Essays in Health Economics

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Introduction

This dissertation examines the effects of health care policy on: 1) access to health care and health outcomes; 2) use of medical technology; and 3) educational attainment.

The first chapter (co-authored with Kenneth Chay and Shailender Swaminathan) examines the impact of Medicare's introduction on hospital insurance, utilization, and mortality rates. The analysis applies an "age discontinuity" design to data both *before and after* Medicare's introduction. We find that Medicare: i) increased hospital utilization and costs among the elderly, but at a lower rate than previously found; and ii) significantly increased life expectancy in the eligible population. The mortality reductions exhibit an age discontinuity *only after* Medicare's introduction – patterns not found in nations that did not introduce a Medicare-style program in the 1960's – with deaths due to heart disease and stroke accounting for most of these reductions. We estimate that Medicare's introduction had a cost-per-life year ratio below $200 (in 1982-84 dollars). We also analyze changes over time in Medicare's impact and the characteristics of the "marginal" person who benefited from coverage. We find that the age-65 discontinuity in insurance rates fell over time, more so for blacks, the less-educated, poor and disabled; and that Medicare's salience rises in recessions. We present evidence that the benefit-cost ratios of Medicare fell during the 1980s, partly due to changes in Medicare's reimbursement formula.

The second chapter examines the impact of Medicare payment reform on hospital costs. 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.

The third chapter explores the role of hospital desegregation on educational attainment. The Civil Rights Act of 1964 and the implementation of Medicare in 1966 had turned the racially segregated hospital care into an integrated one in the United States. This hospital desegregation had provided increased access to hospital care, especially for Southern blacks at early ages, who previously had limited access and treatment. This paper explores the effect of increased access to hospital care among Southern blacks born in the mid- or late-1960s on the cohort-related convergence in educational attainment (i.e., formal schooling) between black and white youths in the 1980s. Using a difference-in-difference-in-differences approach, I document that the reduction in the black-white gap in educational attainment was much greater in Southern states than in Northern states for cohorts born after hospital desegregation (i.e., between 1966 and 1968) relative to those born before the desegregation (i.e., between 1961 and 1963). The black cohorts born after hospital desegregation in the South had a 7-percentage-points increase in their high school completion rate compared to their white counterparts. Also, the college enrollment rate of Southern blacks born after hospital desegregation increased by 4 to 7 percentage points.

Chapter 1

Health Insurance, Hospital Utilization and Mortality: Evidence from Medicare's Origins

> "No longer will older Americans be denied the healing miracle of modern medicine. No longer will illness crush and destroy the savings they have so carefully put away over a lifetime so that they might enjoy dignity in their later years. No longer will young families see their own incomes, and their own hopes, eaten away simply because they are carrying out their deep moral obligations."
>
> *President Lyndon B. Johnson, at the signing of the Medicare legislation, July 1965.*

1.1 Introduction

Medicare was established over 50 years ago and has had a profound effect upon the structure and functioning of the US health care system. Some have suggested that Medicare has caused much of the persistent rise in US health care costs, while others have credited Medicare with stimulating the major technological innovations and medical care advances observed over this time period (Weisbrod, 1991). In addition, Medicare clearly serves to finance a great deal of Medical education and expansion of specialization that has occurred in American Medicine (Iglehart, 1998). However, the impact of Medicare on the health of the elderly has been incompletely assessed with most studies examining only some restricted aspect of Medicare's impact either by estimating Medicare's impact in the current climate or by using only aggregated historical data.

In this paper, we present evidence on the impact of Medicare at the time of its introduction on hospital utilization and health. We use two measures of health: rates of restricted activity, and mortality. We compare changes in these outcomes between the post-Medicare and pre-Medicare period (prior to 1966) for individuals that were eligible for Medicare (age greater than or equal to sixty-five) and for those that were ineligible for Medicare (age less than sixty-five). We further contrast these changes in outcomes in the United States with changes in other countries (e.g., Canada, England and Wales) that did not introduce a Medicare-type program in the 1960s.

We bring together the most comprehensive, detailed, recently released – data to meet our objective, including: 1) hospital and surgical insurance coverage rates *by age*, *both before and after* Medicare's introduction; 2) hospital discharge data *by age and cause* of admission from 1963 onward; 3) outpatient visit rates by age from 1963 on; 4) mortality rates by cause and age for the United States, United Kingdom, Canada, France and Japan from 1950 on; 5) mortality microdata *by cause and age* for the U.S. from 1960 on; and 6) activity limitation rates by age from 1963 on. These data allow for an analysis that utilizes the "age discontinuity" design of one set of studies, while accounting for pre-existing trends as done in the other set of more aggregated studies.

We find that between 1963 and 1968, hospital insurance coverage of those 65-69 years of age increased by 30 percentage points while hospital insurance coverage of those less than sixty-five increased by only about 5 percentage points. In addition, 28 additional elderly (per 1,000 individuals) between 65 and 69 years of age were discharged from a hospital in 1968-69 relative to the pre-Medicare period (1964-66). Over the same period, there was virtually no change in the hospital discharge rate among the non-elderly. Relative to the non-elderly, there were 35 fewer deaths among the elderly (aged 65-69) over the same period. Taken together, the results suggest that the Medicare program played a causal role in reducing the mortality rate among the elderly.

We also calculate the costs and benefits (measured in terms of life-expectancy conditional on survival until age 64). We construct cohort-specific survival curves for three birth cohorts: 1896, 1900, and 1904. The constructed survival curves show that, conditional on surviving until age 64, those born in 1904 lived 1.5 years longer than those born in 1896. We use the variation in birth years to construct a measure of exposure to the Medicare program. While no one from the 1896 birth cohort was exposed to Medicare between 65 and 69 years of age, all of their counterparts from the 1904 cohort were eligible for Medicare. Back of the envelope calculations suggest that it cost about $ 160 additional dollars to extend median life expectancy by one year.

Having established a beneficial effect of the program at the time of its introduction, we also gauge the effects of the program over the next forty years. We find that, in general, the effects of the program (measured in terms of the estimated discontinuity at age sixty-five) waned over time, partly as a result of changes in the characteristics of the "marginal" sixty-five year old individual eligible for Medicare. At the time of its inception, the "marginal" person was much more likely to be poor and/or disabled. Over time, other Government programs (e.g., Medicare's extension to the non-elderly disabled in January 1973, and Medicaid expansion for Supplemental Security Income (SSI) enrollees in 1974) made it possible for the poor and the disabled to gain health insurance even before turning sixty-five. Since the disabled were also more likely to benefit from health care, it is not surprising that the effects of Medicare estimated in studies using data of a more current vintage have found rather small effects.

We conclude that although there may valid reasons to cut back on Medicare expenditure, the program at its inception was an almost unqualified success in improving population health at a very reasonable cost. As the current debate on health care reform gathers steam, it may be instructive to understand the reasons underlying the success of Medicare in its early years.

In the next section, we provide a brief overview of changes in the health care market between 1965 and 1975, and existing research on the impacts of Medicare on health care utilization and health. Section 1.3 outlines our research design and empirical strategy. Section 1.4 presents a summary of our data, section 1.5 presents our results. We discuss possible channels underlying our findings in section 1.6 and conclude with a few policy implications section 1.7.

1.2 Background

1.2.1 Health and Social Insurance Expansions for the Elderly

By the middle of the 1960s, the United States had a health insurance system in place that excluded the majority of the poor, disabled, and the elderly. Health insurance coverage was almost exclusively linked to coverage via the employer.[1] Indeed the health insurance system stood in direct contrast to other developed countries such as Canada and England where National Health and Hospital Insurance systems ensured that all individuals had the right to health care. Against this backdrop, the health insurance expansion efforts over the next decade (1965-1975) were stunning in scope, and represents to this day the most sudden and dramatic transformation of the health care system. Figure 1.1, Panels A and B reveal the magnitude of the change in health insurance. Panel A shows that the most dramatic change in the hospital insurance coverage of the elderly occurred between 1963 and 1968. Panel B shows that hospital insurance coverage between the two years increased

[1]The Kerr-Mills program provided some medical assistance to the elderly poor.

discontinuously by about 25 percentage points at age sixty-five, after remaining close to 5 percent up until age sixty-five.

A. Medicare

Medicare came into effect in 1966, and was the most far-reaching Social Security legislation since the original Social Security Act. All individuals sixty-five and over as of July 1966 were provided hospital health insurance coverage (Part A) that included a $40 deductible for first 60 days in hospital, and $10/day for every day beyond 60.[2] Part B was a voluntary medical health insurance program and included an out-of-pocket premium of $3 per month with a 20 percent coinsurance for diagnostic procedures, X-rays, etc. Approximately 19 million Americans were eligible for Medicare in July 1966 and 15 million availed of part B.[3] Only 15.5 million out of the 19 million eligible for Medicare were receiving Social Security benefits, and were mailed letters with information about program by October 1965. Extra efforts were undertaken to track down those not on the Social Security system, and all of the 19 million were sent letters by the first half of 1966 (*Social Security Bulletin*, 1966). In the first year program, 3.4 million Medicare beneficiaries were admitted to hospital. Relative to 1965, there was a 25 percent increase in hospital days per visit soon after introduction of Medicare.

B. Medicaid

Medicaid was introduced concurrently with Medicare and provided health insurance to the medically needy. Unlike Medicare, implementation of Medicaid was left up to individual States and eligibility was not discontinuous at age sixty-five. Thus, while most of the North introduced Medicaid in 1966, most of the South did not introduce Medicaid until 1970.[4] Further, since Medicaid eligibility was tied to welfare, a sizable fraction of the poor were not eligible and reimbursement rates to providers were lower than that provided by Medicare. The staggered introduction of Medicaid across states allows us to identify the separate impact of Medicare on utilization and health.

[2] Individuals that were not on Social Security payroll were eligible for Medicare in July 1966 as long as they turned 65 years of age by January 1968 (*Social Security Bulletin*, February 1966).

[3] One million were not receiving Social Security benefits because they had not contributed into the system. Yet, they were eligible for Medicare. This policy subsequently was changed in the 1970s so that only those that contributed into the system were eligible for Medicare.

[4] Much of North adopted Medicaid before 1967: IL (Jan. 1966), NY (Oct. 1966), PA (Jan. 1966), OH (July 1966), MI (Oct. 1966). Much of South after 1969: AL (Jan. 1970), MS (Jan. 1970), NC (Jan. 1970), AR (Jan. 1970), FL (Jan. 1970), VA (July 1969), TN (Jan. 1969), SC (July 1968).

C. Social Security Benefits

At the end of 1968, 1.8 million people were receiving cash benefits who could not have received them under the law in effect at the end of 1963. Total social security benefits, including Medicare payments, rose from an annual rate of about $16 billion to an annual rate of about $32 billion–an increase of 100 percent. Social Security amendments in 1967 resulted in a 14 percent increase in cash benefits to Social Security recipients.[5] The expansion of benefits between 1965 and 1967 allowed 62 million aged beneficiaries to stay above the poverty line (*Social Security Bulletin*, 1970).

D. Health Insurance Expansion to the Non-elderly Disabled (1973) and Supplemental Security Income (1974) Recipients

Although the original expansion of Medicare substantially increased health insurance rates among the elderly, it left untouched the coverage rates of the non-elderly disabled. Since much of health insurance in the pre-Medicare period was tied to working, the disabled were most in need of health care and yet the least likely to have health insurance coverage.[6] Many of the disabled were covered by a cash-transfer program – the Social Security Disability Insurance (SSDI) program. Eligibility into this program was based on a very strict definition- individual disability had to be either diagnosed as long-term (expected to last more than one year), or was expected to result in death. After several unsuccessful attempts, Medicare was finally extended to the non-elderly disabled in January of 1973. Individuals were then automatically eligible for Medicare once they were on SSDI for a period of twenty-four months. Close on the heels of this expansion, Social Security introduced the Supplemental Security Income (SSI) program in 1974 that provided cash transfers to the poor elderly and the poor disabled. It was further established that everyone on SSI was eligible to be covered by Medicaid.

1.2.2 Mortality, Disease and Availability of Treatment

Over the first half of the 20th century, the development of drugs (vaccines) had all but eliminated (prevented) deaths due to infectious diseases. This reduction in deaths led to both an increase in life expectancy, and an increase in the mortality rates due to non-communicable disease (e.g., heart disease, stroke, and cancer) that affected individuals at middle and older ages. In 1961-62, about 25 % of individuals over sixty were diagnosed with some form of heart disease (authors' estimates

[5] In 1965, the earliest retirement age to be eligible for full Social Security benefits was 62.

[6] The disabled are much less likely to be employed. In addition, health insurance premiums for the disabled were prohibitively high in the private health insurance market.

from National Health Examination Survey I, 1961-62). Against this backdrop, the importance of the hospital increased since inpatient and surgical care became the dominant mode of treating disease.

Several studies were underway to understand the risk factors for heart disease. Spearheading those efforts the Framingham Heart Study began in 1948, and surveyed individuals between the ages of 25 and 74. This cohort of individuals were then followed and resurveyed periodically. In the early 1960s, the study established[7] that high blood pressure, smoking, and cholesterol levels were all associated with heart disease. Around the same time, the advancement of science made it possible to successfully treat heart disease. Surgical treatment of heart disease was found to be very successful by the 1960s (Beck et al., 1958).[8] As of the latter half of the 1960s, both pacemakers and defibrillators (device to shock heart back into rhythm) were widely available, 35 percent of hospitals had open heart surgery units by 1965 , and over 70 percent of non-profit hospitals had intensive care units by 1965 (Russell, 1979). The technology to treat heart disease increased dramatically between 1971 and 1975 with an increased use of catheterization (procedure to detect blocks in the coronary arteries), and Beta Blockers.

1.2.3 Previous Studies

Most of the work that has used individual level data to estimate the effects of Medicare has relied on data of relatively recent vintage- 1990 and beyond. For example, Card et al. (2008) use data from the 1992-2002 periods, and show that Medicare eligibility at age sixty-five resulted in a 1 percentage point decline in the probability of death among patients with non-deferrable[9] admissions into a hospital. Using data from the 1990s, a separate study by the same authors finds that Medicare had rather negligible effects on mortality rates in the general period (Card et al., 2009). Other studies using recent data find small to negligible effects of Medicare on health and mortality (Polsky et al., 2009), but much stronger effects on both utilization (Card et al., 2008; McWilliams et al., 2007) and beneficial effects on clinical outcomes such as control of blood pressure and cholesterol levels (McWilliams et al., 2003). In general, overall evidence supports the hypothesis that in recent years, Medicare has resulted in increases in health care utilization but not a decline in mortality rates.

A few studies have used data from the 1960s to estimate the impact of Medicare on mortality (Finkelstein and McKnight, 2008) and costs (Finkelstein, 2007) at the time of its introduction. Friedman (1976) presents evidence that rates of limited activity fell more among the elderly than

[7]Some findings of the study were subject to heated debate.

[8]The essential approach involved increasing blood supply to the heart and was found to prevent mortality due to heart disease.

[9]Admissions with a similar probability of admission on weekends and weekdays.

the non-elderly following the passage of Medicare. Studies by the Social Security Administration (1972) found that in the first five years of its existence, Medicare played a decisive role in increasing utilization rates while the number of days per hospitalization increased by 25 percent. A common feature of all of these studies is their reliance on data aggregated to 5-year age groups or at the regional level. The basic conclusion reached from these studies is similar to the conclusion reached from studies using current data: Medicare has resulted in increases in utilization (and costs), but has had rather negligible effects on mortality. We bring to bear on the topic recently released micro data on both hospital insurance and utilization from the National Health Interview Surveys (1963-2006). There are several advantages in the data we use. Specifically, we can calculate age-specific utilization (and costs), and are able to estimate the discontinuity in Medicare eligibility both before and after the introduction of Medicare.

