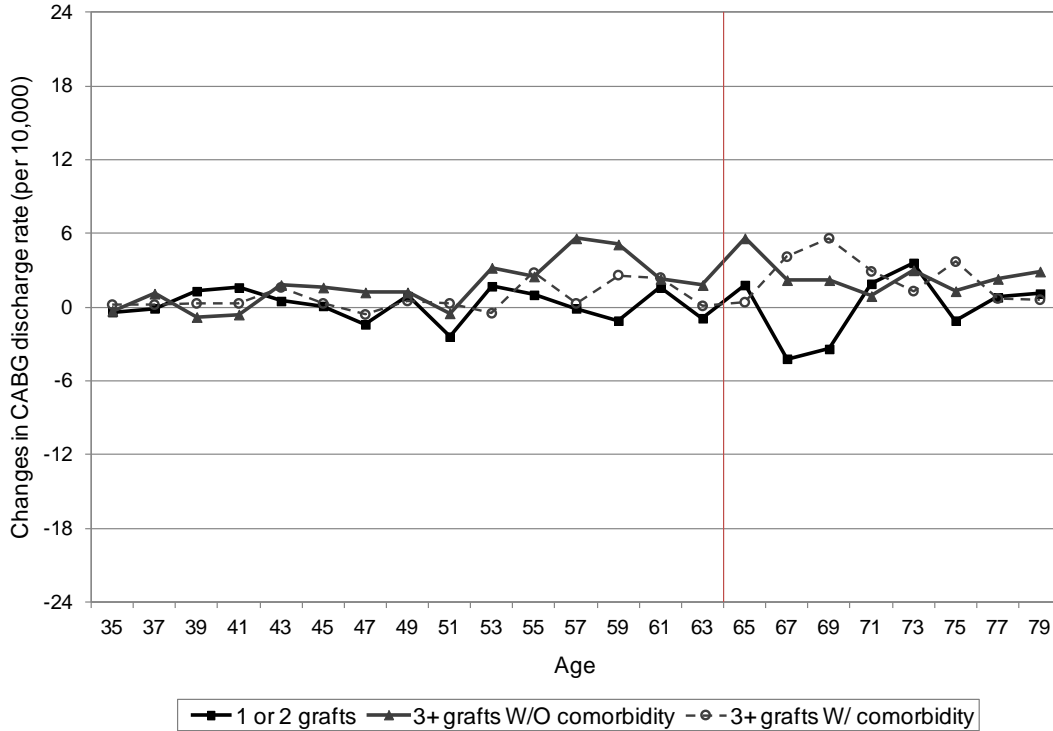


Notes: Figures exclude PPS-waiver states (MA, NY, NJ, and MD) and non-elderly Medicare beneficiaries. The ICD-9-CM codes used for CABG with one or two grafts are 36.11-36.12, 36.15-36.16; three or more grafts are 36.13-36.14. The indication of comorbidity is based on patients' diagnoses at admission: heart attack (Acute Myocardial Infarction: AMI), diabetes mellitus, chronic renal disease, cardiac arrhythmias, Congestive Heart Failure (CHF), or previous heart surgery (see the Data Appendix for details).

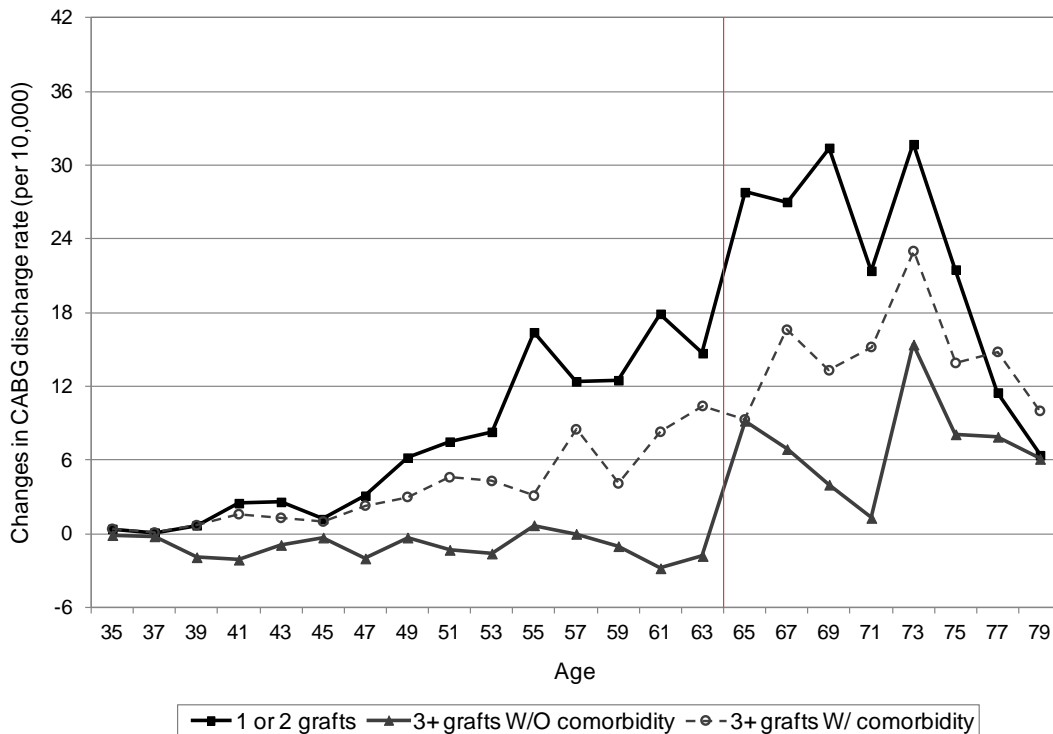
Source: National Hospital Discharge Survey

Figure 5: Changes in CABG discharge rate, by number of grafts and comorbidity

A. Changes in CABG discharge rate from 1980-1981 to 1982-1983 (pre-PPS)



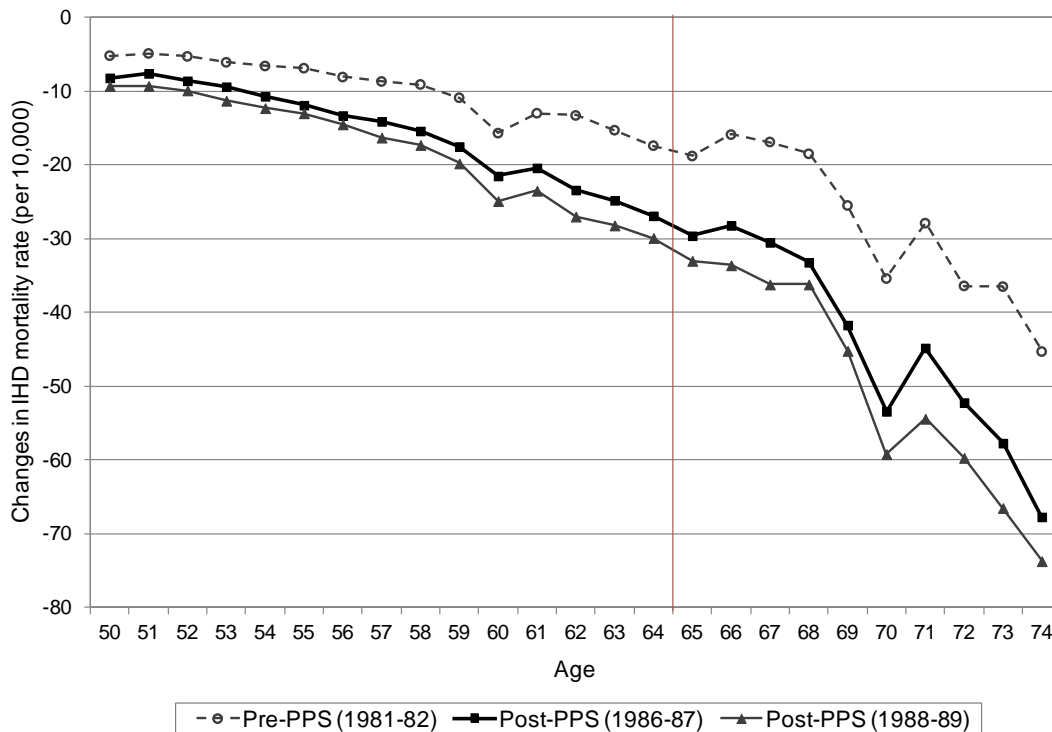
B. Changes in CABG discharge rate from 1980-1981 to 1988-1989 (Post-PPS)



Notes: Figures exclude PPS-waiver states (MA, NY, NJ, and MD) and non-elderly Medicare beneficiaries. The ICD-9-CM codes used for CABG with one or two grafts are 36.11-36.12, 36.15-36.16; three or more grafts are 36.13-36.14. The indication of comorbidity is based on patients' diagnoses at admission: heart attack (Acute Myocardial Infarction: AMI), diabetes mellitus, chronic renal disease, cardiac arrhythmias, Congestive Heart Failure (CHF), or previous heart surgery (see the Data Appendix for details).

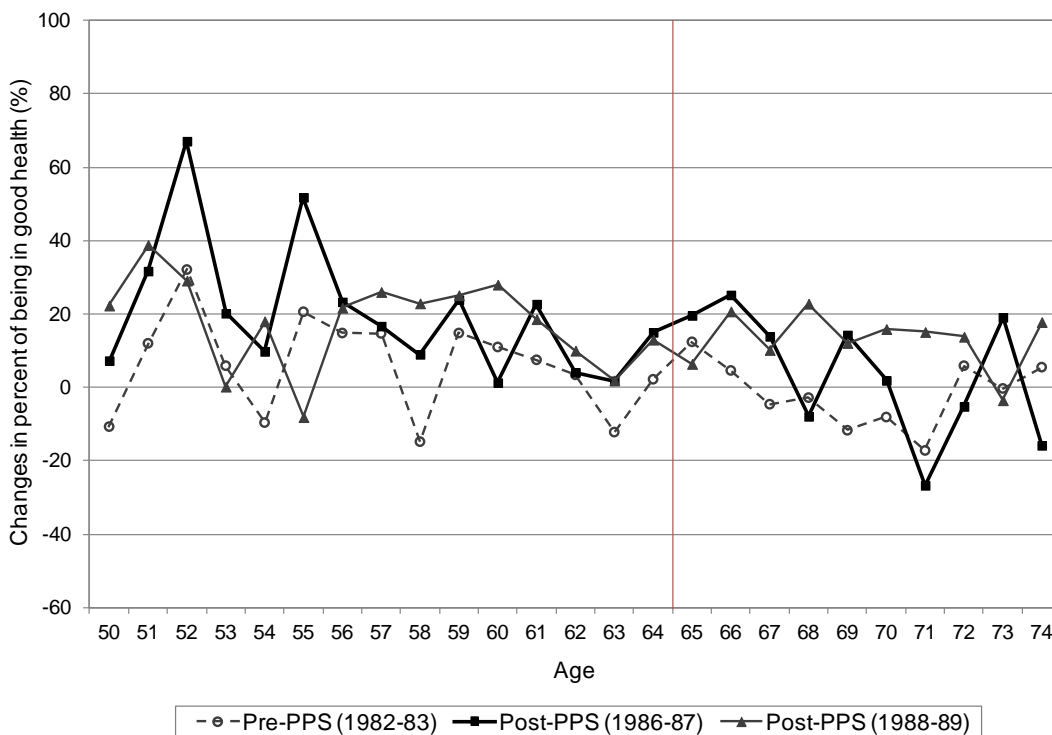
Source: National Hospital Discharge Survey