The availability of age-specific data allows us to rule out several competing hypothesis- a possibility not afforded by aggregate data. For example, Finkelstein (2007) uses aggregate data from the American Hospital Association (AHA) and finds that hospital expenditure increased substantially following the passage of Medicare. Under the assumption that Medicare would cause a larger increase in health insurance among the elderly living in the South (relative to the North), the paper finds a more substantial increase health care costs in the South. However, the study may overstate the increase in utilization and costs since other simultaneous (with the introduction of Medicare) changes affected the health care market: (i) hospital integration; (ii) Medicaid; (iii) increase in personnel costs due to extension of minimum wage ($9-10/hour in $ 2007) to hospital employees in February 1967.[10]

A recent review of the literature (Levy and Meltzer, 2008) on the impact of health insurance on health concludes that the majority of the studies are observational studies that do not speak to the causal impact of health insurance. Even the quasi-experimental studies have "looked at the expansions under relatively narrow contexts". For example, the Card et al. (2008) study examined the effect of Medicare on mortality among a relatively sick inpatient sample.

[10]It is also likely that the increase in minimum wage was relatively more binding in the South than in the North. It was possible to charge the increase in daily expenses as a result of the minimum wage increase to Medicare.

1.3 Empirical Methodology

1.3.1 Estimate the causal effect of Medicare

We now discuss the empirical methodology we use to unravel the causal effect of Medicare on hospital utilization and health. Like a few other studies, we use the comparisons around the Medicare eligibility threshold at age sixty-five to measure the impacts of the program.

We first specify a generic model to highlight the strengths of our methodology, and later present the regression equations actually estimated. Let Y_{it} denote the outcome (health insurance, utilization, restricted activity, mortality) for each observation $i$in period t. In any given year, let the relationship between the outcomes, age, and the covariates take the following form:

$$Y_{it} = \beta_0 + \beta_1 \cdot f(age_{it}) + \beta_2 \cdot g(X_{it}) + \beta_3 \cdot D_{age_{it}>=65} + \varepsilon_{it} \tag{1.1}$$

where f and g specify the functional form of the relationship between the outcome and age, and the outcome and the X's respectively, and The vector of variables in X_{it} includes categorical variables for education, income, region, employment status, marital status.[11]

Since the functional forms of f and g are not observed, we posit a regression equation that expresses the outcome (Y_i) as a function of a fifth order polynomial in age, a linearly additive term in other correlates (X_i). We further split the age 65-and-over dummy variable to include three age-categories: 65-69, 70-74, and 75-79. Without loss of generality, we ignore the time subscript, and rewrite equation (1.1) as

$$\begin{aligned} Y_i \quad &= \alpha + \theta_1 \cdot \mathbf{1}\left\{age_{65-69}\right\} + \theta_2 \cdot \mathbf{1}\left\{age_{70-74}\right\} + \theta_3 \cdot \mathbf{1}\left\{age_{75-80}\right\} \\ &+ \lambda_1 \cdot age + \lambda_2 \cdot age^2 + \lambda_3 \cdot age^3 + \lambda_4 \cdot age^4 + \lambda_5 \cdot age^5 + X_i'\beta + \varepsilon_i \end{aligned} \tag{1.2}$$

The estimated effect of Medicare eligibility – denoted by the parameters θ_1, θ_2, and θ_3 – is affected by the assumed functional form of the relationship between the outcome and age (a fifth-order polynomial), and the outcome and the X's (linear). Unlike any other previous study, however, we use the "discontinuity" along with the comparisons in the changes in these outcomes before and after the introduction of Medicare. This possibility us with a distinct advantage previous studies. In particular, the functional form of the relationship between age, the correlates X_i, and the outcome (expressed as f and g) may play a less important role when we examine changes between the pre- and post-Medicare periods. We return to this point in the results section.

[11] Indicator variables for race are also available and are used for running the Whites only analysis.

Denoting the period after Medicare by A, and the period before Medicare by B, we estimate the following regression:

$$\begin{aligned} Y_{it} &= \alpha + \gamma_1 \cdot \mathbf{1}\{age_{65-69}\} + \gamma_2 \cdot \mathbf{1}\{age_{70-74}\} + \gamma_3 \cdot \mathbf{1}\{age_{75-80}\} \\ &+ \theta_1 \cdot \mathbf{1}\{age_{A,65-69}\} + \theta_2 \cdot \mathbf{1}\{age_{A,70-74}\} + \theta_3 \cdot \mathbf{1}\{age_{A,75-80}\} + \lambda_1 \cdot age + \lambda_2 \cdot age^2 \\ &+ \lambda_3 \cdot age^3 + \lambda_4 \cdot age^4 + \lambda_5 \cdot age^5 + \delta_1 \cdot \mathbf{1}\{After\} + \delta_2 \cdot age \cdot \mathbf{1}\{After\} + X'_{it}\beta + \varepsilon_{it} \end{aligned} \tag{1.3}$$

In equation (1.3), the parameters of interest are θ_1, θ_2, and θ_3 and represent the change in the regression discontinuity (at age sixty-five) between the post- and pre-Medicare periods. We further confirm that there are no discontinuities in the period before Medicare (1963-64).

1.3.2 Estimate Cohort-Specific Survival Curves

In addition to estimating the effects of Medicare on mortality rates, it is important to understand whether Medicare led to an increase in life-expectancy. The standard method to do so is to use the published life tables. However, a well-known drawback in using the published life tables in the United States is that they are, by construction, cross-sectional. More specifically, they assume that the prevailing health care conditions (including medical technology, health insurance coverage, etc.) remain constant over time. In our context, based as it is on a period of dramatic changes in the health care scenario, the cross-sectional life tables cannot convey much useful information. Instead, we construct cohort-specific survival curves. To do so, we take advantage of the fact that individual-level mortality data are available from 1960 onwards. Since these data also provide information on the age of death, we can calculate the number of deaths from any given birth cohort. We present an overview of the approach taken to construct survival curves for the 1896 birth cohort- a cohort that was not affected by Medicare until they turned 70 years old. From the 1960 census, we can estimate, conditional on survival until age 64, the population of 64 year-olds. From the 1960 mortality files, we can calculate the number of individuals from the 1896 cohort that died (because the number of 64 year-olds that died). We use this number to calculate the mortality rate of 64 year olds in 1960.[12] This mortality rate is applied to calculate the population of 65 year olds alive as of 1961. We apply the mortality rate of 65-year olds in 1961 to estimate the number of survivors in 1962. We follow this logic to estimate the complete survival curve for the 1896 cohort. We similarly estimate the survivor curve for the 1899, and 1904 cohorts. We note that this method is very similar to the widely-used Kaplan Meier (KM) survival curve. However, we need to modify the standard approach

[12] A typical problem in constructing cohort-survival curves is that they require that the entire cohort is dead (Siegel et al., 2004).

take to estimate the KM curve since we cannot, by definition) the complete survival curve for the 1896 cohort.[13] Our methodology has been used by the Social Security Administration (Bell and Miller, 2005). We note here that our approach assumes that the conditional probability of survival until age 64 does not change between the 1896 and 1904 cohort. We return to this issue in our discussion of results.

1.4 Data

In this section, we overview all the sources of data we use in our analysis. Here, we focus on describing how the main outcome variables were created, and some of the ways in which we have tried to gauge the extent of measurement error in our key variables. We present a more detailed description of the data used in an Appendix.

1.4.1 National Health Interview Survey (NHIS)

A novel feature of our paper is the use of micro-data on both hospitalization and health insurance coverage both before and after the introduction of Medicare in July 1966. Data on these variables come from the National Health Interview Survey (NHIS). We use data from the 1963-2006 NHIS surveys.[14] The NHIS samples about 40,000 households (130,000 individuals) from the civilian, non-institutionalized population of the United States. The NHIS contains information on health insurance coverage by types and payment sources, i.e., hospital and surgical insurance; private and public insurance. Between 1962 and 1968, insurance coverage data were collected in the NHIS in the fiscal years 1963 and 1968). Beginning in 1968, insurance data were generally collected every 2 years; and from 1989 on, data were collected every year. For 1970, 1983, 1986, 1993, and 1996, only a subset of the sampled individuals received the health insurance questions, resulting in sample sizes ranging 45,000 to 56,000.

Data on hospitalization come are based on responses of sampled members to the question: "*Have you been discharged from a hospital in the 12-month period prior to the interview*?"[15] Questions are asked about both any hospitalization, and also about the specific cause of hospitalization. Since

[13] In order to do so, we will need information about the total number of births in 1896, and in each subsequent year, the number of deaths from that birth cohort.

[14] The NHIS data from the 1962-1968 survey years was recently (January 2008) made publicly available. The questions from the 1963 survey cover the period July 1962-June 1963. The survey shifted to the calendar year format in 1968. In that year, surveys were administered using both the fiscal and calendar year formats.

[15] A hospital discharge from the short-stay hospital is the completion of any continuous period of stay of one or more nights in a hospital (as an inpatient). We did not count hospital discharges that involved hospital admission (and subsequent discharge) of women discharged from a hospital after a normal delivery.

responses are self-reported, we would like to check the veracity of the information provided by validating with more objective measures of hospitalization. Unfortunately, there are no other data we have available that we can use to cross-validate the NHIS hospitalization data prior to 1970. Beginning in 1970, however, we are able to construct age-specific hospitalization measures from the National Hospital Discharge Survey (NHDS). In results not shown here, we verify that the NHIS and NHDS generate overall hospital discharge rates that are very similar.[16] However, at the level of individual causes, we find more discrepancies between the two series. Hence, we only use the NHIS data to generate the overall discharge rates, and use the NHDS (from 1970 onwards) to generate the cause-specific discharge rates.

We also created a dummy variable if the individual was limited in the extent of activity. The question asked if the individual was limited in activity due to any chronic conditions present at the time of the survey.[17] As with all self-reported responses on disability, it is possible that this variable is also plagued with measurement error, especially for those non-elderly individuals that are out of the labor force (Bound and Waidmann, 2007). We return to this issue in our discussion of our findings.

The NHIS also provides information on several socio-economic variables that are potential correlates of the aforementioned outcome variables. These include levels of education, income, race, region of residence, age, employment, and marital status. We use these variables in creating regression "adjusted" estimates of the effects of Medicare on our hospitalization, limited activity rates, and mortality.

1.4.2 National Detail Mortality Files

In addition to limited activity rates, our other measure of health is mortality. We use the 1960-2006 National Mortality Detail Files that provide an annual census of deaths within the United States, derived from the standard Certificate of Death and processed by the NCHS. The data contain the universe of deaths and information on the deceased's race, gender, age at death, and cause of deaths according to the International Classification of Disease (ICD).[18] Although mortality is an objective measure of health, there may be concerns about the validity of number of deaths due to specific

[16] Some of the discrepancies result from the fact that the NHIS, by definition, only includes data on patients discharged alive.

[17] A chronic condition was one that lasted at least three months. As a result, our disability variable may represent a long-term restriction in activity.

[18] Deaths of foreign residents of the United States were excluded from 1970 because those were not uniquely identified before 1970. The total deaths of foreign residents for aged 45 to 80 are 0.08%, on average for 1970-1974, relative to those of residents. For 1972, data files contain only 50 percent sample of deaths occurred in each states and thus we multiply the number of deaths for this year by 2 to get an annual number of deaths. Race-specific analyses exclude data for New Jersey in 1962 and 1963 because this state omitted the item on race from its death certificates.

causes because of changes in ICD classification schemes. In particular, the scheme changed from ICD-7 to ICD-8 in 1968. Since we compare changes in mortality in the pre- and post Medicare periods, it is important to establish that the changes we observe in the number of deaths (due to a particular cause) are not reflecting changes in the way in which deaths are coded. Using the 1968 data, we estimate the number of deaths using both the ICD-7 and ICD-8 schemes. We find that the ICD revisions led to negligible changes in the cause-specific number of deaths, and bolster confidence in our estimated changes in cause-specific death rates in the pre- and post Medicare periods.

1.4.3 World Health Organization (WHO) Mortality Data

The United States was the only country to introduce a Medicare-type health insurance program in the 1960s (i.e., a program that provided health insurance to the elderly beginning in 1966). In order to exploit this fact, we pulled data from the WHO mortality files. The data provide us with the number of deaths by cause of death in 5-year age categories (e.g. 45-49, 55-59, 60-64, 65-69, 70-74, etc.). In analysis presented in this paper, we use the data from the United States, England and Wales, Canada, and France.[19] The data on population used to construct mortality rates are obtained from the WHO.[20] [21] An advantage of using the WHO data is that it allows us to construct a mortality rate series going all the way back to 1954.[22] This allows us to obtain a much clearer picture about trends in mortality rates in the decade before Medicare was introduced.

1.4.4 National Hospital Discharge Survey (NHDS)

The National Hospital Discharge Survey conducted by NCHS since 1965 is national sample of about 500 hospitals, which are non-federal, short-stay hospitals in the United States.[23] The NHDS sample contains about 75,000-100,000 individuals and about 200,000 inpatients records per each survey year. The annual survey is publicly available since 1970, and contains information on patient's age, gender, race, marital status, and geographic region of hospital's location; medical records for hospital admission, discharge, procedure, length of stay, and the patients' expected principal source of payment (available in public-use data from 1979 on).

[19] We also pulled data from several other countries such as Japan and Germany, but do not include them in the current results. However, we note that the findings of our paper are not affected by the particular choice of countries.

[20] We verify that the population totals from the WHO are very close (but not the same) as the unrevised population totals provided by the Census Bureau.

[21] Since our analysis is based on changes in mortality rates (overall and by-cause), the findings may be affected by changes in the ICD classification scheme. Indeed, it is theoretically possible that countries do not adopt an ICD scheme in the same year. We have verified that the countries used in our analysis adopt the ICD scheme in the same year (e.g. ICD-8 adopted in 1968, etc.)

[22] On the other hand, the detail mortality files only provide reliable mortality data from 1960 onwards.

[23] Short-stay hospitals were defined in NHDS as hospitals with an average length of stay of fewer than 30 days are included. Also only hospitals with six beds or more for patient use are included.

In addition to using the NHDS to verify the accuracy of self-reported hospital discharge rates from the NHIS, we also use this survey to estimate the effects of Medicare eligibility on hospital discharge rates (by cause) over time. In particular, we are able to gauge the effects of Medicare on Coronary Artery Bypass Graft (CABG) rates. As mentioned earlier, the comparative effectiveness of this procedure (relative to angioplasty) in patients with significant narrowing and blockages of the heart arteries (coronary artery disease) is not known. Indeed, it is widely believed that the usefulness of CABG decreases substantially in older patients.

1.5 Results

1.5.1 Effect of Medicare on Hospital Insurance Coverage

Panel A of Figure 1.1 plots the fraction of individuals with hospital health insurance for each age between zero and eighty. There are five lines corresponding to one pre-Medicare year (1963 fiscal year), and three post-Medicare years (1968 FY and 1968 CY, 1974 CY and 1986 CY). In 1963, after age twenty,[24] the plots roughly follow the labor force employment pattern reflecting the dominance of employer provided health insurance as a source of coverage. About eighty percent of the individuals between the ages 46 and 52 are covered by hospital insurance. There is a linear decline in health insurance coverage after age 60 reflecting individual retirement from the labor market. Between the years 1963 and 1968, there is roughly a parallel shift of the 1963 line until age sixty-four. In 1968, soon after the introduction of Medicare, insurance rates increased from 73 percent at age sixty-four to about 93 percent at age sixty-five.[25] Although everyone was eligible for Medicare once they turned 65 in 1968,[26] roughly 7 % of the individuals do not have hospital insurance coverage. Over time, most of the elderly are covered by health insurance possibly reflecting greater awareness about the existence of Medicare for the elderly. In 1974, we also note a slight increase (relative to 1968) in the hospital insurance coverage for the near-elderly (55-64 year olds) and this pattern persists through 1986. These changes resulted in a decrease in a "jump" in hospital insurance rates at age sixty-five.

Panel B uses the same data as Panel A, but now plots the growth in hospital insurance rates (at every age) since 1963. In each year, the growth in insurance rates is fairly constant until age

[24]There is a considerable dip in hospital insurance coverage at age 18 (even in 1963) as children age out of their parents' health insurance policy. This pattern continues and is accentuated in later years since children lose Medicaid coverage around age 18 (in several states) in addition to being removed from employer provided health insurance of their parents.