Figure 6: Changes in Ischemic Heart Disease (IHD) mortality rate relative to 1976-1977



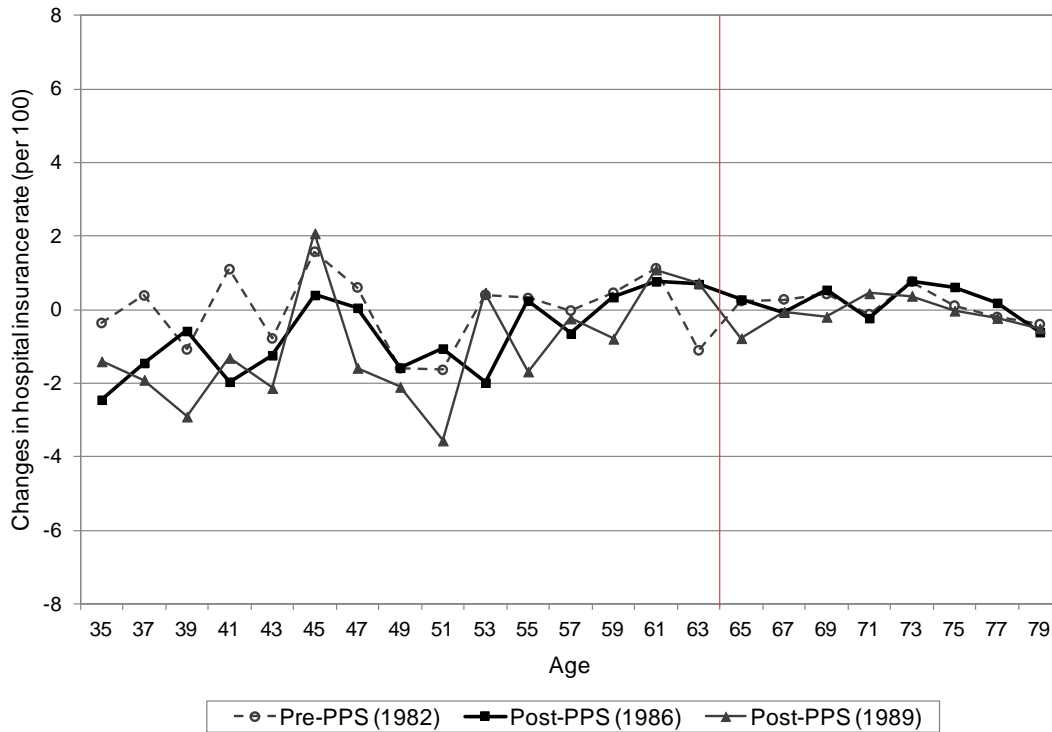
Note: The ICDA-8 (1976-1977) and ICD-9 (1981-1989) codes used for IHD mortality rate are 410-414.
 Source: Multiple Cause-of-Death Mortality Data

Figure 7: Changes in percent of being in good health (persons with IHD) relative to 1976-1977



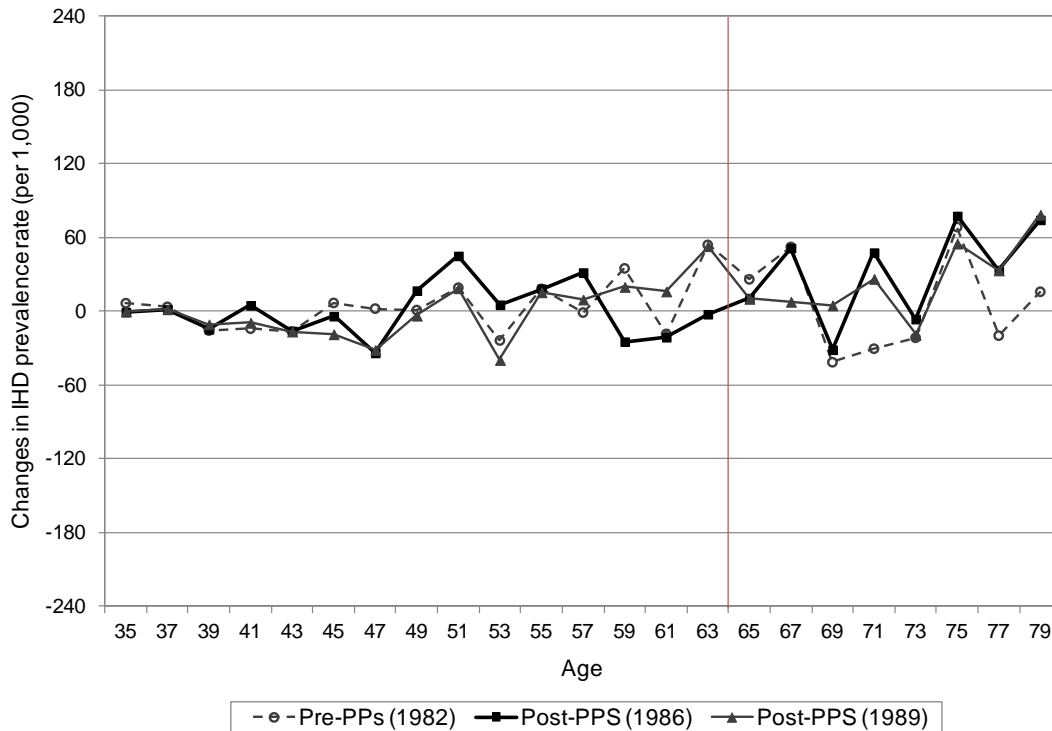
Notes: Percent of being in good health is based on the share of people with IHD reporting “excellent,” “very good,” or “good” to the question on their health status. The ICDA-8 (1976-1977) and ICD-9 (1982-1989) codes used for IHD conditions are 410-414.
 Source: National Health Interview Survey

Figure 8: Changes in hospital insurance rate relative to 1980 (per 100 persons)



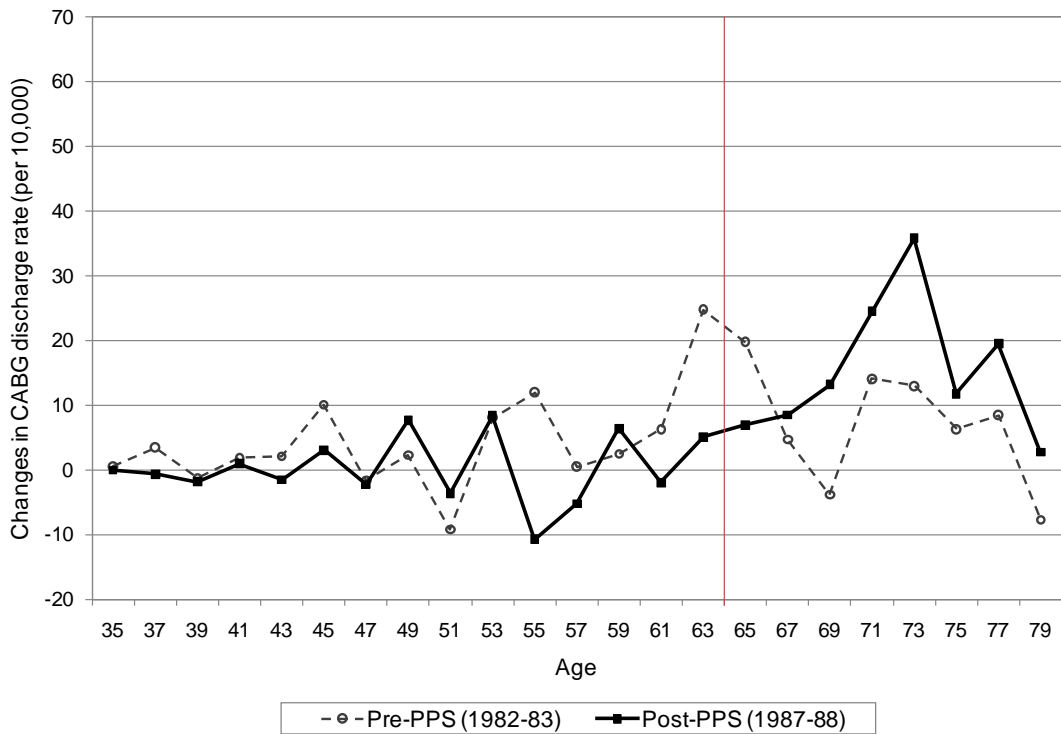
Notes: Figure excludes non-elderly Medicare beneficiaries. Hospital insurance includes Medicare, Medicaid, private insurance, and any public assistance program that paid for health care (see the Data Appendix for details).
Source: National Health Interview Survey

Figure 9: Changes in Ischemic Heart Disease (IHD) prevalence rate relative to 1980 (per 1,000 persons)

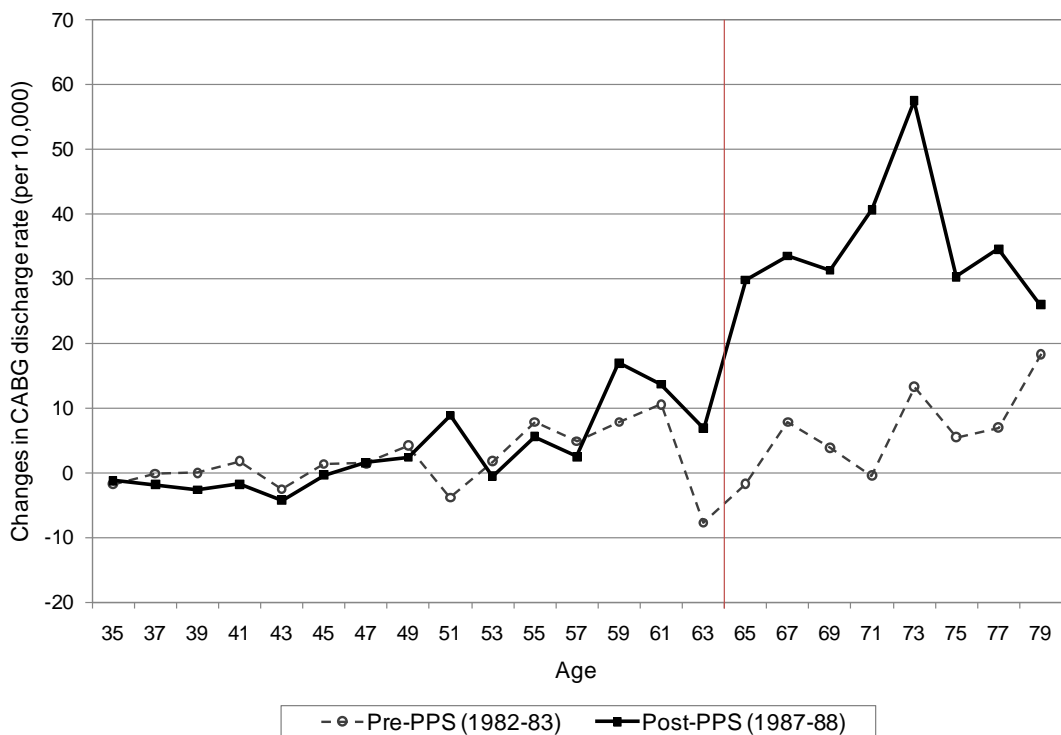


Notes: Figure excludes non-elderly Medicare beneficiaries. The ICD-9-CM diagnosis codes used for Ischemic Heart Disease (IHD) are 410-414.
Source: National Health Interview Survey

Figure 10: Changes in CABG discharge rate, by Certificate-of-Need (CON) status
 A. Changes in CABG discharge rate relative to 1980-1981, states that repealed CON before 1989



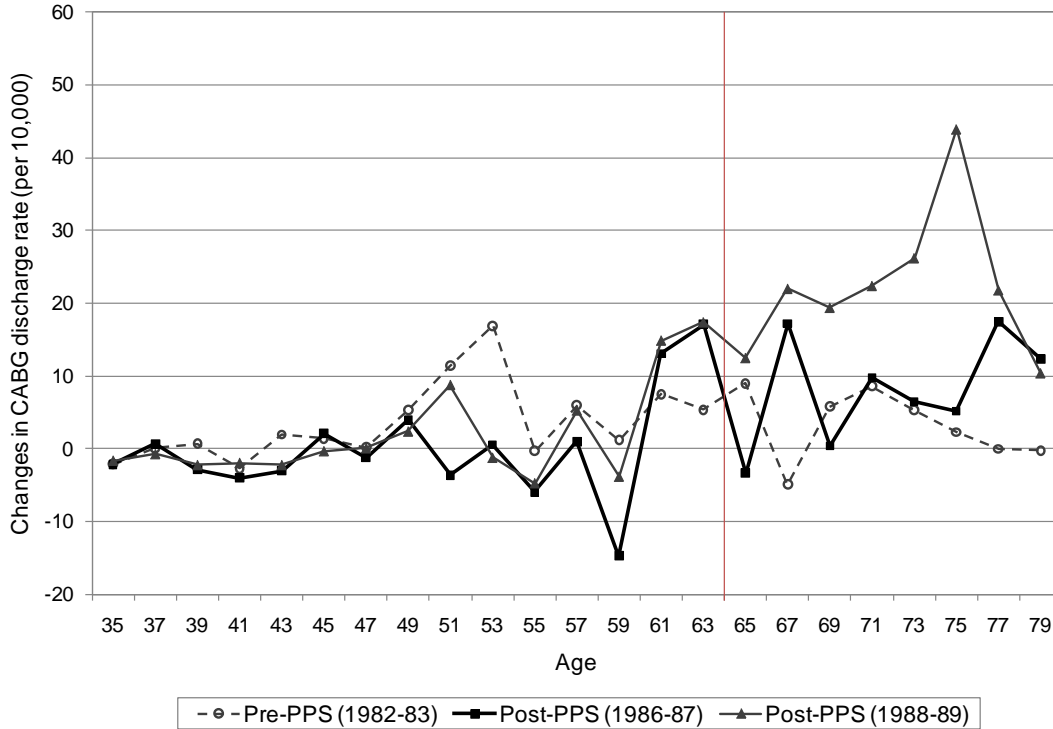
B. Changes in CABG discharge rate relative to 1980-1981, states that maintained CON



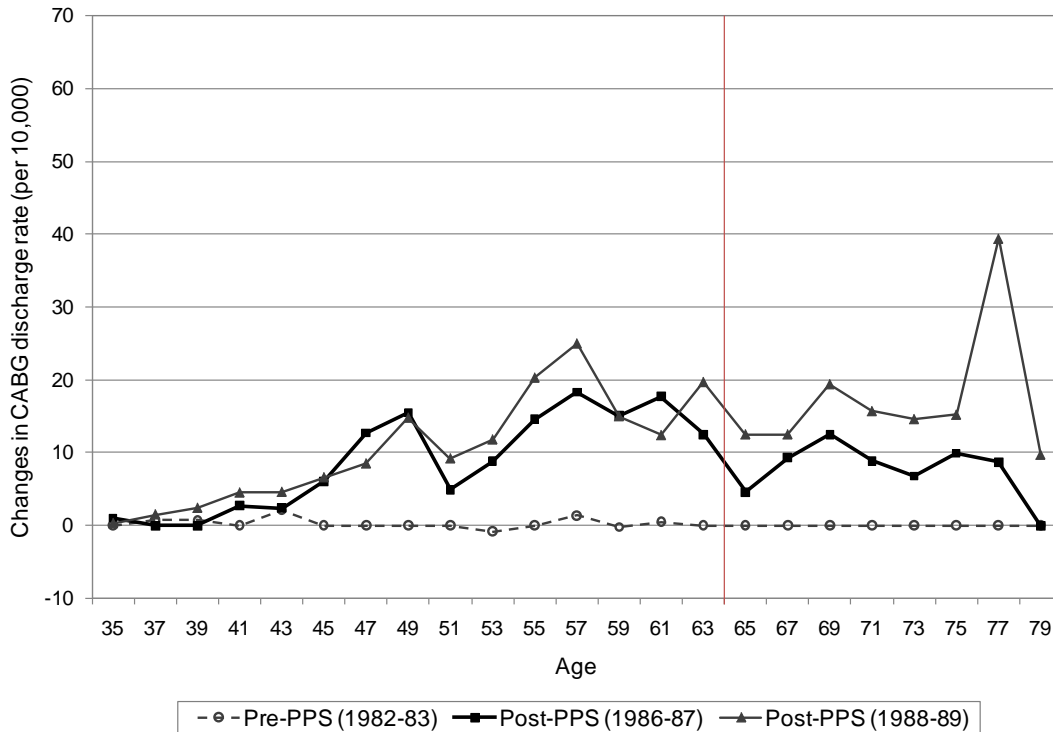
Notes: Figures exclude PPS-waiver states (MA, NY, NJ, and MD) and non-elderly Medicare beneficiaries. The ICD-9-CM code used for CABG is 36.1x. States that repealed CON for open-heart surgery (i.e., CABG) before 1989 are Idaho, New Mexico, Minnesota, Utah, Arizona, Kansas, Texas, Wyoming, California, Colorado, and South Dakota.

Source: National Hospital Discharge Survey

Figure 11: Changes in hospital discharge rate, by cardiac procedure (PPS-waiver states)
 A. Changes in CABG discharge rate relative to 1980-1981



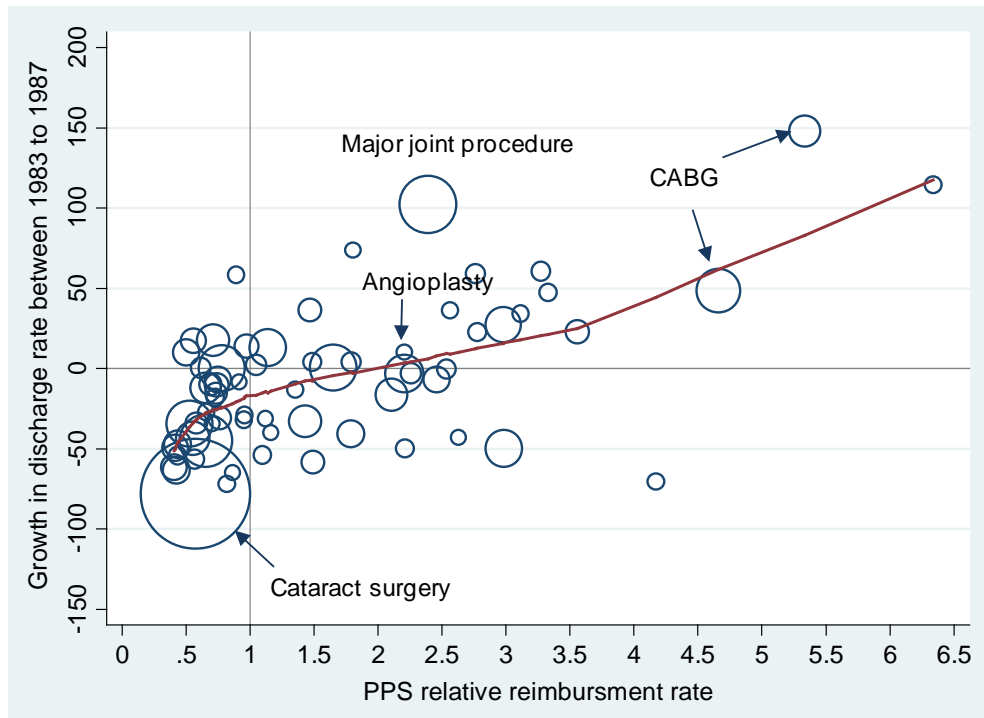
B. Changes in Angioplasty discharge rate relative to 1980-1981



Notes: PPS-waiver states are Massachusetts, New York, New Jersey, and Maryland. Figures exclude non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)). The ICD-9-CM codes used for CABG and Angioplasty are 36.1x and 36.0x, respectively.