[25]There is some increase in hospital insurance rates of the non-elderly (<65) between the 1968 fiscal year (July 1967-June 1968), and the 1968 calendar year due, in part, to the expansion of Medicaid to South Carolina and Washington D.C in July 1968.

[26]Up until the early 1970s, everyone who turned sixty-five was eligible for Medicare irrespective of contributions to the Social Security system.

sixty-five. The constancy is remarkable and suggests that in the absence of Medicare, the growth in hospital insurance coverage would have been flat at all ages beyond sixty-five as well. Thus, we may be able to identify the effect of Medicare not merely at the discontinuity (i.e., age sixty-five), but at ages over sixty-five as well.

Table 1.1 shows the discontinuity in hospital insurance rates for the elderly. The outcome variable is the percent with health insurance at each age. Column 1 confirms the finding in Panel A of Figure 1.1, and shows that before Medicare (1963), there is no discontinuity in insurance rates. Column 2 (Panel A) presents discontinuity estimates for the growth in health insurance coverage between 1963 and 1968. The point estimates suggest that 24 more elderly (aged 65-69) gained insurance coverage in 1968 that would have remained without health insurance coverage in 1963. Similarly, about 30 more elderly aged 70-74 , and 39 more elderly aged 75-79 , have hospital insurance in 1968 relative to 1963. Column 3 shows that the discontinuity in insurance rates falls slightly in 1974 (relative to that in 1968) due, in part, to the introduction of Medicare to the non-elderly disabled and the expansion of Medicaid enrollees. The next three columns of Panel A show that the results are robust to adjusting for several individual characteristics. Indeed, the explanatory power of the regression increases and standard errors on the estimates fall once we adjust for individual characteristics. The discontinuity estimates are larger for Blacks (Panel C) than Whites (Panel B) possibly indicative of greater employer provide health insurance among Whites.

1.5.2 Effect of Medicare on Hospital Discharge Rates

In Figure 1.2, Panel A, we plot the hospital discharge rates by age for the years 1963-64 and 1969-70. Hospital discharge rates decline between the ages of zero and thirteen, increase between ages 14 and 19, stay fairly constant until age 35, and then increase gradually over age.[27] Discharge rates in 1969-70 are very similar to that in 1963-64 until age sixty-four. There is a noticeable decoupling of the two lines beginning at age sixty-five. This figure provides strong evidence that Medicare resulted in an increase in hospital discharges. In Panel B, we plot the growth in hospital discharge rates since 1963-64. There is effectively a zero growth in discharge rates between 1963-64 and 1965-66, suggesting that there were no pre-Medicare trends in hospital discharge rates. On the other hand, there is a rapid growth in discharge rates for the elderly between the years 1963-64 and 1969-70. The discharge rates for the non-elderly do not increase between these periods suggesting that other programs changing concomitantly with Medicare such as the Civil Rights Act and the associated desegregation of hospitals, Medicaid and Social Security payment increases are not the primary

[27] Hospital admissions for delivery are omitted from Figure 1.2.

reason for the trends depicted in Figure 1.2.[28]

Table 1.2 presents results of the discontinuity in hospital discharge rates. The absolute value of the t-ratios is presented as well. The first set of three columns does not adjust for individual characteristics and essentially fits a regression model to the data plotted in Figure 1.2. Column 1a shows that in the period 1964-66, discharge rates for the elderly did not increase discontinuously at age sixty-five. Column 1b presents discontinuity estimates for the change in discharge rates between 1964-66 and 1968-69. We find that 28 additional elderly (per 1000) between 65 and 69 years of age were discharged from a hospital in 1968-69 relative to the pre-Medicare period (1964-66). For the same age groups, there were 35 additional discharges in 1971-72 relative to the pre-Medicare period. For any given year, the discontinuity in discharge rates was higher at older ages. Thus, in 1968-69, the discontinuity increased from 28 (per 1000) at ages 65-69 to over 76 (per 1000) at ages 75-80. We note that this pattern is very consistent with an increase in the discontinuity in hospital insurance rates with age (column 1b of Table 1.1). The results do not differ appreciably across Panels A (all races) and B (Whites). This finding is not surprising since our identification strategy relies on the discontinuity in Medicare eligibility at age sixty-five. Other programs that might have impacted Blacks and Whites differently (Civil Rights Act) did not rely on any age criteria to determine eligibility.

1.5.3 Effect of Medicare on Rates of Limited Activity

Panel A of Figure 1.3 plots the change in the rates of limited activity between two pre-Medicare periods (1963-64 and 1965-66) and a pre-Medicare and post-Medicare periods (1963-64 and 1969-70). There is virtually no change in limited activity rates in the two pre-Medicare periods. However, beyond age sixty-five the limited activity rates fall in the post-Medicare period. This graph makes a persuasive case that the introduction of Medicare may have helped lower limited activity rates. Since no pre-Medicare trends exist (Panel A), Panel B plots the change in limited activity rates using 1965-66 as the base period. In both years 1969-70 and 1971-72, it is pretty clear that Medicare reduced limited activity rates. However, between 1965-66 and 1973-74, we find that limited activity rates actually increased for the non-elderly aged 45-64. We hypothesize that much of this increase in the rates was due to an "earlier accommodation of health limitations" (Bound and Waidmann 1992).[29] In the appendix, we plot a similar change in rates as in Panel B, but separately for employed and

[28] Medicare was the only program that strictly tied eligibility to age.

[29] The evidence clearly suggests that the movement of older men in relatively poor health out of the labor force and onto disability rolls-a phenomenon that we shall refer to as the earlier accommodation of health limitations-can account for a large fraction of the drop in the work force attachment of these men that occurred during the 1970s.

unemployed. It is clear that when we restrict the sample only to those employed, Medicare helped lower the rates of self-reported disability. For the unemployed, disability rates presumably went up for the non-elderly as individuals withdrew from the labor market and reported limited ability to work so as to take advantage of a rise in benefits from disability insurance.[30]

In Panel C, we plot the annualized number of days with restricted activity for each age between forty-five and eighty.[31] While steadily increasing with age in the pre-Medicare period, the elderly report substantially less restricted activity days in 1971-72 than their counterparts in the 1963-64. On the other hand, for the exact same time periods, there is virtually no difference among the non-elderly.

Table 1.3 presents regression coefficients of the discontinuity in limited activity rates for the graphs plotted in Figure 1.3. The first column shows that in the pre-Medicare period, 1965-66, there is no significant discontinuity in rates upon turning sixty-five. The next three columns report the change in the coefficients by 1969-70, 1971-72, and 1973-74. By 1969-70, there were 35 less disabled elderly aged 65 to 69 than would have been the case in the absence of Medicare. The effects of Medicare on lowering self-reported disability rates continue to exist at older ages (70-74 and 75-79) as well. By 1973-74, the discontinuity estimates rise appreciably, but as Figure 1.3 depicts, much of this rise is because the increase in self-reported disability rates among the non-elderly. The last three columns report the change in limited activity rates after adjusting for individual characteristics. The discontinuity estimates are robust to inclusion of these characteristics, while the explanatory power of the regressions roughly doubles. Taken together, this suggests that Medicare eligibility may be randomly assigned since the covariates introduced are uncorrelated with the treatment but are correlated with the outcome (i.e., limited activity rates). We will return to this point more directly when we consider alternative explanations to our findings. The results of Whites (Panel B) are in general similar to those for all races (Panel A), but there is a slightly higher reduction in limited activity rates for Whites.

1.5.4 Effect of Medicare on Mortality Rates

A. Mortality Rates: Overall and By Cause of Death 1954-1989

Panel A of Figure 1.4 plots mortality rates in the United States between 1954 and 1989. The line with the solid squares represents the difference in the rates between those aged 65-69 and those aged

[30] In particular, the non-elderly disabled enrolled in Social Security Disability Insurance (SSDI) for a period of twenty-four months were eligible for Medicare beginning in January 1973.

[31] The data appendix provides details on how this variable was constructed.

60-64. The line connected with triangles represents the differences between those aged 60-64 and 55-59. Although the data used here (provided by the WHO) are aggregated to five-year age categories, it provides us with a complete picture of mortality rates in the pre-Medicare era. The plots show that while the difference in the mortality rates between the Medicare eligible and ineligible groups fell rapidly in the post-Medicare period, the difference in rates between two groups ineligible for Medicare was left virtually unaffected. Between 1966 and 1971, 65-69 and 60-64 difference in rates fell by roughly 18 (per 10,000 individuals). Even considering the average mortality rate over the entire pre-Medicare period on which we have data (1954-1965), Panel A reveals that the difference in mortality rates between the age groups (65-69 and 60-64) fell by about 12 per 10,000 individuals. Panel B further confirms the fact that only the 65-69 minus 60-64 difference in mortality rates fell at the time that Medicare was introduced.

In Panels C and D, we plot the difference in mortality rates (65-69 and 60-64) by cause of death. More than half of the decline shown in the top line in Panel A is explained by heart disease. About 15 percent of the decline is due to stroke. None of the decline can be explained by either cancer or diabetes. This should come as little surprise since cancer treatment was virtually non-existent at the time.[32] We are a bit more cautious in drawing inferences about changes in diabetes mortality rates since it is likely that diabetes was a significant risk factor in heart disease deaths.

B. International Comparisons of Mortality Rates

Panel A in Figure 1.5 plots the age (65 to 69) – (60 to 64) difference in mortality rates for three countries: United States (solid squares), England and Wales (dashed line), and Canada (solid line). The US is the only country that shows a declining trend after 1967. Panel B confirms that for Medicare ineligible groups (60-64 minus 55-59), the US pattern looks very similar to that in the other two countries. Finally, in Panel C, we plot the difference in log mortality rates between age groups.[33] The sharp contrast between the United States and the other countries suggests very clearly that the relative mortality rate of the elderly fell in the immediate post-Medicare period.

C. Mortality Changes in the United States (1963-64 to 1973-74)

We next present results using the number of deaths (by age) from the mortality detail files and population counts from the census bureau. Panel A of Figure 1.6 plots the change in mortality rate

[32] The inability to treat cancer at the time led Nixon to his "War on Cancer".

[33] The log mortality rate is preferred by demographers because of the well established exponential relationship between mortality rate and age.

relative to 1963-64. By 1965-66 no change in the mortality rates are observed and establishes the fact that no trends existed in the pre-Medicare period.[34]

When we consider the changes up until 1969-70, the graph suggests that mortality rate declined for only the ages affected by Medicare (65 and over). A similar pattern is observed when we plot the (1971-72)-(1963-64) difference in mortality rates. However, by 1973-74, there is a fall in mortality rates even at ages less than sixty-five. Panel B shows that much of this early decline in mortality rates is driven by declines in heart disease mortality rates. This finding may be consistent with the rapid increase in the role of medical care in treating heart disease.[35] On the other hand, it is also consistent with Medicare's extension to the disabled[36] under sixty-five years of age. Panel B also suggests that although there was a decline in deaths due to heart disease, deaths due to Cancer actually begins to increase beginning at age 72. This is consistent with a competing risks story where individuals that do not die from heart disease, end up dying at a later age from Cancer.[37] Panel B also confirms that the changes in heart disease mortality rate explain much of the overall changes in mortality.

Table 1.4 presents the regression discontinuity coefficients for the plots shown in Figure 1.6. The first three columns include data on all races, while the remaining three columns focus only on Whites. We present results for all-cause mortality in Panel A, heart disease in Panel B, Stroke in Panel C, and Cancer in Panel D. Among those 65-69 years old, there are about 13 fewer deaths (per 10,000) in 1969-70 compared to their counterparts in 1965-66. This reduction in mortality rates remains fairly steady when we consider changes by 1971-72 or 1973-74. The mortality discontinuity is slightly lower when we only consider Whites as opposed to all races. However, we note that the discontinuity estimates for discharges (Table 1.2) are similar for Whites and all races. This might suggest that the non-Whites enter the hospital in worse health states than Whites so that the marginal benefit from hospitalization is higher among non-Whites. Remarkably, the lower mortality discontinuities for Whites (relative to results for all races) persist for each of the causes of death detailed in Table 1.4. Although, the number of deaths in the post-Medicare period is generally lower for all Medicare eligible age groups considered, we note that 2-3 more deaths due to cancer (per 10,000) in the 75-80

[34] We note that some part of the 1966 data on mortality counts refers could refer to deaths that occurred between July 1966 and December 1966. We find only minor differences when deaths that occurred in the second half of 1966 were removed from the numerator.

[35] This period was at the cusp of major improvements in treatment of heart disease including the use of Beta Blockers.

[36] Individuals on SSDI for a period of 24 months were eligible for Medicare coverage beginning on January 1, 1973. Although mental ailments constitute the bulk of SSDI recipients today, in the early 1970s, SSDI recipients were primarily those with heart disease and/or diabetes and cancer (Social Security Administration).

[37] Using annual data on the number of deaths due to heart disease and Cancer, Honore and Lleras-Muney (2006) shows that the "War on Cancer" cannot be dubbed as a complete failure once we view dying from Cancer as a competing risk to dying from heart disease.

age group in 1973-74 relative to 1965-66. This may suggest that some of those that did not die at younger ages due to (say) heart disease or stroke, end up dying at later ages due to cancer- a distinct possibility since heart disease and cancer share some common risk factors (i.e., smoking).

1.5.5 Costs and Benefits of Medicare (1966-1970)

Although the mortality estimates suggest that there the introduction of Medicare led to a decrease in mortality, they do not directly allow us to measure the benefits of the program. However, as detailed in the methods section, we are able to construct cohort-specific survival curves to estimate the gains in life expectancy (conditional on survival until age sixty-four) for cohorts that were, to varying degrees, affected by Medicare between the ages of 65 and 69. In addition to simply measuring benefits, we also provide a baseline estimate of the cost of expanding Medicare. In estimates presented here, we use the costs of hospital discharges as our measure of the costs of the program.[38]

Table 1.5 presents the results of our calculations. The three columns represent our estimates of the costs and benefits of the program for the 1896, 1899, and 1904 birth cohorts respectively. No one from the 1896 birth cohort was exposed to Medicare between the ages of 65 and 69. Relative to this cohort, there were 146.5 additional discharges (per 1,000) in the 1899 cohort, and 184.2 (per 1,000) in the 1904 cohort, while the median life expectancy (conditional on surviving until age 64) was 79.28, 80.26, and 80.73 respectively. The average cost per discharge was about $1,250 in 1982-84 dollars. The cost per-life year is $187.3 for the 1899 cohort and $159.45 for the 1904 cohort. This calculation assumes that all of the gains in life expectancy can be attributed to the Medicare program. This does not seem completely unreasonable because we are only measuring gains conditional on survivors to age sixty-four. Indeed, given secular improvements in nutrition, and public health sanitation, the survivors to age sixty-four in the 1896 cohort were likely more positively selected (from the population of all births in 1896) than those in the 1904 cohort. This would imply that our estimate of the gains in life-expectancy would, if anything, underestimate the true gains in life expectancy across cohorts. Nevertheless, even if we were to take the conservative approach, and assume that only 50 percent of the over all gains in life expectancy is due to medical care,[39] our cost per-life year estimates would be $374.6 and $318.9 for the 1899 and 1904 birth

[38] Technically, since the Medicare program also included coverage for outpatient visits to the doctor (Part B), simply using hospital costs is likely to give us an underestimate of the total costs of the program. Nevertheless, data from the SSA indicates that in the first two years of the program, $6.3 billion was disbursed on hospital insurance (part A) and $2.1 billion dollars on part B. Thus, roughly 75 percent of total Medicare expenditures was devoted to part A of the program.

[39] Cutler (2006) argues that even if we look at overall gains in life expectancy from 1960 onwards, about 50 percent may be attributed to medical care.

cohorts respectively.