Source: National Hospital Discharge Survey

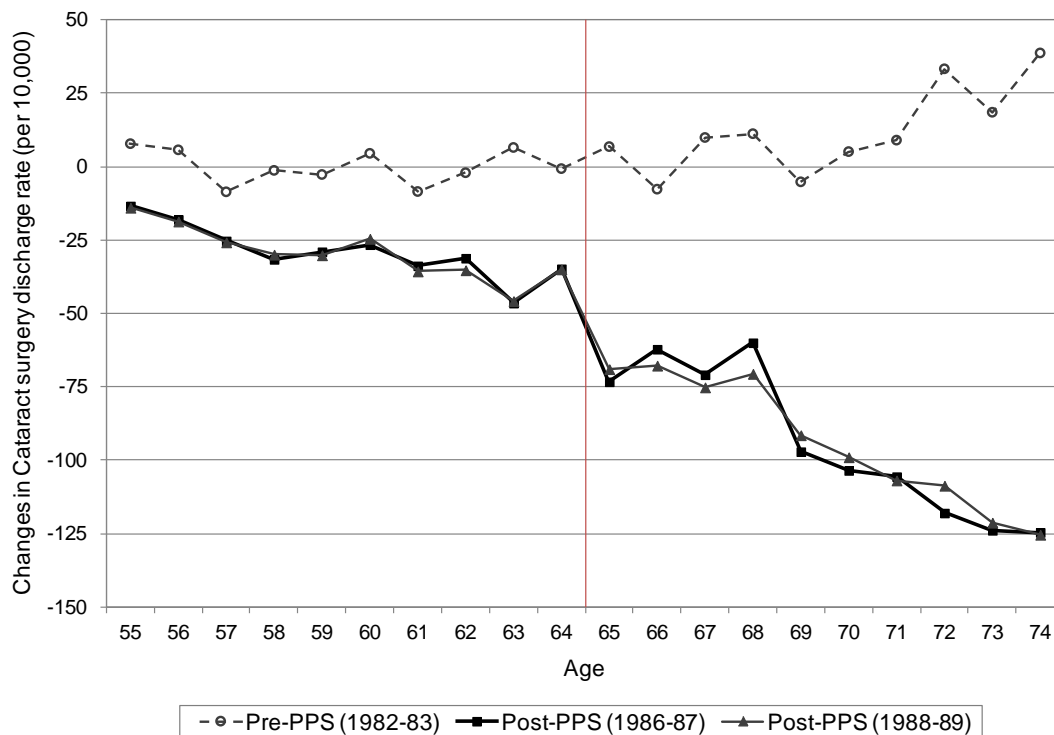
Figure 12: Growth in hospital discharge rate by PPS relative reimbursement rate, 65-74 year olds



Notes: Figure includes surgical procedures among 250 most frequent DRGs for aged 65-74 in 1987. The PPS relative reimbursement rates are DRG weights in 1987. The line is estimated from the local linear regression. Growth in discharge rate is weighted by the number of discharges in 1983 (the size of circles). CABG with and without catheterization are depicted separately.

Source: National Hospital Discharge Survey

Figure 13: Changes in Cataract surgery discharge rate relative to 1980-1981



Notes: Figure excludes non-elderly Medicare beneficiaries. The ICD-9-CM codes used for Cataract surgery are 13.1-13.6.

Source: National Hospital Discharge Survey

Table 1: Hospital discharge rates and profit margins under Medicare PPS, by cardiac procedure
[absolute value of t-ratio]

	Discharge rate (per 10,000)			Costs, reimbursements, and profit margins (per discharge)		
	Pre-PPS 1982-83 (1)	Post-PPS 1988-89 (2)	Changes between pre-and post-PPS (3)	Marginal costs 1988-1992 (4)	PPS reimbursements 1988-1992 (5)	Profit margins 1988-1992 (6)
<u>A. CABG</u>						
aged 60-64	34.4	38.8	4.4			
aged 65-69	33.1	61.7	28.6	\$23,564	\$29,535	\$5,971
Difference	-1.3	22.9	24.2			
DID estimates			24.14*** [4.18]			
<u>B. Angioplasty</u>						
aged 60-64	3.0	41.8	38.8			
aged 65-69	3.5	40.8	37.3	\$9,701	\$10,703	\$1,002
Difference	0.5	-1.0	-1.5			
DID estimates			-1.45 [0.43]			

Notes: Hospital discharge rates exclude PPS-waiver states (i.e., Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)). The ICD-9-CM codes used for CABG and Angioplasty are 36.1x and 36.0x, respectively. Marginal costs are based on the estimation of equation (14) in the text, weighted by number of discharges; marginal costs and PPS reimbursements are in 1992 dollars. Difference-in-differences (DID) estimates are adjusted for age dummies and estimated standard errors are corrected for heteroskedasticity and clustered at the age-level. Absolute values of t-ratio are in square brackets.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Sources: National Hospital Discharge Survey, *Federal Register*, Healthcare Cost and Utilization Project (HCUP), and Medicare Cost Reports

Table 2: Discontinuity in hospital discharge rates at age 65 and over, by cardiac procedure
[absolute value of t-ratio]

	Discontinuity in hospital discharge rates (per 10,000)			
	Pre-PPS	Post-PPS		
	Change after 1980-81	Change after 1982-1983 by		
	1982-1983	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
A. CABG				
Ages 65 to 69	-4.78 [1.33]	17.72*** [3.38]	20.64*** [3.40]	13.45** [2.43]
Ages 70 to 74	-2.66 [0.59]	19.62*** [4.68]	26.75*** [3.28]	26.92*** [4.38]
Ages 75 to 80	-4.31 [0.82]	7.92 [1.31]	8.28 [1.35]	32.05*** [4.06]
Year effect	7.25** [2.52]	4.60 [1.65]	6.90** [2.52]	3.57 [1.24]
B. Angioplasty				
Ages 65 to 69	-0.55 [0.50]	2.78 [1.38]	-9.03** [2.50]	-1.38 [0.27]
Ages 70 to 74	-2.44* [1.84]	-3.73 [1.33]	-10.67** [2.43]	-4.62 [0.72]
Ages 75 to 80	-2.28 [1.49]	-14.08*** [3.91]	-36.17*** [7.19]	-28.45*** [3.62]
Year effect	2.37*** [3.39]	20.48*** [13.86]	43.45*** [22.06]	46.81*** [13.02]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey (NHDS). PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 3: Discontinuity in CABG discharge rate at age 65 and over, by hospital CABG-volume
[absolute value of t-ratio]

	Discontinuity in CABG discharge rate (per 10,000)		
	All hospitals (Panel hospitals) (1)	High CABG-volume hospitals (annual volume ≥ 200) (2)	Low CABG-volume hospitals (annual volume < 200) (3)
Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983			
Ages 65 to 69	-6.76** [2.24]	-3.08 [1.38]	-3.69* [1.91]
Ages 70 to 74	-4.61 [1.16]	-1.39 [0.52]	-3.22 [1.37]
Ages 75 to 80	-4.87 [1.07]	-1.09 [0.33]	-3.78 [1.26]
Year effect	7.51*** [3.06]	3.50** [2.14]	4.01*** [2.98]
Panel B. Post-PPS: changes from 1982-1983 to 1986-1987			
Ages 65 to 69	17.82*** [4.55]	15.02*** [5.95]	2.80 [1.16]
{mean of 1982-1983}	{26.60}	{15.87}	{11.65}
Ages 70 to 74	16.53*** [4.81]	10.57*** [3.07]	5.96*** [2.90]
Ages 75 to 80	9.16** [2.23]	6.90* [1.84]	2.26 [0.90]
Year effect	-0.27 [0.14]	-2.00 [1.03]	1.73 [1.35]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey (NHDS). Included are panel hospitals that had been contained in the data during the entire time period from 1980 to 1987 during which the same hospital ID format had been consistently used. PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time. The mean CABG discharge rates of 1982-1983 are in curly brackets.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 4: Discontinuity in CABG discharge rate at age 65 and over, by number grafts and comorbidity
[absolute value of t-ratio]

	Discontinuity in CABG discharge rate (per 10,000)		
	CABG with		CABG with
	1 or 2 grafts	3+ grafts without comorbidity	3+ grafts with comorbidity
	(1)	(2)	(3)
<i>Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983</i>			
Ages 65 to 69	-1.99 [0.97]	-1.1 [0.42]	0.53 [0.29]
Ages 70 to 74	0.81 [0.37]	-0.61 [0.24]	-0.12 [0.08]
Ages 75 to 80	-0.62 [0.23]	-2.38 [0.97]	-1.72 [0.93]
Year effect	0.36 [0.28]	3.43** [2.56]	2.14** [2.57]
<i>Panel B. Post-PPS: changes from 1982-1983 to 1988-1989</i>			
Ages 65 to 69	7.82*** [3.18]	9.70*** [3.27]	-0.07 [0.02]
Ages 70 to 74	-1.52 [0.36]	10.58*** [3.13]	2.67 [0.65]
Ages 75 to 80	-18.07*** [4.01]	12.34*** [4.45]	-3.31 [0.85]
Year effect	20.61*** [15.51]	-5.12*** [4.03]	9.17*** [5.14]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey. The ICD-9-CM codes used for CABG with one or two grafts are 36.11-36.12, 36.15-36.16; three or more grafts are 36.13-36.14. The indication of comorbidity is based on patients diagnoses at admission; heart attack (Acute Myocardial Infarction: AMI), diabetes mellitus, chronic renal disease, cardiac arrhythmias, Congestive Heart Failure (CHF), or previous heart surgery (see the Data Appendix). PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 5: Discontinuity in Ischemic Heart Disease (IHD) mortality rate at age 65 and over
[absolute value of t-ratio]

	Discontinuity in IHD mortality rate (per 10,000)			
	Pre-PPS		Post-PPS	
	Change after 1976-77		Change after 1981-1982 by	
	1981-1982	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
Ages 65 to 69	6.68*	0.06	-0.36	1.08
	[2.00]	[0.08]	[0.33]	[0.90]
Ages 70 to 74	3.10	0.71	-2.17	1.33
	[0.46]	[0.39]	[1.15]	[0.63]
Ages 75 to 80	-1.96	-0.52	-4.09	0.34
	[0.20]	[0.22]	[1.56]	[0.10]
Year effect	-21.23***	-11.45***	-14.95***	-19.68***
	[10.64]	[19.95]	[22.12]	[22.45]

Notes: Data consist of Ischemic Heart Disease (IHD) mortality rates for forty-five to eighty year-olds calculated at the year-age level from the Multiple Cause-of-Death Mortality Data. All analyses use year-age cell population counts as frequency weights; adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age and age squared. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time. ICDA 8 (1976-78) and ICD-9 (1979-1991) codes used for IHD are 410-414.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 6: Discontinuity in percent of being in good health at age 65 and over, persons with IHD
[absolute value of t-ratio]

	Discontinuity in percent of being in good health among persons with IHD (%)			
	Pre-PPS		Post-PPS	
	Change after 1976-77		Change after 1982-1983 by	
	1982-1983	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
Ages 65 to 69	3.07	8.74	4.20	5.05
	[0.52]	[1.30]	[0.60]	[0.71]
Ages 70 to 74	6.30	-4.25	3.28	3.53
	[0.72]	[0.42]	[0.40]	[0.49]
Ages 75 to 80	32.68**	-2.46	-16.12	-9.90
	[2.66]	[0.20]	[1.33]	[0.94]
Year effect	-0.94	6.59	10.91***	10.69***
	[0.22]	[1.43]	[2.87]	[2.75]
Sample size	2,249	1,379	1,533	1,528

Notes: Data consist of forty-five to eighty year-old respondents with IHD conditions in the National Health Interview Survey (NHIS). Percent of being in "good" health is based on the share of people with IHD reporting "excellent," "very good," or "good" to the question on their health status. All analyses use analytical weights provided by the NHIS and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 7: Ordered logit estimates and implied quality-adjusted life year (QALY) weights
[absolute value of t-ratio]

	Ordered logit estimates and QALY weights			
	Pre-PPS		Post-PPS	
	1982-83		<i>Changes after 1982-83 by 1988-89</i>	
	Estimates (1)	QALY weights (2)	Estimates (3)	QALY weights (4)
Ischemic Heart Disease (IHD)	-1.38*** [19.04]	0.66	0.18** [2.09]	0.04
IHD × Ages 65 to 69	0.25*** [2.58]	0.06	-0.04 [0.20]	-0.01
IHD × Ages 70 to 74	0.52*** [3.05]	0.13	-0.05 [0.23]	-0.01
IHD × Ages 75 to 80	0.94*** [6.37]	0.23	-0.55** [2.30]	-0.13
Other circulatory disease	-1.31*** [44.70]	0.68	0.18*** [3.91]	0.04
Respiratory disease	-1.43*** [29.44]	0.65	0.15*** [4.00]	0.04
Digestive disease	-1.74*** [51.50]	0.58	0.21*** [4.75]	0.05
Skin and musculoskeletal disease	-1.31*** [34.67]	0.68	0.19*** [4.69]	0.05
Impairments	-1.39*** [28.76]	0.66	0.15*** [2.88]	0.04
Other chronic disease	-1.69*** [39.98]	0.59	0.23*** [6.16]	0.06
Year effect	---	---	0.08*** [2.64]	0.02
Cut points				
Cut 1	-3.2454	---	-3.2710	---
Cut 2	-1.8157	---	-1.8498	---
Cut 3	-0.2971	---	-0.3163	---
Cut 4	0.8508	---	0.8874	---
Sample size	60,486		130,306	

Notes: Data consist of forty-five to eighty year-old respondents in the National Health Interview Survey (NHIS). Outcome variable is the categorical variable on self-reported health status; “excellent”, “very good”, “good”, “fair”, and “poor.”. All analyses use analytical weights provided by the NHIS. Estimated standard errors are corrected for heteroskedasticity and clustered at the age level. Each cut point indicates the value at which health status move to next category. Age, age squared, and indicators for ages 65-69, 70-74, 75-80 are not shown.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 8: Cost-per-QALY of the increased use of CABG relative to 1982, ages 65 to 69

	Post-PPS	
	1986 (1)	1988 (2)
Increase in CABG discharges (per 10,000)	89.1	106.9
Average CABG costs (per discharge)	\$28,982	\$30,432
Increase in CABG costs (per 10,000)	\$2,582,087	\$3,253,045
Increase in IHD survivors (per 10,000)		
[upper bound]		
age 65	0.98	0.67
age 66	1.09	0.17
age 67	1.74	1.81
age 68	2.81	3.75
age 69	4.07	2.85
Increase in life years (per 10,000)		
[upper bound]	10.69	9.25
Increase in QALY weights (0.72 in 1982)	0.06	-0.01
Increase in QALY (per 10,000)	8.34	6.57
Increase in QALY due to CABG use (per 10,000)		
[upper bound]	2.42	1.90
Cost-per-life-year (1992 dollars)		
[lower bound]	\$832,976	\$1,212,635
Cost-per-QALY (1992 dollars)		
[lower bound]	\$1,067,918	\$1,707,936

Notes: All costs are 1992 dollars. Increase in CABG discharge is estimated from the RD estimation similar to that used in Table 2, except using separate indicator variables for each age between 65 and 69; and multiplied by the age-specific survival rates for each age as weights when summing up the increased CABG discharges of each age. Average cost of CABG in 1986 is based on the average cost of 1984 in Cutler et al, (2001); average cost of CABG in 1988 is estimated from HCUP data. Increase in Ischemic Heart Disease (IHD) survivors is upper bound of 95% confidence interval of estimates from the RD estimation using IHD survival rates for forty-five to sixty-nine year olds as outcome variables on separate indicator variables for each age between 65 and 69, fifth-order polynomial in age, year effects, and year effects interacted with age, age squared, and age cubic; estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time. Increase in quality-adjusted life year (QALY) weights come from Table 7. The lower bound estimates are based on the conservative assumption: Hunink et al (1997) show that both medical and surgical treatments (drug therapy, angioplasty, and CABG) explained 29% of IHD survival gains between 1980 and 1990; as an upper bound, all 29% of IHD survival gains between 1982 and 1988 are completely attributed to the increased use of CABG.

Table 9: Discontinuity in hospital insurance rate and IHD prevalence rates at age 65 and over
[absolute value of t-ratio]

	Pre-PPS		Post-PPS	
	Change after 1980 by		Change after 1982 by	
	1982 (1)	1984 (2)	1986 (3)	1989 (4)
A. Hospital insurance rate (per 100)				
Ages 65 to 69	0.38 [0.57]	-1.00 [1.08]	-0.62 [0.55]	-0.85 [1.01]
Ages 70 to 74	0.66 [0.69]	-1.56 [1.28]	-1.00 [0.67]	-0.44 [0.39]
Ages 75 to 80	0.20 [0.16]	-2.31 [1.54]	-1.05 [0.54]	-0.86 [0.60]
Year effect	-0.14 [0.26]	0.99 [1.26]	0.44 [0.46]	0.04 [0.06]
Sample size	57,735	57,925	45,768	60,521
B. IHD prevalence rate (per 1,000)				
Ages 65 to 69	7.85 [0.30]	3.47 [0.11]	22.01 [0.62]	-44.73* [1.92]
Ages 70 to 74	-64.65* [1.90]	30.04 [0.73]	67.76 [1.51]	16.26 [0.49]
Ages 75 to 80	-8.44 [0.19]	-48.83 [1.02]	77.16 [1.43]	-11.26 [0.34]
Year effect	19.84 [0.94]	33.08 [1.50]	-21.28 [0.87]	16.12 [1.02]
Sample size	58,517	58,832	46,497	62,462

Notes: Data include forty-five to eighty year-olds in the National Health Interview Survey (NHIS). The hospital health insurance rate is based on binary variable equal to one if the individual has any hospital insurance (i.e., Medicare (Part A), Medicaid, private insurance, and any public assistance program that paid for health care) and zero otherwise. The Ischemic Heart Disease (IHD) prevalence rates are based on total number of reported chronic conditions of Ischemic heart disease. Information about the prevalence of chronic conditions was obtained from responses to the question, "During the past 12 months, did anyone in the family (you, your __, etc.) have ___?" ICD-9 codes used for Ischemic heart disease in NHIS are 410-414. All analyses use analytical weights provided by the NHIS and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 10: Discontinuity in CABG discharge rate at age 65 and over, by CON status
[absolute value of t-ratio]

	Discontinuity in CABG discharge rate (per 10,000)		
	All states (PPS states) (1)	States repealed CON before 1989 (2)	States maintained CON (3)
<i>Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983</i>			
Ages 65 to 69	-4.78 [1.33]	-1.61 [0.19]	-3.98 [0.63]
Ages 70 to 74	-2.66 [0.59]	-6.90 [0.68]	2.18 [0.30]
Ages 75 to 80	-4.31 [0.82]	-14.77 [1.27]	2.66 [0.32]
Year effect	7.25** [2.52]	11.17* [1.93]	4.76 [1.07]
<i>Panel B. Post-PPS: changes from 1982-1983 to 1988-1989</i>			
Ages 65 to 69	20.64*** [3.40]	10.77 [0.87]	20.27*** [3.41]
Ages 70 to 74	26.75*** [3.28]	28.91*** [2.74]	26.66*** [3.39]
Ages 75 to 80	8.28 [1.35]	24.63* [1.79]	6.92 [0.80]
Year effect	6.90** [2.52]	-9.89 [1.50]	8.04* [1.85]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey. The states that repealed their Certificate-of-Need (CON) programs between 1983 and 1988 are Idaho, New Mexico, Minnesota, Utah, Arizona, Kansas, Texas, Wyoming, California, Colorado, and South Dakota. PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 11: Discontinuity in hospital discharge rates at age 65 and over, PPS-waiver states
[absolute value of t-ratio]

	Discontinuity in hospital discharge rates (per 10,000)			
	Pre-PPS		Post-PPS	
	Change after 1980-81 by		Change after 1982-1983 by	
	1982-1983	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
A. CABG				
Ages 65 to 69	-3.41 [0.45]	1.87 [0.17]	10.35 [0.88]	9.31 [1.33]
Ages 70 to 74	1.27 [0.15]	0.09 [0.01]	8.91 [0.71]	24.30* [1.99]
Ages 75 to 80	-5.36 [0.52]	7.80 [0.68]	16.51 [1.04]	28.12*** [2.74]
Year effect	5.88 [1.01]	-1.18 [0.20]	3.53 [0.44]	-0.24 [0.05]
B. Angioplasty				
Ages 65 to 69	-0.44 [0.72]	-8.40** [2.23]	-6.67 [1.30]	2.86 [0.40]
Ages 70 to 74	-0.58 [0.76]	-11.05*** [3.50]	-8.89 [1.33]	-4.30 [0.58]
Ages 75 to 80	-0.73 [0.79]	-14.17*** [3.22]	-5.27 [0.55]	-20.49** [2.63]
Year effect	0.39 [0.70]	16.41*** [8.85]	20.17*** [4.85]	26.47*** [7.14]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey. PPS-waiver states are Massachusetts, New York, New Jersey, and Maryland. Non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

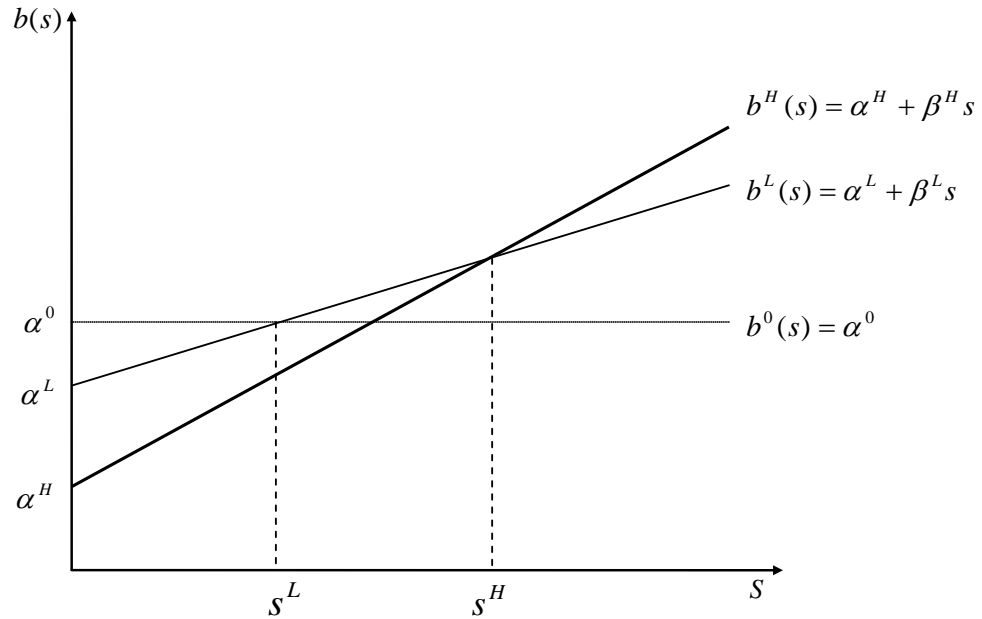
Table 12: Discontinuity in Cataract surgery discharge rate at age 65 and over
[absolute value of t-ratio]