The aforementioned calculations are based on benefits accruing to the entire population. When we focus on only the increase in hospital discharges attributable to Medicare, the increase in life expectancy per person discharged from a hospital are considerably larger. To see this, we note that there were roughly 25 more elderly (per 100) that were insured in the age group 65-69 (Table 1.1). In addition, there were roughly 35 more individuals (per 1,000) aged 65-69 were discharged from a hospital (Table 1.2). Thus, approximately 1 in 7 (35/250) elderly who gained health insurance was discharged from a hospital. Thus, per person discharged, there was approximately a 8 year gain in life expectancy.

1.5.6 Alternate Explanations

Although the results presented thus far suggest that Medicare played a causal role in reducing mortality rates, it is possible that factors not directly accounted for in our analysis might affect the magnitude of our estimated parameters. Notwithstanding the fact that we cannot, by definition, assess the magnitude of the bias due to unmeasured factors, we try to understand whether other changes that occurred concomitantly with the introduction of Medicare somehow mask the true effect of Medicare. The strength of any research design is based on its ability to rule out alternate explanations of our findings. In sub-section A below, we show how we are able to separate the effects of Medicaid from the effects of Medicare. Further, the strength of our research design is predicated on the notion that there were no other discrete changes at age sixty-five in the pre-and post-Medicare periods. The sub-sections B, C, and D address concerns about the validity of our research design.

A. Medicaid

Introduced along with Medicare in July 1966, Medicaid remains, to this day, the most important source of health insurance coverage to the poor and disabled. Although Medicaid does not have an age eligibility requirement, it is possible to use Medicaid to supplement Medicare coverage, and to help pay the premiums involved in Medicare part B. It may thus be important to gauge the importance of Medicare in the absence of Medicaid. We exploit the fact that Medicaid was not adopted by any of the Southern states until January 1970. Thus, while most of the Northern States adopted Medicaid in 1966, most of the Southern States did not adopt Medicaid until 1970. Thus, for the Southern region of the US, the only health insurance program that was introduced between 1963-64 and 1968-69 was Medicare. Figure 1.7 plots changes in hospital insurance rates separately for the South and North. The magnitude of the discontinuity estimate is roughly the same in the South as it is in the North, and suggests that the effects of Medicare were fairly substantial even in the absence of Medicaid.

B. The 1965 and 1967 Social Security Amendments

The 1965 and 1967 amendments to the Social Security program increased cash earnings of recipients by about 20 percent between 1963 and 1967.[40] According to the Social Security Administration, at the end of 1968, about 1.8 million people were receiving SS who could not have received them under the law in place at end of 1963. The minimum cash benefit payable at age sixty-five increased 37% – from $40 to $55 per month. More than 62 million aged beneficiaries were kept out of poverty as a result of the 1965 and 1967 amendments. We cannot directly include income as a covariate in the mortality regressions since questions about income only began to be included in the mortality file beginning in the 1980s. Instead, from the NHIS we calculate, for each age, the fraction of individuals with income $< 150\%$ of the poverty line. We estimate whether the SS amendments led to a discontinuous increase in income levels at age sixty-five. Table 1.8 presents those results. We find that there is no evidence that relative poverty rates declined substantially among the elderly (compared to the near-elderly) between 1965-66 and 1969-70 or 1971-72. This suggests that the SS amendments are unlikely to bias our estimated effects of the Medicare program.

C. Increase in Retirement at Age Sixty-five following Passage of Medicare

The importance of the health insurance for the elderly cannot be understated- and was one of the reasons underlying the original passage of Medicare. Indeed, it is possible in the pre-Medicare era that some individuals continue to work at age sixty-five and beyond simply to be assured of employer provided health insurance. The introduction of Medicare may induce such individuals to then retire from the labor force at age sixty-five. If retirement leads to an improvement in health (Bound and Waidmann, 2007), the estimated effect of Medicare on mortality may be confounded by retirement. In order to check for this possibility, we estimated a regression of labor force participation on a fourth order polynomial in age, and a dummy variable for age greater than sixty-five. Table 1.8 shows that there was no discontinuous change of retirement probabilities at age sixty-five following the introduction of Medicare. This bolsters confidence in our finding that retirement was not a confounding factor in our estimates.

[40]Since Medicare was introduced as part of the "War on Poverty" program, there were other, more direct efforts to reduce poverty. Perhaps the most important among these was the SS amendments, but programs such as Head Start also played an important role in improving individual welfare (Ludwig and Miller, 2007).

D. Cohort-specific changes in Education

Although our regression results persuasively suggest that Medicare led to a causal decline in mortality rates, they still do not decisively rule out the presence of cohort specific differences in either education or early-child health. Indeed, this problem is simply an artifact of our inability to simultaneously identify year, age, and cohort effects in a regression framework. Using similar regressions to that discussed in the aforementioned paragraph, we check to see if there were discontinuous changes in education levels in cohorts born before and after 1898.[41] We find no evidence of such a discontinuity in education levels suggesting that the fall in mortality in the post-Medicare era is not caused because those cohorts have, on average, more educated individuals.

1.5.7 Reconciling Our Findings with Prior Studies Using Aggregate Data

In this paper, we find that Medicare's introduction had, arguably, substantial causal effects on improving the health of the elderly. Indeed, this finding seems to be at odds with findings from prevailing studies that point to a rather small impact of Medicare's introduction on mortality. The one study that found beneficial impacts of Medicare on mortality focused on a relatively sick inpatient sample. We review the findings of two different sets of studies, and try to understand the reasons underpinning the difference in findings.

A study by Finkelstein and McKnight (2008) finds that the introduction of Medicare had no impact on elderly mortality rates. The main set of results in their study compares the change in mortality rates of the elderly living in the North with the change for those living in the South. Under the maintained assumption that changes in insurance coverage due to Medicare would be higher in the South compared to the North, they hypothesize that the decline in mortality rates should be higher in the South.[42] In Panel A of Figure 1.7, we plot the growth in hospital insurance (by age) between 1963 and 1974 and show that hospital insurance coverage for the elderly did grow more in the South than in the North, although the same was true for the non-elderly. Similarly, in Panel B, we plot the growth in hospital discharge rates. We find that although the hospital discharge rates for the elderly did increase for Southern residents in the post-Medicare period, they also increased for those in the North. Table 1.6 confirms that the growth in hospital insurance coverage for the elderly is about 10 percent higher in the South than it is in the North. However, in Table 1.7, we

[41] This approach is valid because decisions about education levels are made early on in the life-cycle. So the regression discontinuity at age sixty-five (in 1961-63) is estimating whether high school attainment changes discontinuously for cohorts born before 1898 and those born later.

[42] Their study used aggregate state-level data on hospital insurance coverage for the elderly in 1963, and assumed that states with the lowest coverage in 1963 (Southern states) would exhibit the maximum growth in health insurance coverage post-Medicare.

show that the growth in hospital discharge rates for the elderly is not significantly higher in the South. This finding suggests that the implied first-stage – the effect of health insurance coverage on discharge rates – is weak. In the absence of an effect of Medicare expansion on discharge rates, the negligible effects on mortality should not come as a surprise. On the contrary, it should be expected.

1.5.8 Effect of Medicare on Hospital Utilization

In general, overall evidence supports the hypothesis that in recent years, Medicare has resulted in increases in health care utilization but not a decline in mortality rates. In order to investigate this further, we estimate the RD coefficients on the impact of Medicare for each of the years between 1970 and 2005. For this analysis, we restrict the sample to 45 to 69 year-olds. In Figure 1.8, Panel A, we present the results for overall hospital discharge rates, while Panel B presents the results for heart disease discharges. The figure shows the estimated RD at ages 65-69, and the associated confidence interval. For this analysis, we use data from the NHDS. Since the NHDS data begins in 1970, we cannot examine changes between the pre- and post-Medicare periods. However, we note that the size of the RD equals 36 (per 1,000 individuals), and is similar to the RD coefficient estimated off the changes (Table 1.2). We find that the coefficient has in general been declining reaching about 18 by the year 2000. This suggests that the effect of Medicare on hospitalization has, in general, fallen over time. However, the decline has not been monotonic. As Figure 1.8 reveals, the effect of Medicare has followed a cyclical pattern – its effect has been greatest in times of recession and least when the economy has been strong. This is possibly a reflection of individuals losing employer provided health insurance coverage in a recession. Panel B of Figure 1.8 reveals that much of the cyclical pattern is driven by acute conditions such as heart disease rather than chronic conditions such as diabetes.

1.5.9 Effect of Medicare on Mortality: 1970-1990

The fundamental finding from several studies using data from more recent years has found that Medicare has had rather small effects on mortality. The one exception is the study by Card et al. (2008). However, their study was based on a finding using a sample of relatively sick inpatients. In this sub-section, we discuss the effects of Medicare on mortality in the two decades between 1969 and 1989. Figure 1.10 shows plots of the estimated coefficient on the dummy variable for age between 65 and 69, that are based on regressions for 50 to 69 year-olds with a quartic polynomial in age and using a moving sample of three years (with time effects). The findings reveal that beginning in about the mid-1980s, Medicare eligibility did not lead to a decrease in overall mortality rates. The basic conclusion remains the same even when we focus just on heart disease. We also note that the effects of Medicare are smallest during recession years (1971-73 and 1981-83) – possibly reflecting the possibility that most of the deaths occurring in recession years are "sudden" and are caused by increased stress levels. The effect of medical care, and hence the effect of health insurance, is possibly much less in this case.

1.6 Discussion

The findings of this paper suggest that the introduction of Medicare led to both an increase in hospital utilization, and a decrease in mortality rates. In addition, back of the envelope calculations suggest that this decrease in mortality was achieved at a relatively low cost. Conditional on survival until age 64, an individual born in 1904 lived approximately 1.4 years than his counterpart born in 1896. There was approximately an 8 year gain in life expectancy for each additional elderly person discharged from the hospital in the early years (1969-70) of the Medicare program. Since the mid 1980s, however, we are unable to reject the hypothesis that Medicare had no impact on mortality. In this section, we discuss the possible reasons for our findings.

1.6.1 Changes in Characteristics of Marginal Person

As the quote at the beginning of this paper suggests, Medicare was introduced as a means to reduce the financial burden on the elderly- with medical care costs comprising a large share of their overall budget. Indeed, in some ways, it was meant to benefit those at the lower end of the income distribution- those that did not have the wherewithal to purchase private health insurance.

In addition, it was the only source of health insurance for the disabled who suffered the double whammy of being out of work, and without health insurance. The introduction of Medicare provided the poor and disabled, for the first time, a source of health care coverage. Soon, other programs would be introduced; Medicaid was adopted by all states except Arizona by 1970, Medicare was extended to the non-elderly disabled in 1973, and those on SSI were eligible for Medicaid beginning in 1974. Thus, by the mid-1970s, many of those most in need of health care had access to health insurance. This fact is reflected in panels A and B of Figure 1.10, and in Table 1.8. Panel A of Figure 1.10 shows the Black-White difference in insurance coverage by age. To the extent that Black-White difference in insurance coverage is also correlated with (say) the difference in insurance coverage across income sub-groups, it is clear that in the period since the mid-1970s, Medicare eligibility at age 65 does not narrow the insurance coverage rates across the income sub-groups. Panel B shows the difference in insurance coverage between individuals that report activity limitations (due to chronic conditions) and those that do not. Once again, it is clear that much of the difference in insurance coverage between the sub-groups is removed by the mid-1970s.

In Table 1.8, we present estimates of the discontinuity in hospital insurance rates at age 65 over time. We present these estimates for various sub-groups. In 1968, only about 58 percent of the 60-64 year-old Blacks reported some form of hospital insurance while by 1986 more than 81 percent of Blacks reported hospital insurance coverage by 1978. This dramatic change in insurance coverage of the non-elderly resulted in a substantial fall in the RD coefficient – from 30 percent in 1968 to 18 percent a decade later. Similarly, for the non-elderly below the 150% of the poverty line, 58% reported hospital insurance coverage in 1968 while 80% reported coverage by 1978. The discontinuity coefficient is also roughly halved- going from 30% in 1968 to just over 15% in 1968. A similar trend is observed for those with a high school education or less.

1.6.2 Increased Use of Expensive Procedures such as CABG to Treat Coronary Heart Disease in the Elderly

The evidence presented above clearly suggests that some of the changes in the estimated effect of Medicare on mortality may be attributed to changes in the characteristics of the marginal person. In addition to the rapid rise in health insurance coverage, the period beginning in the late 1970s and through the 1980s also witnessed a rapid influx of technology into the health care arena. Despite disagreements over the exact reasons underlying this surge in adoption of medical technology, this period marked a serious turning point in the production of medical care in the United States. In particular, the treatment options for coronary heart disease increased. Two widely used procedures to remove blockages in the coronary arteries are the Coronary Artery Bypass Graft (CABG), and Angioplasty.[43] The first CABG procedure was performed in New York City in 1960, but the surgery was not widely used until the second half of the 1970s. Even so, as Figure 1.11 panel A illustrates, it was initially largely used among individuals less than age 65. However, beginning in about the mid-1980s, CABG was increasingly used among the elderly patients with the gap between the numbers of procedures performed on 65-69 versus 60-64 year-olds decreasing rapidly. Indeed it appears from Panel B that the number of procedures among the non-elderly stays relatively constant out. This decline results in a greater discontinuity in the rate of CABG procedures at age 65. This is interesting

[43] Angioplasty was first developed in Zurich in 1977, and by the mid-1980s was widely adopted by leading medical centers.

in light of the fact that there have been few randomized control trails that show the superiority of the CABG procedure over less expensive alternatives such as angioplasty.[44] Although the increase in CABG rates among the elderly seen in Panel B may be due to greater refinements in the surgery leading to lower associated risk, the narrowing of the elderly and near-elderly gap is interesting. We note that in 1984, the reimbursement rate for CABG was $24,000/procedure under Medicare, while it was roughly $12,000/procedure outside of Medicare. This period was also at the cusp of the era of "selective contracting" where insurance companies could "shop" for the cheapest procedure. Medicare, possibly due to "downward sticky prices" did not enter into selective contracting. The higher relative price of CABG in Medicare may have led to an increased use of CABG among the elderly.[45] Although preliminary, these findings suggest that the decreased cost-effectiveness of Medicare may be due to the increased use of expensive medical technologies that do not lead to substantial improvements in population health. Thus, a "value-based" health insurance design must be seriously considered by Medicare. This design basically would reduce patient cost-sharing for those therapies that clinically benefit the patient.

1.7 Summary and Conclusion

The impact of health insurance on health has been a long-standing and widely researched question in health economics. However, most studies examine the impact in a relative narrow context- either the effect for a particular sub-group, or in a particular time-period. In addition, most studies examine the effect of Medicare on health, without simultaneously examining the impact of Medicare on health care utilization. This is, in some ways, a glaring omission since the only way in which health insurance can affect health is via its impact on utilization. Thus, not finding an impact of Medicare on health may either imply that medical care has no effect on health or imply that health insurance has no effect on access to care. On the other hand, finding an impact of Medicare on health, but not finding an impact on utilization-even in studies with the most compelling designs-does not generate any specific policy prescription.

In this paper, we examine the effects-on hospital utilization and health-of arguably the most dramatic expansion of health insurance coverage in the United States- the introduction of Medicare in July 1966. We bring together the most comprehensive data that has been brought to bear to answer the question. We use individual level data on health insurance, hospitalization, and

[44]The short-run cost of angioplasty is only half of that of CABG.

[45]This analysis is clearly very preliminary. We are in the process of collecting data on the relative prices of procedures to treat coronary heart disease within and outside of Medicare. However, a detailed study on the issue, although interesting, is outside the scope of the current paper.

health both before and after the introduction of Medicare. Further, we exploit the fact that the United States was the only country to have introduced a Medicare-type program by comparing country-specific differences in mortality rates between the elderly and non-elderly in the pre- and post-Medicare periods.