	Discontinuity in Cataract surgery discharge rate (per 10,000)			
	Pre-PPS		Post-PPS	
	Change after 1980-81 by		Change after 1982-1983 by	
	1982-1983	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
<u>Cataract surgery</u>				
Ages 65 to 69	2.93 [0.61]	-30.23*** [4.59]	-31.43*** [5.39]	-32.61*** [5.21]
Ages 70 to 74	18.32** [2.28]	-76.21*** [7.03]	-72.37*** [7.13]	-75.54*** [7.28]
Ages 75 to 80	62.70*** [7.47]	-156.96*** [12.63]	-154.34*** [11.82]	-159.56*** [11.76]
Year effect	2.84 [1.08]	-44.63*** [11.99]	-45.66*** [12.41]	-47.94*** [13.50]

Notes: Data consist of hospital discharge rates for forty-five to eighty year-olds calculated at the year-age level from the National Hospital Discharge Survey. Non-elderly Medicare beneficiaries (i.e., people under aged of 65 who have received Social Security Disability Insurance (SSDI) for 24 months as well as those diagnosed with end-stage renal disease (ESRD)) are excluded. All analyses use cell population counts as frequency weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

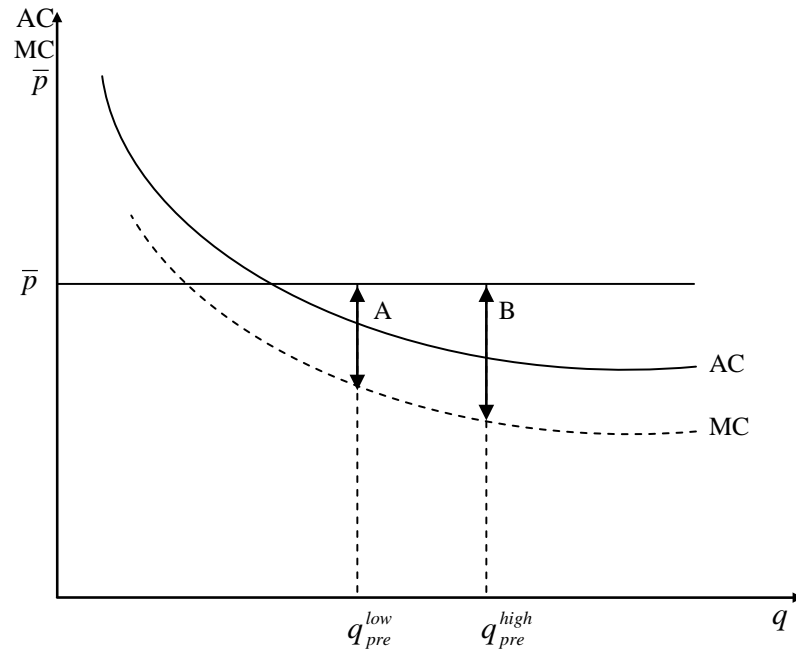
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Appendix Figure 1: The benefits function of each cardiac treatment



Notes: The s indicates patients' severity of illness. The function, $b^H(s)$, $b^L(s)$, and $b^0(s)$ represent benefits from CABG, angioplasty, and drug therapy, respectively. s^H and s^L are benchmark values that the hospital chooses to provide CABG for patients whose illness severity is higher than s^H ; angioplasty for those whose illness severity is between s^H and s^L and ; drug therapy for those whose illness severity is less than s^L .

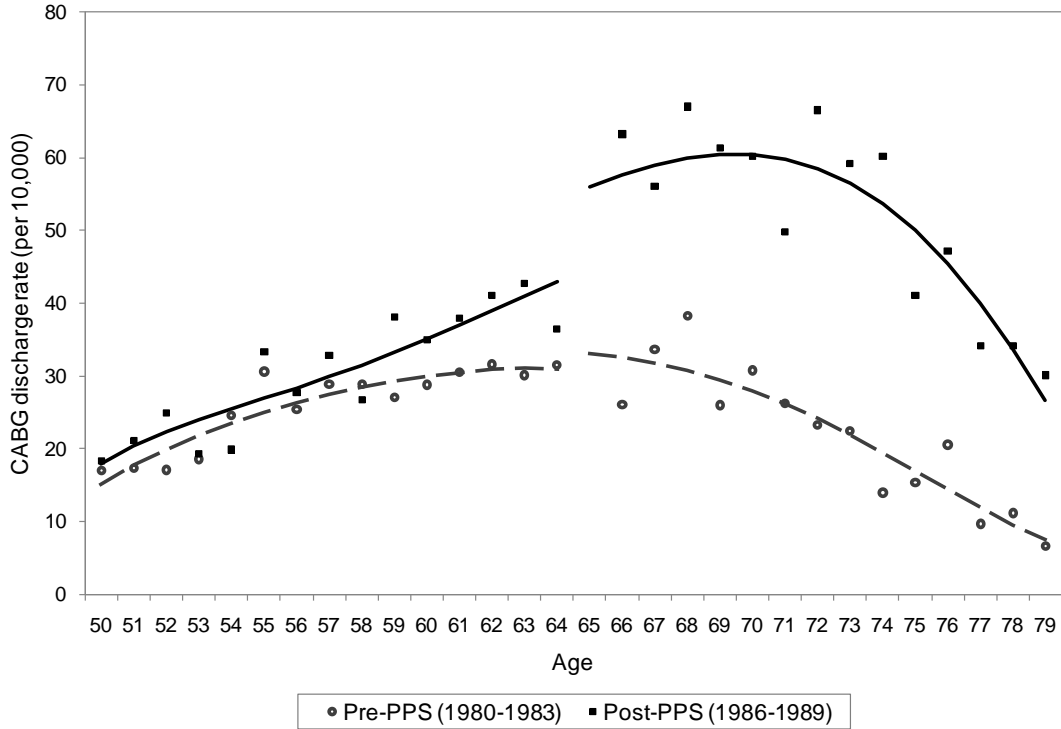
Appendix Figure 2: Hospitals' responses to PPS by their pre-PPS CABG volume



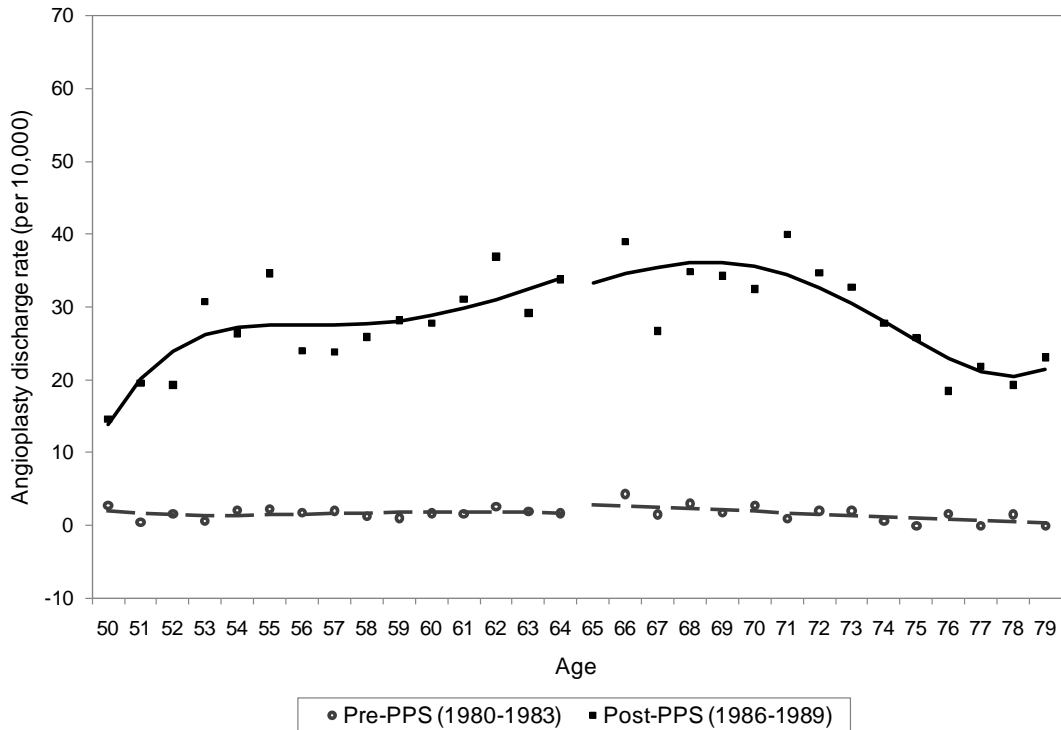
Notes: \bar{p} indicates the Medicare payment under PPS. AC and MC exhibit average cost and marginal costs of CABG, respectively.

Appendix Figure 3: Hospital discharge rate, by cardiac procedure

A. CABG discharge rate, pre- and post-PPS periods



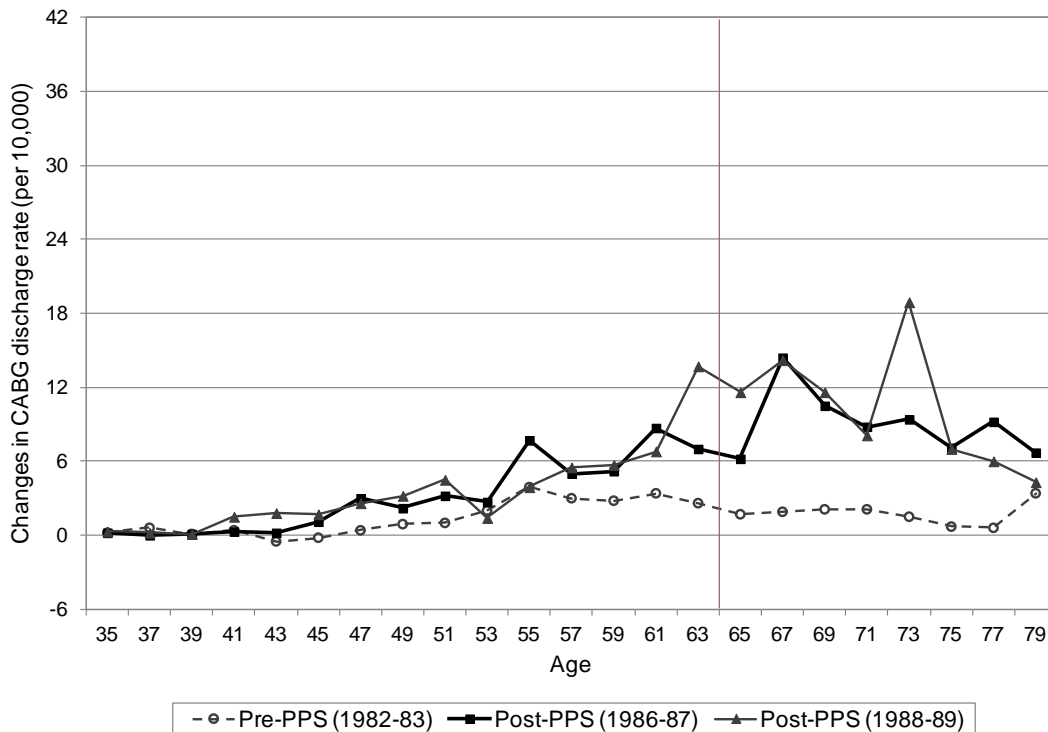
B. Angioplasty discharge rates pre- and post-PPS periods



Notes: Figures excludes PPS-waiver states (MA, NY, NJ, and MD) and non-elderly Medicare beneficiaries. Points represent means for discharge rate in each age cell. Points for people age 65 are not shown in the figure. Fitted lines are adjusted for fifth-order polynomial in age and a dummy for the age of 65 or over. The ICD-9-CM codes used CABG and Angioplasty are 36.1x and 36.0x, respectively.