We find that the introduction of Medicare had a causal impact on increase hospitalization rates, and in reducing mortality rates. Indeed, cost-benefit calculations suggest that conditional on survival until age 64, birth cohorts born in 1904 lived, on average, 1.4 years longer than the cohorts born in 1896. Thus, cohorts that were exposed to Medicare from age 65 onwards (1904 cohort) lived longer than their counterparts that were not exposed to Medicare until age 70 (cohorts born in 1896). More importantly, this gain in life expectancy was achieved at a cost of roughly 200 dollars per individual discharged from a hospital.

We also find that the effects of Medicare on mortality have, in general, declined over time. By the mid-1980s, we cannot reject the hypothesis that Medicare reduces mortality rates. We find some evidence that a large part of the declining effect of mortality is due to changes in the characteristics of the marginal person becoming eligible for Medicare at age 65. As the health insurance market for the non-elderly disabled and poor has expanded over time, those most in need of health care can, arguably, access it even before turning 65.

This paper has important implications for health care reform. First, it highlights the fact that health insurance can work- if targeted to the right individuals. Second, it also suggests that for these individuals, the use of expensive, high-cost technology is not essential to improve health outcomes. Medicare was introduced at a time when many of the technologies we see in the medical care arena were unavailable. Yet, it led to an unequivocal reduction in limited activity rates, and mortality rates. The mortality rates due to heart disease also plummeted among the elderly in the post-Medicare era despite the fact that Beta Blockers, and modern revascularization procedures had not infiltrated the market. It is possible that some technologies are indeed beneficial in improving health outcomes, but much more vigorous screening procedures must be employed before they enter the market. The recent emphasis on studies on comparative effectiveness of medical technologies is a step in the right direction. It takes over 10 years for a new drug to make it to the market, and often, randomized control trials must decisively demonstrate that the drug is substantially more effective than already existing drugs. Similar demands must be made of new medical technologies.

Current proposals call for a cut in Medicare expenditures by over 500 million dollars to help defray some of the cost of expanding health insurance. While such cuts are probably warranted, they do not detract from the fact that Medicare, in its early years, led to a causal improvement in the health of the elderly population at a very reasonable cost. It is probably time to understand, in some detail, the health care market of the 1960s and early 1970s. Health insurance expansion has worked once in the past, and if we understand the reasons for the success in Medicare's early years, health care reform may be so designed so that the proposed expansion can once again lead to improved health.

Table 1.1: Discontinuity in hospital insurance rates at ages 65-and-over,
among individuals aged 45 to 80
[absolute value of t-ratio]

	Discontinuity in hospital insurance rate (per 100) by age group (deviated from fifth-order polynomial in age)					
	Unadjusted for individual characteristics			Adjusted for individual characteristics		
		Growth after FY 1963 by			*Growth* after FY 1963 by	
	FY 1963 (1a)	FY 1968 (1b)	CY 1974 (1c)	FY 1963 (2a)	FY 1968 (2b)	CY 1974 (2c)
A. All races						
Ages 65 to 69	-1.88	23.68***	18.79***	-0.14	24.79***	17.80***
	[1.20]	[19.18]	[16.10]	[0.10]	[21.57]	[16.08]
Ages 70 to 74	0.46	30.38***	24.61***	2.44	30.91***	23.90***
	[0.15]	[19.70]	[16.86]	[0.86]	[21.53]	[17.28]
Ages 75 to 80	-1.94	38.79***	34.21***	0.83	39.61***	33.05***
	[0.42]	[20.12]	[18.89]	[0.19]	[22.08]	[19.25]
Year effect	---	4.98	-3.34	---	3.11	-2.55
		[1.49]	[1.03]		[1.03]	[0.84]
Year-age trend (÷10)	---	-0.01	2.71***	---	-0.37	1.42***
		[0.01]	[4.47]		[0.65]	[2.53]
R-squared	0.042	0.058	0.097	0.212	0.207	0.217
Sample Size	39,164	78,298	73,445	39,164	78,298	73,445
B. Whites only						
Ages 65 to 69	-1.97	22.56***	17.87***	-0.57	23.68***	16.68***
	[1.22]	[17.96]	[15.07]	[0.38]	[20.00]	[14.74]
Ages 70 to 74	1.47	28.48***	23.61***	2.53	29.16***	22.61***
	[0.47]	[18.12]	[15.97]	[0.85]	[19.69]	[16.02]
Ages 75 to 80	0.04	38.23***	33.71***	1.44	38.84***	32.42***
	[0.01]	[19.54]	[18.29]	[0.32]	[21.01]	[18.41]
Sample Size	35,545	71,099	66,755	35,545	71,099	66,755
C. Blacks only						
Ages 65 to 69	-2.36	36.01***	30.66***	1.23	37.14***	30.84***
	[0.42]	[7.54]	[6.67]	[0.24]	[8.20]	[6.94]
Ages 70 to 74	-15.96	54.47***	44.40***	-5.60	53.06***	42.39***
	[1.57]	[9.28]	[7.83]	[0.57]	[9.45]	[7.58]
Ages 75 to 80	-27.36*	48.45***	46.65***	-13.66	49.84***	45.84***
	[1.82]	[6.43]	[6.71]	[0.94]	[7.02]	[6.83]
Sample Size	3,358	6,678	6,183	3,358	6,678	6,183

Notes: Samples based on forty-five to eighty year-olds in the *National Health Interview Surveys*. Outcome variable is percent with hospital insurance. FY 1963 and FY 1968 are for fiscal years (July 1 to June 30); CY 1974 is for calendar year. All analyses are weighted by NHIS annual sampling weights and adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age. Individual characteristics in columns (2a) to (2c) include indicators for gender, race, region of residence, education and income category fixed effects, unemployment status, marital status, and veteran status. Estimated standard errors are corrected for heteroskedasticity.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level

Table 1.2: Discontinuity in hospital discharge rates at ages 65-and-over, among individuals aged 45 to 80
[absolute value of t-ratio]

	Discontinuity in discharge rates from short-stay hospital (per 1,000) (deviated from fifth-order polynomial in age)					
	Unadjusted for individual characteristics			Adjusted for individual characteristics		
		Growth after 1964-66 by			*Growth* after 1964-66 by	
	1964-66 (1a)	1968-69 (1b)	1970-72 (1c)	1964-66 (2a)	1968-69 (2b)	1970-72 (2c)
A. All races						
Ages 65 to 69	3.11	27.74**	35.32***	-5.06	26.60**	35.44***
	[0.29]	[2.50]	[3.13]	[0.43]	[2.39]	[2.94]
Ages 70 to 74	-23.25	46.35***	31.46***	-30.08	45.74***	33.42***
	[1.21]	[3.69]	[2.81]	[1.38]	[3.61]	[2.93]
Ages 75 to 80	-83.97***	75.98***	83.10***	-87.19***	73.68***	82.33***
	[3.21]	[3.89]	[6.45]	[2.95]	[3.75]	[6.25]
Year effect	---	14.99	8.03	---	16.79	8.84
		[0.53]	[0.36]		[0.59]	[0.38]
Year-age trend (÷10)	---	-3.92	-0.03	---	-4.15	-0.69
		[0.72]	[0.01]		[0.75]	[0.16]
Sample Size	114,846	228,944	225,884	114,846	228,944	225,884
B. Whites only						
Ages 65 to 69	2.62	27.74**	37.10***	-4.97	26.20*	36.99***
	[0.23]	[2.00]	[2.99]	[0.41]	[1.89]	[2.79]
Ages 70 to 74	-23.66	46.27***	31.38***	-29.58	45.49***	32.40***
	[1.27]	[3.14]	[2.63]	[1.43]	[3.07]	[2.69]
Ages 75 to 80	-74.33**	68.92***	87.39***	-77.24**	66.10***	85.70***
	[2.70]	[3.35]	[6.32]	[2.58]	[3.18]	[6.08]
Year effect	---	9.27	2.87	---	11.29	2.56
		[0.28]	[0.12]		[0.34]	[0.10]
Year-age trend (÷10)	---	-2.92	0.48	---	-3.11	0.03
		[0.46]	[0.11]		[0.48]	[0.01]
Sample Size	104,688	208,204	205,323	104,688	208,204	205,323

Notes: See notes to Table 1.1. Samples based on forty-five to eighty year-olds in the *National Health Interview Surveys*. Outcome variable is number of discharges from short-stay hospital in past twelve months per 1,000 individuals. For 1964 to 1966, discharges are for fiscal years; for 1968 they are for both fiscal and calendar year; 1969 and 1970 to 1972 are for calendar years. Estimated standard errors are corrected for heteroskedasticity and clustering at the age-level over time.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level

Table 1.3: Discontinuity in activity limitation at ages 65-and-over, among individuals aged 45 to 80
[absolute value of t-ratio]

	Discontinuity in activity limitation rate (per 1,000), deviated from fifth-order polynomial in age							
	Unadjusted for individual characteristics				Adjusted for individual characteristics			
		Change after 1965-1966 by				*Change* after 1965-1966 by		
	1965-1966 (1a)	1969-1970 (1b)	1971-1972 (1c)	1973-1974 (1d)	1965-1966 (2a)	1969-1970 (2b)	1971-1972 (2c)	1973-1974 (2d)
A. All races								
Ages 65 to 69	13.64	-34.98^{***}	-32.10^{***}	-53.69^{***}	-8.89	-32.33^{***}	-33.28^{***}	-45.20^{***}
	[1.13]	[4.09]	[4.77]	[3.79]	[0.80]	[3.71]	[4.81]	[3.24]
Ages 70 to 74	15.66	-57.89^{***}	-45.24^{***}	-83.89^{***}	-5.99	-60.61^{***}	-43.71^{***}	-69.27^{***}
	[0.99]	[5.23]	[4.53]	[6.02]	[0.34]	[5.64]	[5.03]	[4.85]
Ages 75 to 80	-5.89	-51.66^{***}	-45.00^{***}	-112.15^{***}	-19.04	-60.38^{***}	-51.48^{***}	-102.56^{***}
	[0.26]	[3.96]	[3.51]	[6.46]	[0.80]	[4.67]	[4.00]	[5.59]
Year effect	---	-2.75	34.43	-34.67	---	-3.03	33.18	-2.35
		[0.14]	[1.38]	[1.13]		[0.15]	[1.35]	[0.07]
Year-age trend (÷10)	---	0.70	-3.84	14.21^{**}	---	3.97	0.60	14.01^{**}
		[0.18]	[0.87]	[2.44]		[1.03]	[0.13]	[2.27]
R-squared	0.080	0.070	0.067	0.066	0.157	0.148	0.149	0.149
Sample Size	77,994	148,629	155,797	147,154	77,994	148,629	155,797	147,154
B. Whites only								
Ages 65 to 69	9.83	-39.66^{***}	-36.95^{***}	-59.50^{***}	-9.33	-37.36^{***}	-40.10^{***}	-51.20^{***}
	[0.69]	[4.50]	[4.60]	[3.85]	[0.74]	[4.28]	[5.22]	[3.39]
Ages 70 to 74	8.50	-59.65^{***}	-50.05^{***}	-85.59^{***}	-8.21	-63.03^{***}	-49.98^{***}	-70.61^{***}
	[0.44]	[5.04]	[4.68]	[5.62]	[0.41]	[5.47]	[5.27]	[4.51]
Ages 75 to 80	-13.09	-56.23^{***}	-44.24^{***}	-115.87^{***}	-20.22	-63.58^{***}	-53.97^{***}	-108.18^{***}
	[0.48]	[4.15]	[3.24]	[6.24]	[0.73]	[4.65]	[4.02]	[5.51]
Sample Size	71,243	135,198	141,787	134,120	71,243	135,198	141,787	134,120

Notes: See notes to Table 1.1. Samples based on forty-five to eighty year-olds in the *National Health Interview Surveys*. Outcome variable is indicator for activity limitation due to chronic conditions (per 1,000 individuals). Fiscal years are used for 1965 to 1966; calendar years for every other year. Estimated standard errors are corrected for heteroskedasticity and clustering at the age-level over time.

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

Table 1.4: Discontinuity in mortality rates at ages 65-and-over, among those aged 45 to 80
[absolute value of t-ratio]

	Discontinuity in mortality rate (per 10,000) by age group and cause (deviated from fifth-order polynomial in age)					
	All races			Whites only		
	Change after 1965-1966 by			*Change* after 1965-1966 by		
	1969-1970	1971-1972	1973-1974	1969-1970	1971-1972	1973-1974
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
<u>A. All-cause</u>						
Ages 65 to 69	-13.08***	-17.02***	-20.30***	-9.90***	-11.67***	-14.09***
	[4.53]	[6.99]	[5.93]	[4.52]	[4.62]	[4.78]
Ages 70 to 74	-6.07	-8.26	-8.64*	-10.56*	-14.41***	-16.97***
	[0.77]	[1.50]	[1.92]	[1.70]	[2.70]	[6.19]
Ages 75 to 80	-17.75***	-10.60**	-24.03***	-19.67***	-15.51***	-27.77***
	[2.93]	[2.23]	[4.52]	[3.52]	[3.46]	[6.80]
<u>B. Heart disease</u>						
Ages 65 to 69	-5.93***	-8.67***	-10.27***	-5.03***	-6.74***	-8.19***
	[4.92]	[8.29]	[6.18]	[4.65]	[5.49]	[5.04]
Ages 70 to 74	-1.31	-4.29	-4.92**	-3.48	-6.94**	-8.76***
	[0.37]	[1.50]	[2.64]	[1.21]	[2.51]	[6.45]
Ages 75 to 80	-7.64***	-5.31*	-13.58***	-8.70***	-7.57***	-15.22***
	[2.79]	[1.98]	[5.11]	[3.30]	[2.85]	[7.76]
<u>C. Stroke</u>						
Ages 65 to 69	-1.89**	-2.97***	-3.51***	-1.44***	-2.03***	-2.42***
	[2.62]	[6.44]	[6.21]	[5.35]	[6.50]	[6.39]
Ages 70 to 74	-1.24	-2.63***	-3.41***	-1.74***	-3.53***	-4.49***
	[1.51]	[2.72]	[4.06]	[3.68]	[4.44]	[7.34]
Ages 75 to 80	-5.34***	-5.50***	-7.83***	-5.99***	-6.49***	-8.69***
	[3.61]	[4.58]	[5.29]	[4.21]	[5.64]	[6.09]
<u>D. Cancer</u>						
Ages 65 to 69	-2.36***	-1.71***	-2.88***	-1.61***	-0.60	-1.53**
	[3.74]	[2.92]	[3.61]	[2.76]	[0.90]	[2.01]
Ages 70 to 74	-1.20	0.39	0.92	-1.89	-0.49	-0.36
	[0.68]	[0.36]	[0.99]	[1.24]	[0.43]	[0.48]
Ages 75 to 80	0.51	3.65***	2.64***	0.52	3.13***	2.51***
	[0.51]	[3.92]	[2.90]	[0.58]	[3.37]	[3.04]

<u>Notes</u>: Data consist of mortality rates for forty-five to eighty year-olds calculated at the year-by-age level from the *National Mortality Detail Files* (see text for further details). The outcome variable is the mortality rate (per 10,000 individuals) in each calendar year. 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 clustering at the age-level over time.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level

Table 1.5: Cost-per-life year ratios (for whites)

	Birth year		
	1896	1899	1904
	(1)	(2)	(3)
Age at end of 1966	70	67	62
Ages eligible for Medicare	70+	67+	65+
Ages of added Medicare relative to 1896 cohort	---	67 to 69	65 to 69
Added discharges (implied) relative to 1896 cohort	---	146.5 (per 1,000)	184.2 (per 1,000)
Median life expectancy (for survivors to age 64)	79.28	80.26	80.73
Percent surviving to			
Age 71	80.2	81.2	81.7
Age 76	62.3	64.6	66.3
Age 81	43.7	47.2	49.0
Age 85	30.0	33.0	34.2
Cost-per-life year ($1982-84)		$187.30	$159.45
Cost-per-QALY ($1982-84)			

Notes: Additional discharges calculated from regression similar to that used in Table 2, column (1c) for whites, except using sample of 45 to 69 year-olds and allowing for different indicators for each age between 65 and 69. Use the age-specific survival rates for each birth cohort as weights when summing up the additional discharges. Average cost-per-discharge $1,250 in 1982-84 dollars. See text for more details.

Table 1.6: Hospital insurance rates for South and North regions, before and after Medicare
(estimated standard error)

	Hospital insurance rates (per 100) by region and age group									
	July 1, 1962 to June 30, 1963					*Growth* by 1974 Calendar Year				
	age 5-14 (1a)	age 35-44 (1b)	age 45-54 (1c)	age 55-64 (1d)	age 65-74 (1e)	age 5-14 (2a)	age 35-44 (2b)	age 45-54 (2c)	age 55-64 (2d)	age 65-74 (2e)
A. All races										
South	56.94	68.99	68.93	63.02	53.71	20.93***	14.52***	14.11***	17.62***	42.23***
						(0.73)	(0.89)	(0.90)	(1.09)	(1.10)
North	78.79	83.26	82.62	79.49	66.25	10.01***	7.06***	8.25***	10.23***	31.89***
						(0.45)	(0.54)	(0.54)	(0.65)	(0.73)
South − North	-21.86***	-14.28***	-13.69***	-16.47***	-12.54***	10.92***	7.46***	5.86***	7.39***	10.34***
	(0.62)	(0.76)	(0.79)	(0.97)	(1.23)	(0.86)	(1.04)	(1.05)	(1.27)	(1.32)
B. Whites only										
South	63.97	72.21	72.52	66.64	58.52	17.87***	13.83***	13.25***	16.66***	38.14***
						(0.79)	(0.92)	(0.93)	(1.14)	(1.18)
North	81.82	84.73	83.83	80.90	67.55	8.27***	6.56***	8.02***	9.60***	30.75***
						(0.45)	(0.53)	(0.54)	(0.65)	(0.73)
South − North	-17.86***	-12.51***	-11.31***	-14.26***	-9.03***	9.59***	7.28***	5.22***	7.06***	7.39***
	(0.67)	(0.80)	(0.82)	(1.03)	(1.31)	(0.91)	(1.06)	(1.07)	(1.31)	(1.39)

Notes: Estimated standard errors corrected for heteroskedasticity.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level

Comparison of difference in insurance rates for 55-64 and 65-74 year-olds in the South versus North.

1. All races
   - i) July 1962 to June 1963 = 3.93 (per 100), [t-ratio = 2.51]
   - ii) *Growth* by 1974 Calendar year = 2.95 [1.62]
2. Whites only
   - i) July 1962 to June 1963 = 5.23 (per 100), [t-ratio = 3.14]
   - ii) *Growth* by 1974 Calendar year = 0.33 [0.17]

Table 1.7: Growth in hospital discharge rates after Medicare for South and North regions (estimated standard error)

	Growth in hospital discharge rates (per 1,000) between 1964-1966 and 1970-1972				
	age 5-14 (1)	age 35-44 (2)	age 45-54 (3)	age 55-64 (4)	age 65-74 (5)
A. All races					
South	3.26	-9.31	15.08	2.55	42.95***
	(2.74)	(9.97)	(10.44)	(9.06)	(13.63)
North	2.51	4.14	9.83**	8.12	30.66***
	(2.56)	(4.27)	(4.33)	(5.42)	(9.77)
South − North	0.75	-13.45	5.25	-5.57	12.29
	(3.59)	(8.47)	(11.93)	(8.12)	(16.24)
B. Whites only					
South	0.83	-15.62*	8.34	-5.34	38.65***
	(2.71)	(9.27)	(12.61)	(9.80)	(13.67)
North	1.31	0.48	8.86	7.42	31.37***
	(2.85)	(5.13)	(5.32)	(5.21)	(10.23)
South − North	-0.48	-16.10*	-0.52	-12.76	7.28
	(3.16)	(8.30)	(13.76)	(10.02)	(13.91)

Notes: Estimated standard errors corrected for heteroskedasticity and clustering at the age-level over time.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level

Comparison of difference in discharge rates for 55-64 and 65-74 year-olds in the South versus North.

1. All races, *Growth* between 1964-66 and 1970-72 = 17.86 [0.97]
2. Whites only, *Growth* between 1964-66 and 1970-72 = 20.04 [1.15]

Table 1.8: Discontinuity in hospital insurance rate at age-65 across time, individuals aged 45-69
[absolute value of t-ratio]

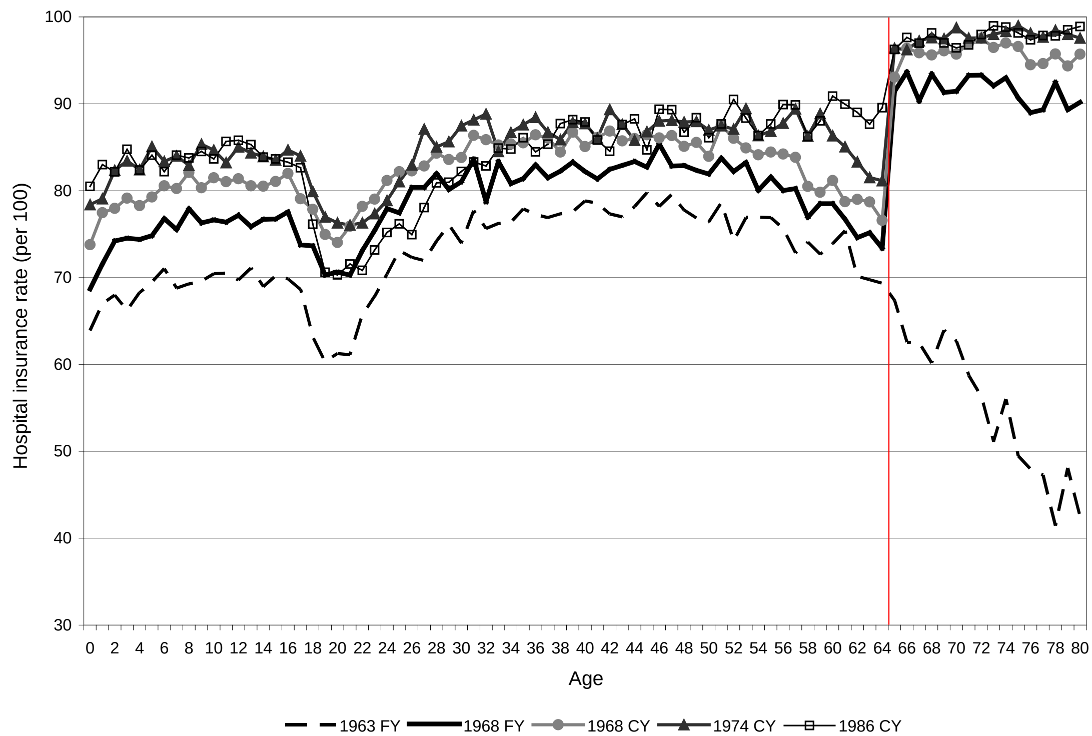
	Insurance rate at age 65 (per 100), deviated from fourth-order polynomial in age					
	1963 FY (1)	1968 CY (2)	1974 CY (3)	1978 CY (4)	1984 CY (5)	1986 CY (6)
All races	-2.98	17.84***	15.89***	10.71***	9.01***	7.27***
	[1.72]	[14.36]	[14.05]	[11.33]	[9.44]	[5.63]
{ages 60-64 rate}	{71.7}	{78.9}	{83.5}	{89.3}	{89.7}	{89.4}
Sample Size	32,875	31,459	28,613	26,502	24,514	14,193
Whites	-3.24	16.39***	15.13***	9.58***	8.06***	7.65***
	[1.81]	[13.24]	[13.50]	[10.07]	[8.62]	[5.99]
	{74.3}	{81.1}	{85.2}	{90.2}	{91.0}	{90.3}
Blacks	0.54	30.14***	20.39***	18.81***	15.60***	0.58
	[0.09]	[5.46]	[3.93]	[4.63]	[3.39]	[0.10]
	{46.3}	{57.5}	{68.1}	{81.7}	{79.3}	{81.6}
<u>Whites only</u>						
HS graduate or less	-3.46	18.42***	16.39***	9.97***	8.41***	9.08***
	[1.75]	[13.21]	[12.81]	[8.97]	[7.31]	[6.01]
	{72.6}	{79.2}	{84.0}	{89.4}	{89.9}	{89.4}
Some college or	-6.39	6.88***	9.39***	6.25***	4.54***	3.41
more	[1.61]	[2.95]	[4.24]	[3.71]	[3.31]	[1.72]
	{86.0}	{90.7}	{91.1}	{94.6}	{95.5}	{95.0}
Below 150% of	-0.73	30.09***	28.52***	15.81***	17.29***	16.08***
poverty line	[0.22]	[8.45]	[9.49]	[5.88]	[4.92]	[3.00]
	{52.8}	{58.6}	{70.3}	{80.7}	{75.9}	{72.8}
Above 150% of	-2.03	12.66***	8.02***	5.09***	5.24***	4.54***
poverty line	[0.99]	[10.56]	[7.02]	[5.38]	[6.00]	[4.15]
	{83.9}	{87.0}	{90.8}	{94.4}	{94.8}	{95.2}

Notes: See notes to Table 1.1. Samples based on forty-five to sixty-nine year-olds in *the National Health Interview Surveys*. Entries are the estimated coefficient on an indicator equal to one if the individual is aged 65 to 69 from year-specific regressions that adjust for a fourth-order polynomial in age. Estimated standard errors are corrected for heteroskedasticity. For a two-person household, 150 percent of the poverty line (median income) is $2,982 ($4,868) in 1963, $3,393 ($6,809) in 1968, $4,817 ($10,406) in 1974, $6,374 ($14,165) in 1978, and $10,707 ($24,565) in 1986. The income cutoffs used in the NHIS for 150 percent of the poverty line are below $3,000 in 1963 and 1968, below $5,000 in 1974, below $7,000 in 1978, and below $10,000 in 1986.

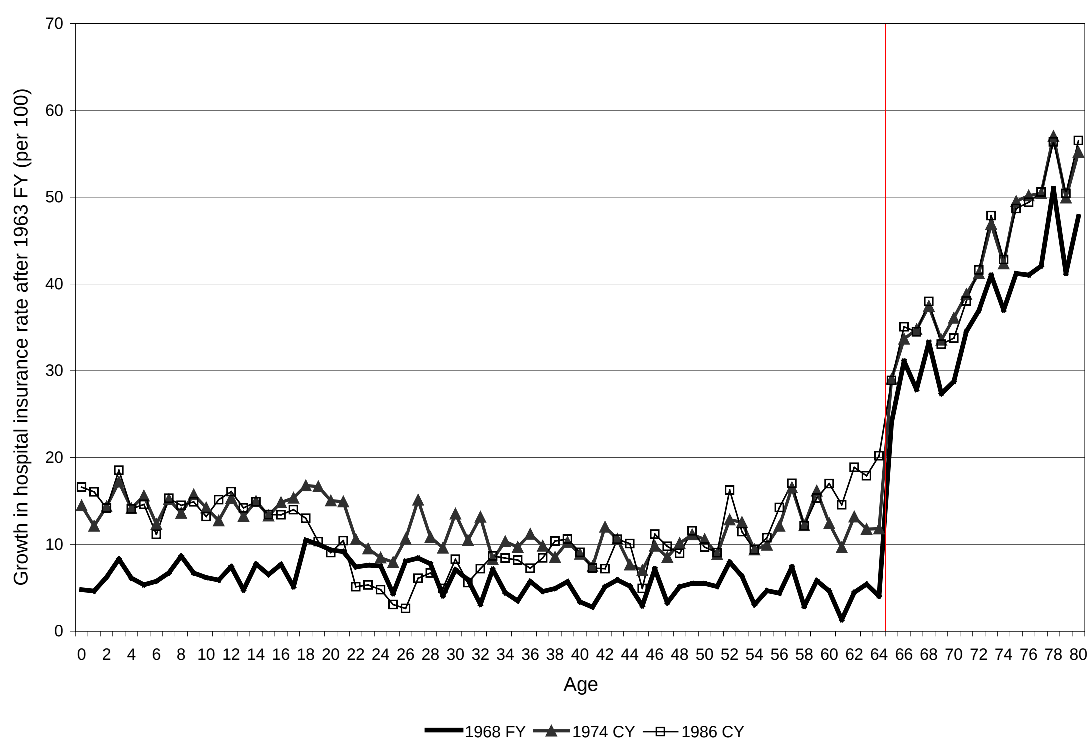
*** significant at 1-percent level, ** significant at 5-percent level

Figure 1.1: Hospital Insurance rates in the United States, by age and year

A. Percent with hospital insurance



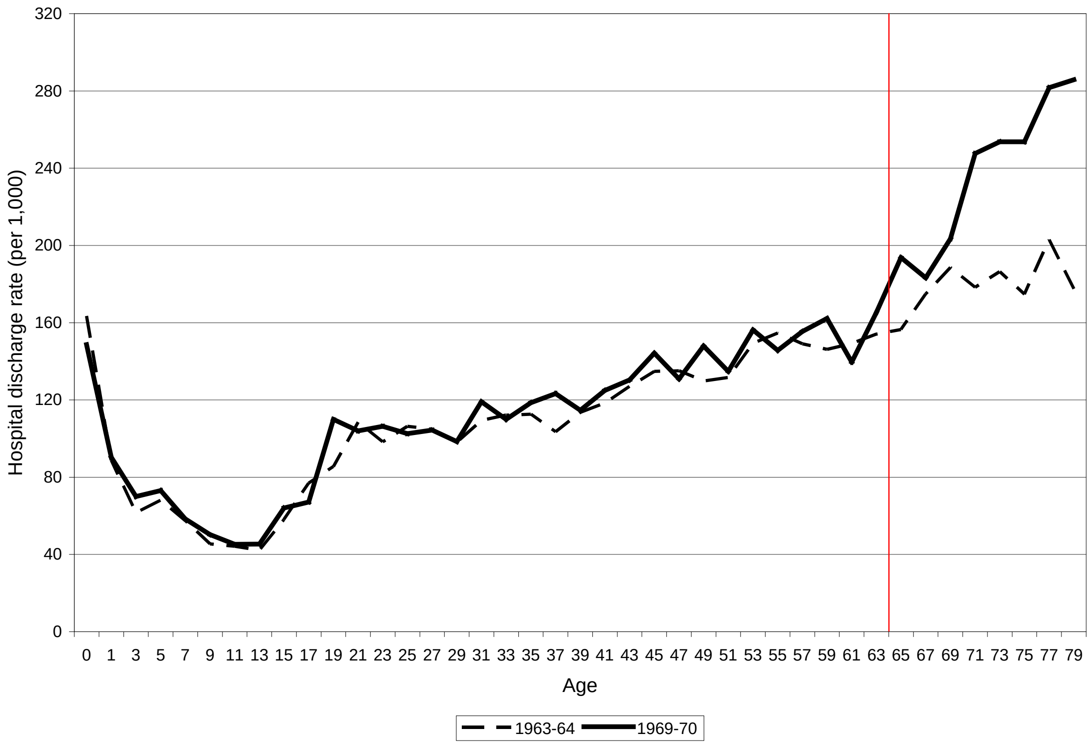
B. Growth in percent with hospital insurance after 1963 fiscal year



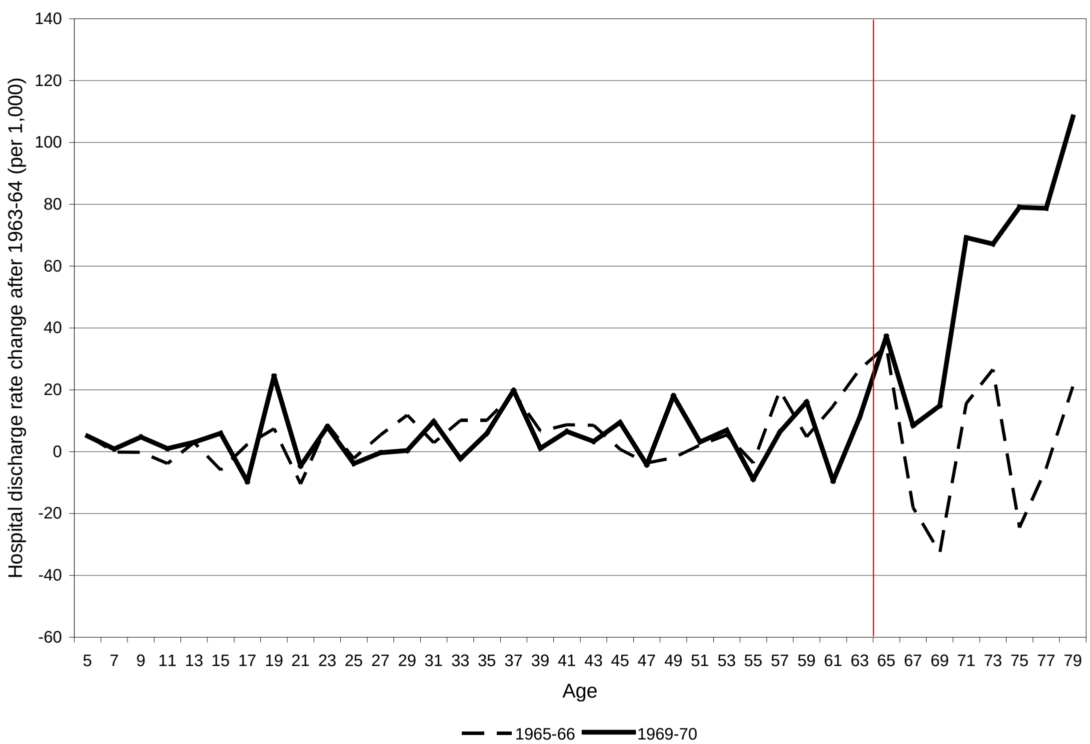
Notes: Data come from the *National Health Interview Surveys*.