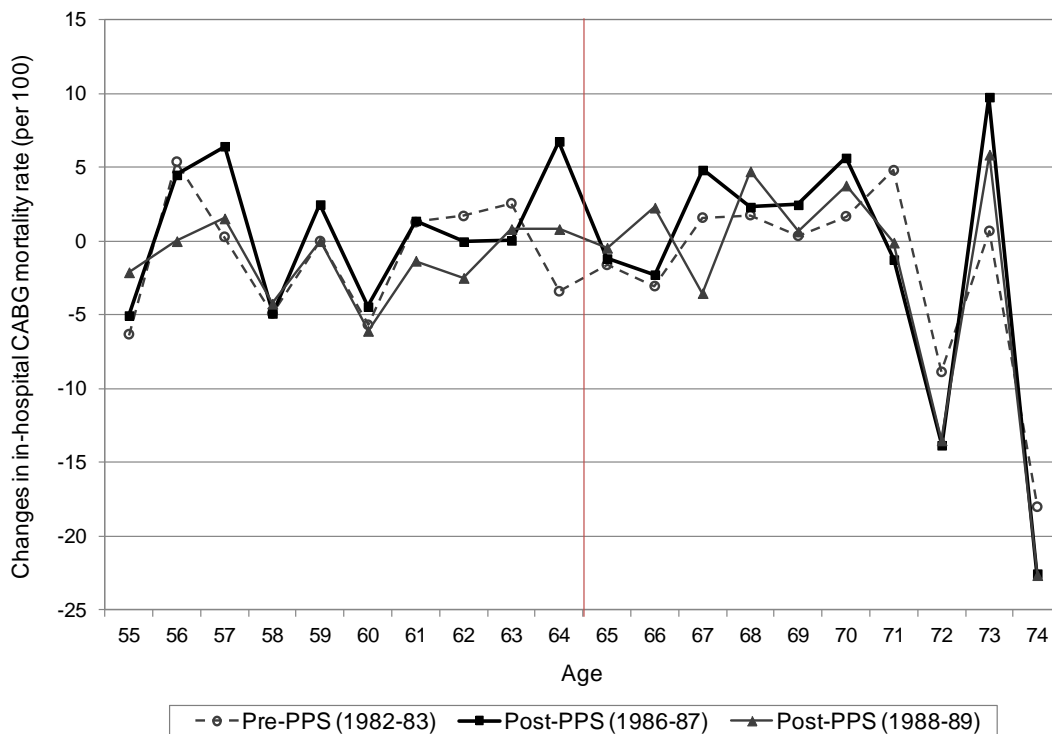
Source: National Hospital Discharge Survey

Appendix Figure 4: Changes in CABG discharge rates relative to 1980-1981, heart attack (AMI) patients



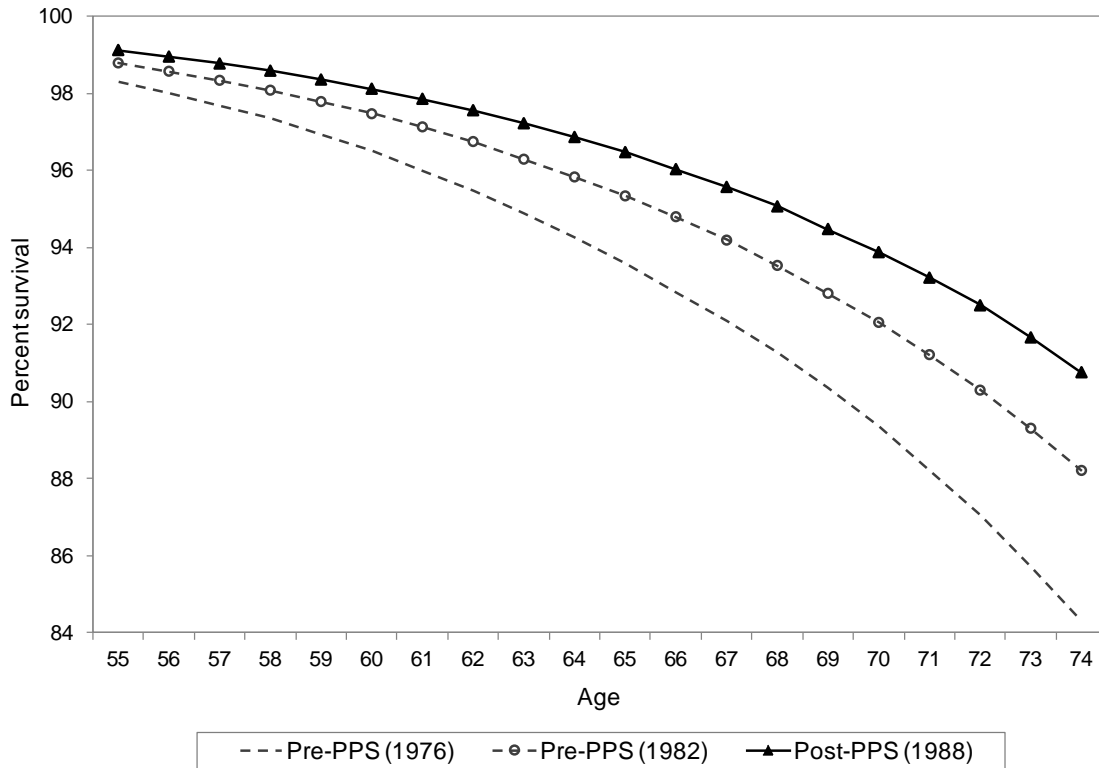
Notes: Figure excludes PPS-waiver states (Massachusetts, New York, New Jersey, and Maryland) and non-elderly Medicare beneficiaries. The ICD-9-CM codes used for CABG are 36.1x. And ICD-9 code used for heart attack (AMI: Acute Myocardial Infarction) is 410.
Source: National Hospital Discharge Survey

Appendix Figure 5: Changes in in-hospital CABG mortality rate relative to 1980-1981



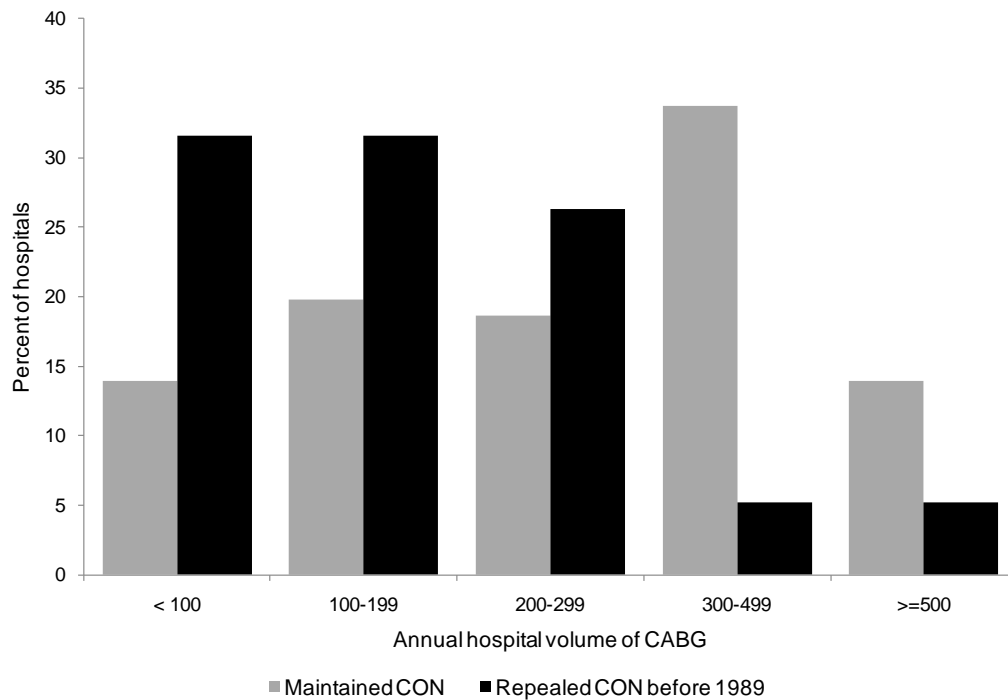
Notes: Figure excludes non-elderly Medicare beneficiaries. The ICD-9-CM code used for CABG is 36.1x.
Source: National Hospital Discharge Survey

Appendix Figure 6: Survival Curve for Ischemic Heart Disease mortality, survivors to age 45



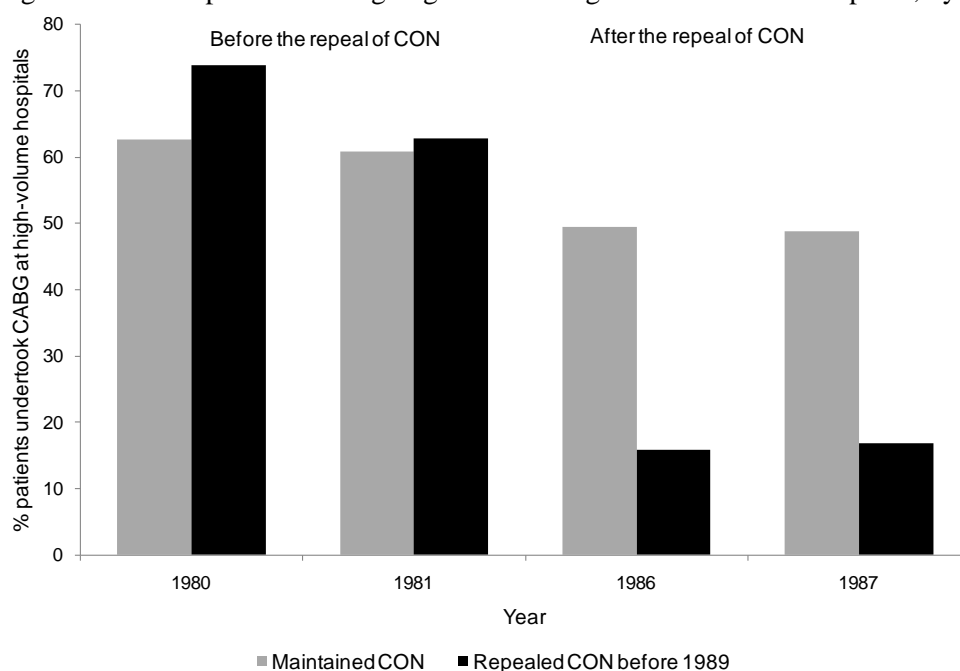
Note: Survival rates for Ischemic Heart Disease are calculated conditional on survival to age 45.
 Source: Multiple Cause-of-Death Mortality Data