Figure 1.2: Hospital Discharge rates from the *National Health Interview Survey*, all races

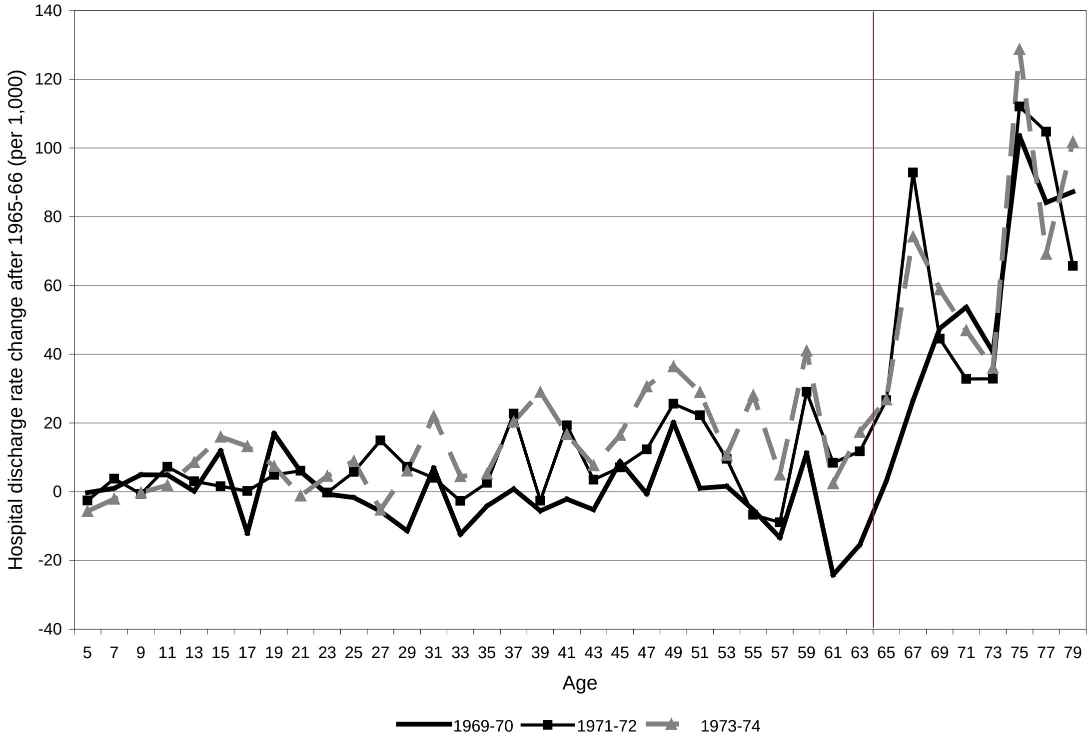
A. Hospital discharge rate per 1,000 individuals



B. Growth in hospital discharge rate after 1963 to 1964



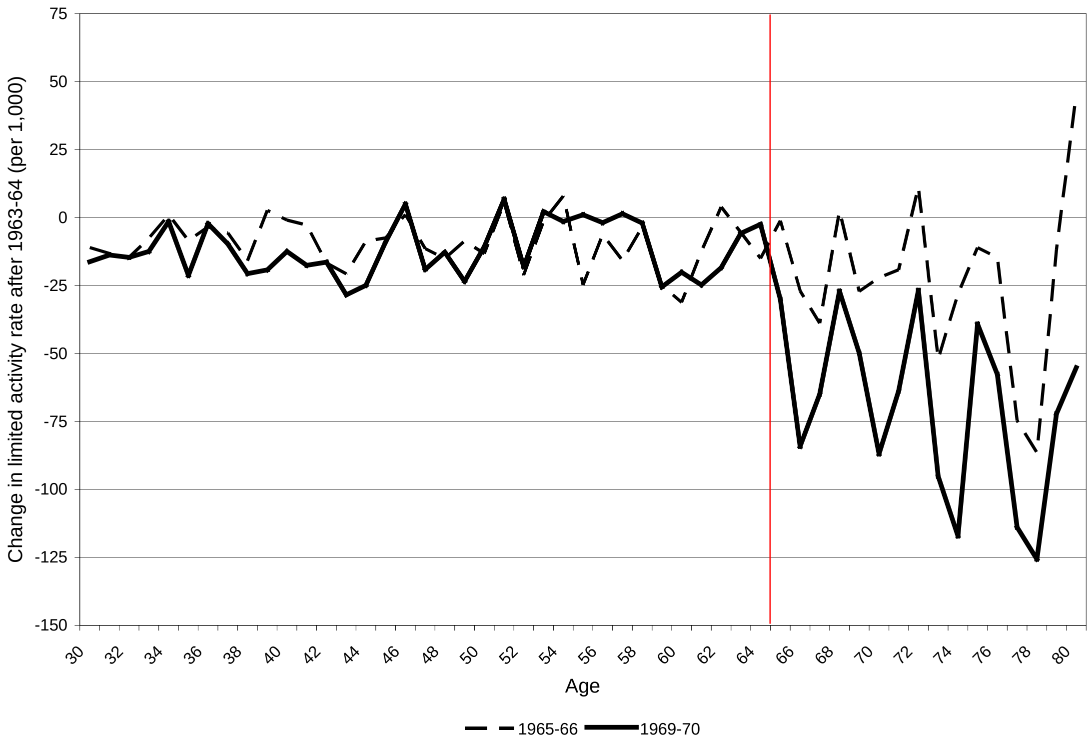
C. Growth in hospital discharge rate after 1965 to 1966



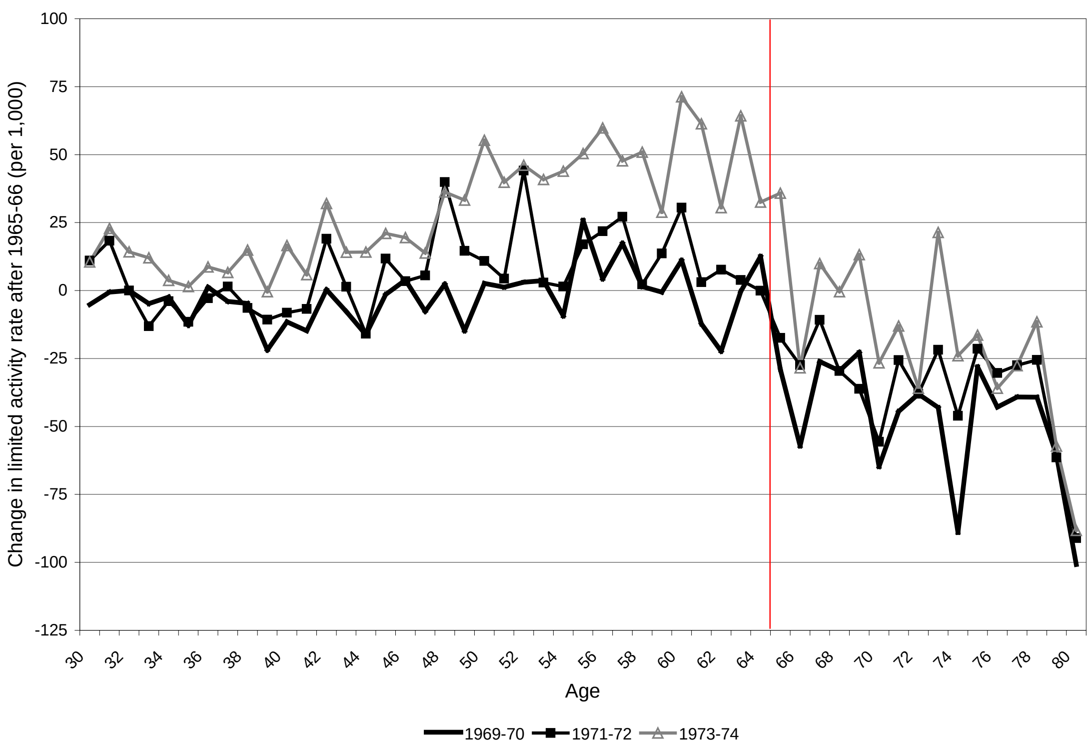
Notes: Data come from the *National Health Interview Surveys*. Discharges due to delivery of infant are excluded from the hospital discharge rate.

Figure 1.3: Limited Activity Rates (due to chronic conditions), per 1,000 individuals

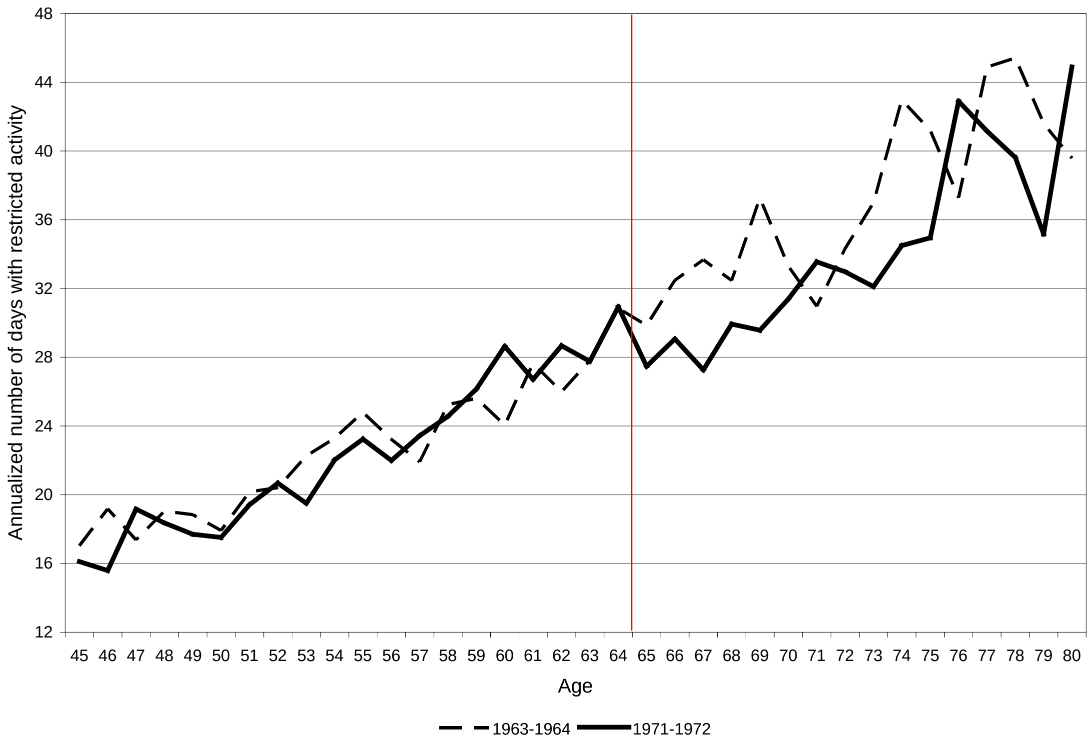
A. Change in limited activity rate relative to 1963-1964



B. Change in limited activity rate relative to 1965-1966



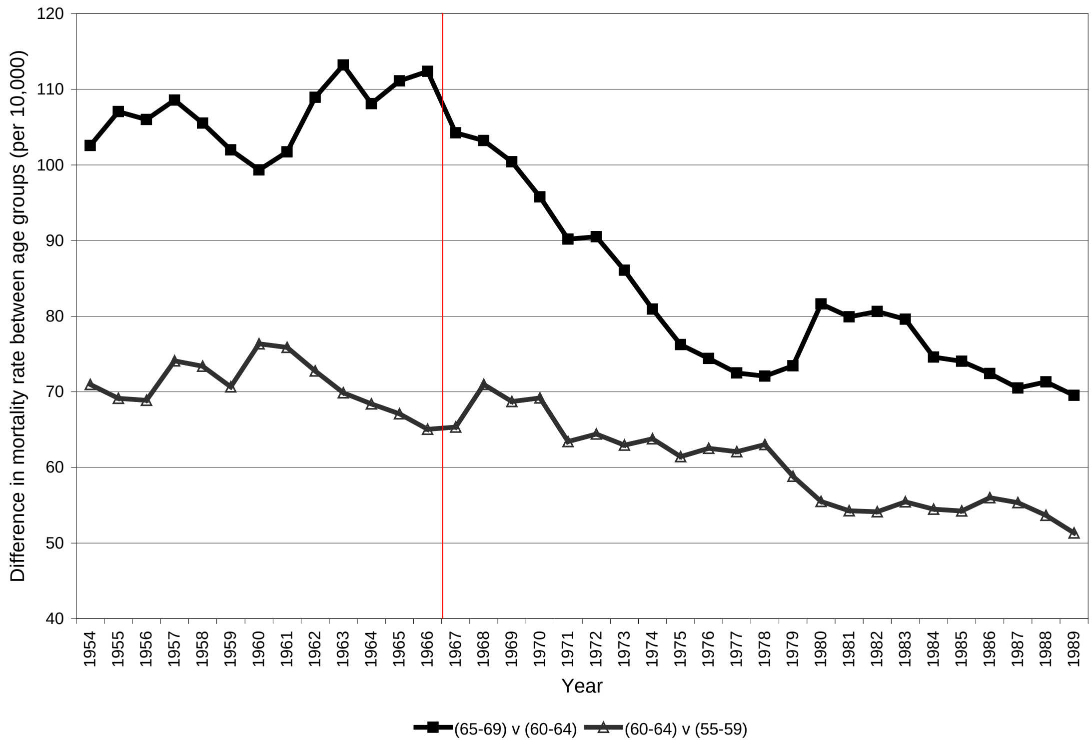
C. Annualized number of days with restricted activity



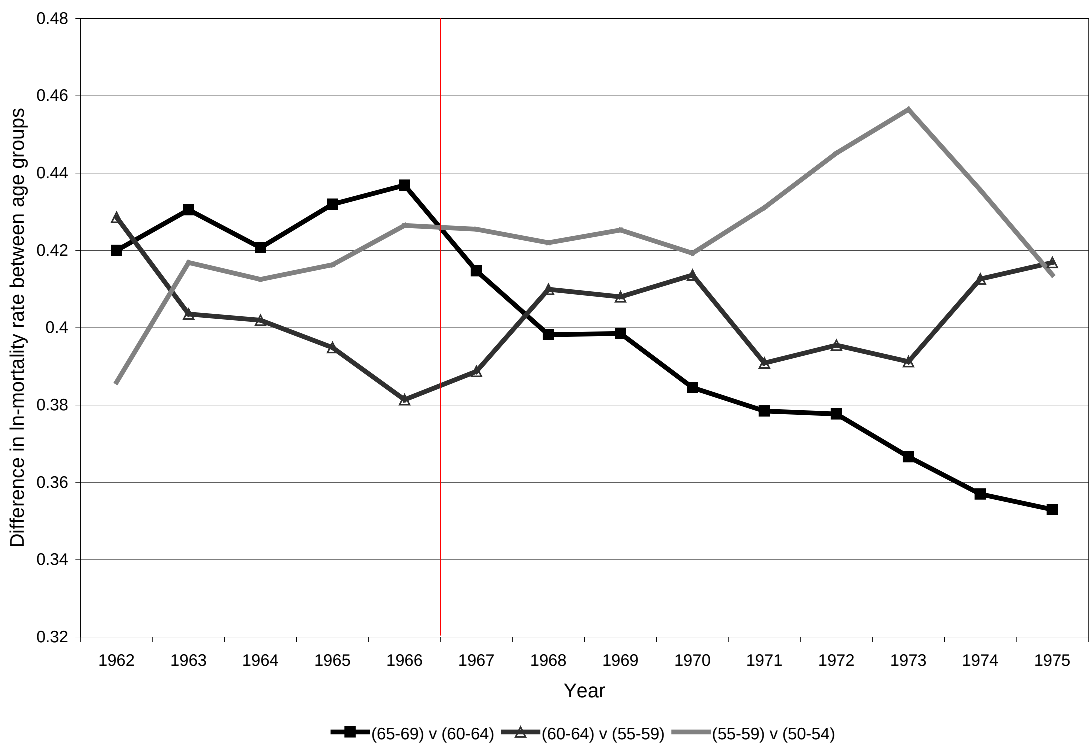
Notes: Estimated discontinuity effects [absolute value of t-ratio] for ages 45-80 deviated from 5th-order polynomial, year and year-age effects: age 65-69 = -5.46 [3.92]; age 70-74 = -4.16 [2.06]; age 75-79 = 4.35 [1.59].