Appendix Figure 7: Distribution of hospitals by annual CABG volume, by CON status (1989-1992)



Notes: Figure includes panel hospitals contained in all 4 years (1989-1992). The CABG volume is based on the mean annual CABG discharges of patients aged 45 to 85. States that repealed their CON (Certificate-of-Need) programs before 1989 and included in the data are AZ, CA, and CO. DRG codes used for CABG are 106 and 107.
 Source: Healthcare Cost and Utilization Project

Appendix Figure 8: Percent patients undergoing CABG at high CABG-volume hospitals, by CON status



Notes: Hospitals are categorized as high CABG-volume hospitals if they performed 200 or more CABGs annually for patients aged 45 to 85 before PPS. Figure excludes PPS-waiver states (MA, NY, NJ, and MD). States that repealed their CON programs before 1989 are ID, NM, MN, UT, AZ, KS, TX, WY, CA, CO, and SD. The ICD-9-CM codes used for CABG are 36.1x.

Source: National Hospital Discharge Survey

Appendix Table 1: Discontinuity in percent of being in good health at age 65 (persons with IHD)
[absolute value of t-ratio]

	Discontinuity in percent of being in good health among persons with IHD (%)			
	Pre-PPS		Post-PPS	
	Change after 1976-77 by		Change after 1981-1982 by	
	1981-1982	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
Good health (%)				
Ages 65 to 69	-1.97 [0.26]	13.60* [1.81]	9.05 [1.43]	9.49 [1.55]
Ages 70 to 74	2.10 [0.18]	-0.39 [0.03]	7.19 [0.71]	6.75 [0.64]
Ages 75 to 80	16.07 [1.02]	14.13 [0.96]	-0.14 [0.01]	5.55 [0.50]
Year effect	2.30 [0.37]	3.51 [0.66]	7.83* [1.77]	7.89* [1.97]
Sample size	2,206	1,336	1,490	1,485

Notes: Data consist of forty-five to eighty year-old respondents with IHD conditions in the National Health Interview Survey (NHIS). Percent of being in “good” health is based on the share of people with IHD reporting “excellent,” “very good,” or “good” to the question on their health status. All analyses use analytical weights provided by the NHIS and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Estimated standard errors are corrected for heteroskedasticity and clustered at the age-level over time.

*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Data Appendix

National Hospital Discharge Survey (NHDS)

The NHDS is an annual national sample of about 200,000 inpatient records within 500 hospitals (non-federal, short-stay) in the United States. It contains information on medical records for hospital admissions and discharges with diagnosis and procedure codes based on the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM codes); patients' expected source of payment (Medicare, Medicaid, other public assistance, and private insurance), age, gender, race, and marital status; hospital characteristics (ownership, bed-size, and locations).

ICD-9-CM codes for CABG by number of grafts and indication of comorbidity

To examine the impact of PPS on patient composition, I use the number of grafts used in CABG, and the indication of comorbidity as a measure of patients' severity of illness. The ICD-9-CM codes used for CABG by number of grafts and the indication of comorbidity are as follows:

Measure of Patients' Severity of Illness	ICD-9-CM codes
<u>CABG by number of grafts</u>	
Aortocoronary bypass for heart revascularization, otherwise specified	36.10
Aortocoronary bypass of one coronary artery	36.11
Aortocoronary bypass of two coronary arteries	36.12
Aortocoronary bypass of three coronary arteries	36.13
Aortocoronary bypass of four or more coronary arteries	36.14
Single internal mammary-coronary artery bypass	36.15
Double internal mammary-coronary artery bypass	36.16
Other bypass anastomosis for heart revascularization (from 1984)	36.19
<u>Indication of comorbidity</u>	
Heart attack (Acute Myocardial Infarction: AMI)	410
Diabetes mellitus	250
Chronic renal disease	585-586
Cardiac arrhythmias	427
Congestive Heart Failure (CHF)	428.0
Previous heart surgery	V15.1

Estimation of hospital-level discharges

The NHDS provides analytical weights per discharge record (hospital-discharge-level weights) for national (or regional) estimates. To estimate hospital-level CABG volumes, I derive hospital-level weights. From 1965 through 1987, the NHDS used a two-stage stratified sample design: 1) a sample of hospitals; and 2) discharge records within a hospital. The details are as follows:

- (1) In the first stage, the universe of hospitals were classified into 28 *primary strata* by four geographic regions and by seven bed-size categories.
- (2) In the second stage, no particular stratification is specified for discharges within a hospital. But usually discharges are arranged in some systematic order so that a pseudo-stratification is present.

To obtain national (or regional) estimates, the individual discharge record is inflated by the reciprocals of two sampling probabilities – i.e., the probability of selecting the sample hospitals and the probability of selecting the discharge record within a hospital. The analytical weights contained in the NHDS are the inverse of the product of these two selection probabilities, adjusted for non-response and population weighting ratio as follows;

$$WEIGHT_{hd} = \left(\frac{1}{P_h^1} \frac{1}{P_d^2} A \right)$$

where \hat{P}_h^1 is the first stage probability of hospital h within a stratum, \hat{P}_d^2 is the second stage probability of discharge record d within a hospital h , and A is the adjustment factor (the hospital level non-response adjustment and the population weighting ratio).

However, the hospital-level estimates (i.e., individual hospital's CABG volume) can be obtained by multiplying the first stage probability of selecting the sample hospitals to analytical weights originally provided by the NHDS

$$P_h^1 \cdot WEIGHT_{hd} = \left(\frac{1}{P_d^2} A \right)$$

To approximate the first stage sampling probabilities, I use hospital sampling rates by 28 size-by-region strata (four geographic regions classified by seven bed-size categories). Suppose that the first stage probability of selecting the sample hospitals is same across hospitals within each one of 28 primary strata. Then the first stage probabilities can be estimated by dividing the total number of universe hospitals within each stratum by the number of sample hospitals within each stratum,

$$\hat{P}_h^1 = \hat{P}^1 = \frac{H_s}{h_s}$$

where s denotes the primary strata and H_s denote the number of universe hospitals within each strata s , and h_s is the number of sample hospitals within each strata. Then the hospital-level estimate of discharges is given by

$$\hat{X}_h = \sum_{d=1}^{d_h} \hat{P}_h^1 \cdot WEIGHT_{hd} = \hat{P}^1 \sum_{d=1}^{d_h} WEIGHT_{hd} = \frac{H_s}{h_s} WEIGHT_h$$

where $WEIGHT_h$ is the hospital-level sum of analytical weights.

Using hospital identifiers in the restricted NHDS, I can calculate the hospital-level sum of analytical weights. Also, I can estimate the first stage probability of selecting sample hospitals: proportion of sample hospitals within each stratum based on information from the Vital and Health Statistics Series No. 13.

National Health Interview Survey (NHIS)

The NHIS samples about 130,000 individuals (40,000 households) from the civilian, non-institutionalized population of the United States. The NHIS contains information on health insurance coverage by types (hospital and doctor/physician) and payment sources (Medicare, Medicaid, Other public insurance, and Private insurance); the acute and chronic health conditions (i.e., Ischemic Heart Disease); self-reported health status; and individual demographic and socio-economic characteristics such as age, gender, race, marital status, levels of education, employment status, and family income.

Hospital insurance coverage

The NHIS contains information on health insurance coverage by types (hospital and doctor/surgeon) and payment sources (Medicare, Medicaid, other public insurance, and private insurance). Beginning in 1968, the NHIS collected insurance data generally every 2 years; and every year from 1989 on. Thus, the NHIS provides information on insurance coverage for 1980, 1982, 1983, 1984, 1986, and 1989-1991 during the study period. I use *hospital insurance* coverage rate by age given that Medicare PPS applied to hospital inpatient services.

Prevalence of chronic disease

In the NHIS, conditions are considered chronic if they (1) were first noticed more than 3 months before the date of interview, or (2) belong to a group of conditions regardless when they began. Examples of conditions that are considered chronic regardless of their time of onset are diabetes, heart conditions, emphysema, and arthritis. Also, the prevalence of chronic conditions is defined as the number of chronic cases reported to be present or assumed to be present at the time of the interview. Thus, the number of ischemic heart disease prevalence includes the cases if (1) a respondent reports as to have a chronic condition, (2) a respondent indicates “conditions of cardiovascular system” in the provided list, and (3) ICD codes are 410-414, 429.6 assigned by the NHIS from the detailed question.

Self-report health status

The general health status question was asked to classify people according to their own (or the respondent’s) perception of their health status. From 1975 to 1981, the question asks: “Compared to other persons’ age, would you say that ___’s health is excellent, good, fair, or poor?” In 1982 major changes in the question were made. First, the response option of “*very good*” was added to be consistent with other NCHS surveys and to improve the ability to differentiate among people. Second, another major conceptual change was the question: “Would you say ___ health in general is excellent, very good, good, fair, or poor?” This was to remove the phrase “compared to other persons’ age.”

Healthcare Cost and Utilization Project (HCUP)

The 1988-1992 Nationwide Inpatient Sample (NIS) of Healthcare Cost and Utilization Project (HCUP) is hospital database including about 6 million hospital discharge records (over 800 hospitals in 8-11 states) annually. Eight states are CA, CO, FL, IL, IA, MA, NJ, and WA. Three more states added from 1989 are AZ, PA, and WI. It contains clinical records (admissions and discharges) classified by DRG and ICD-9-CM codes; total charges amounts; patients’ insurance type (Medicare, Medicaid, and private).

Merging HCUP data with Medicare Cost Reports using AHA Data

To estimate costs, I merge the HCUP data with Medicare Cost Reports using American Hospital Association (AHA) Annual Survey data. Since HCUP data provides information on total charges instead of total costs, I multiply the total charges by the cost-to-charge ratio from Medicare Cost Reports to estimate costs. However, HCUP and Medicare Cost Report do not have common hospitals identifiers and thus I bridged two data sets using AHA data. Each data set has the following hospital ID information:

- (1) HCUP: HCUP hospital IDs and AHA IDs
- (2) AHA: AHA IDs and Medicare Provider Numbers
- (3) Medicare Cost Reports: Medicare provider Numbers

Therefore, I first merge the HCUP with AHA data using AHA IDs, which is then merged with Medicare Cost Reports using Medicare Provider Numbers.