Figure 1.4: Mortality rates over time in the United States, differences across age groups

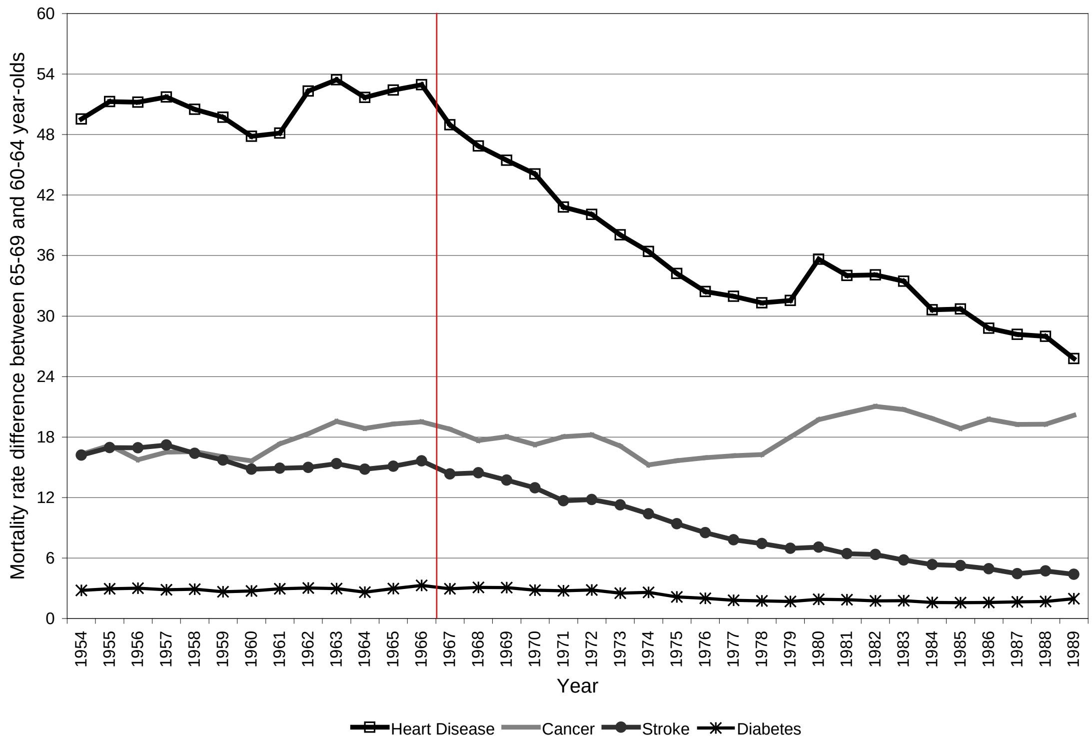
A. Age group differences in all-cause mortality rates (per 10,000 individuals)



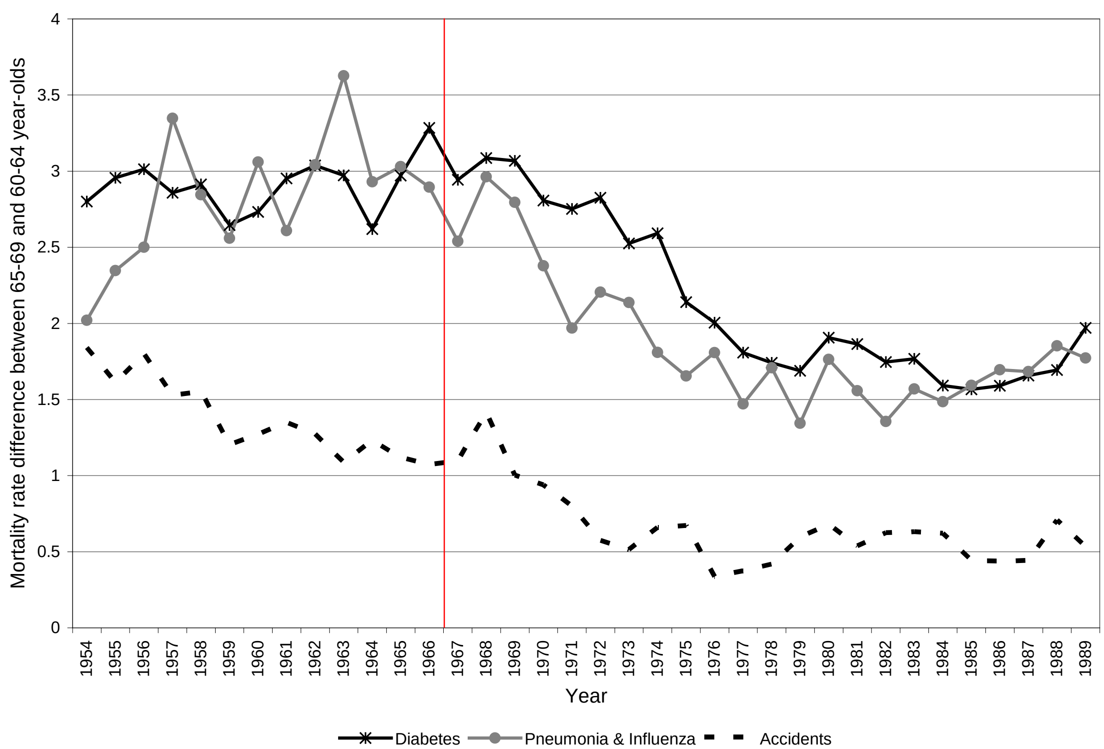
B. Age group differences in natural logarithm of all-cause mortality rate



C. Mortality rate differences between 65-69 and 60-64 year olds, by cause of death



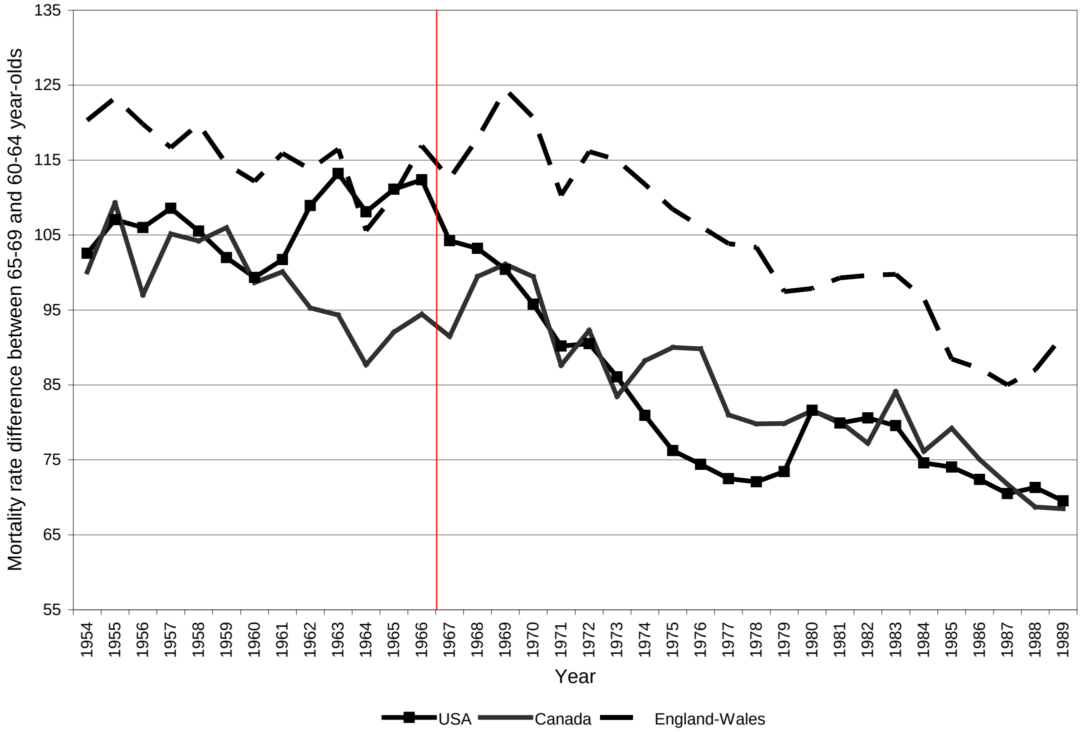
D. Mortality rate differences between 65-69 and 60-64 year olds, by cause of death



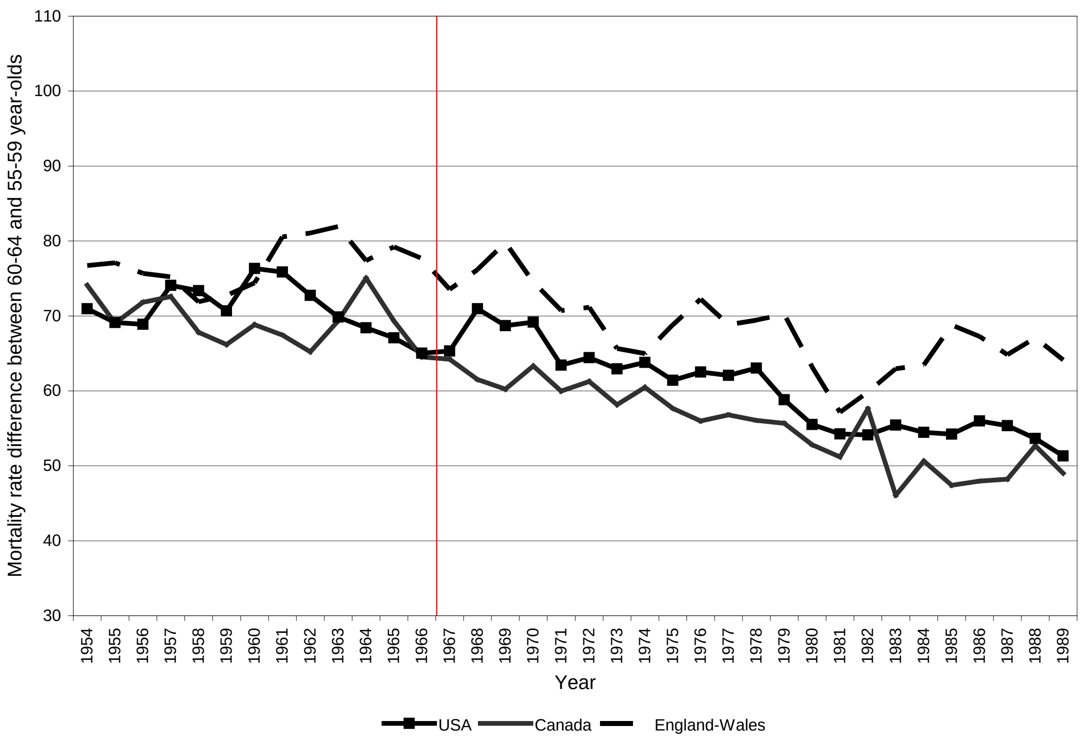
Notes: Data come from the *World Health Organization Mortality Files*. The mortality rates are for the entire United States population – that is, it includes blacks and whites, as well as other races.

Figure 1.5: Between age-group differences in all-cause mortality rates (pre 10,000), United States, Canada, and England and Wales

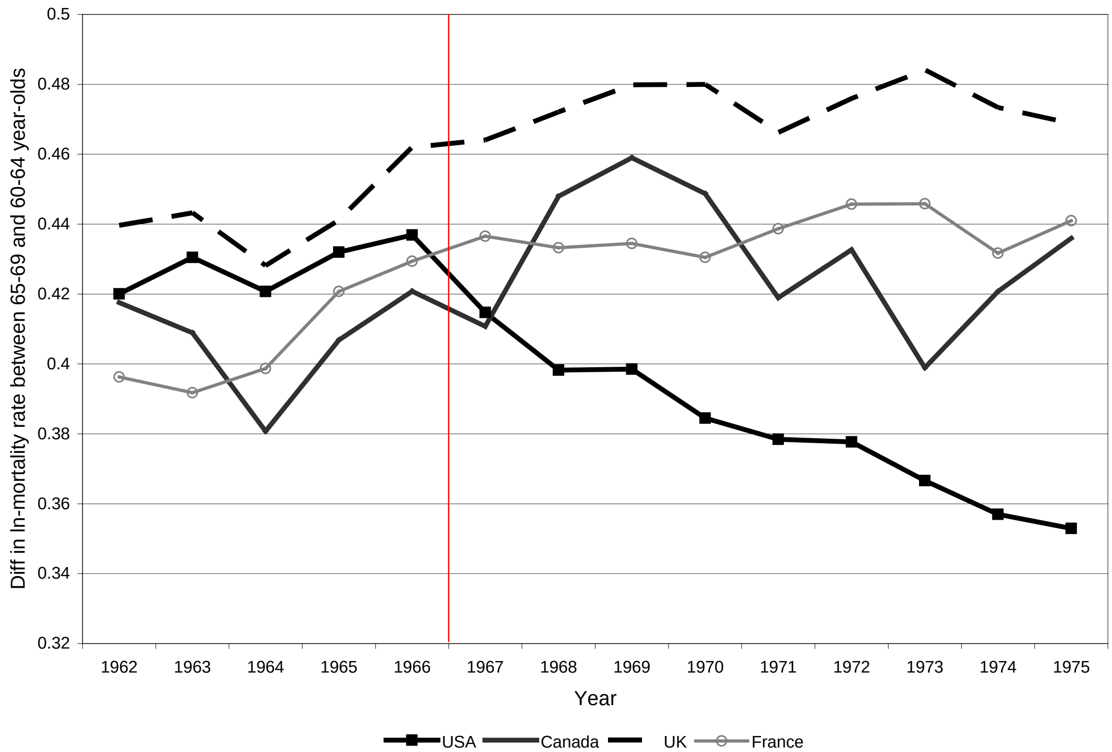
A. Difference between 65-to-69 and 60-to-64 year olds



B. Difference between 60-to-64 and 55-to-59 year olds



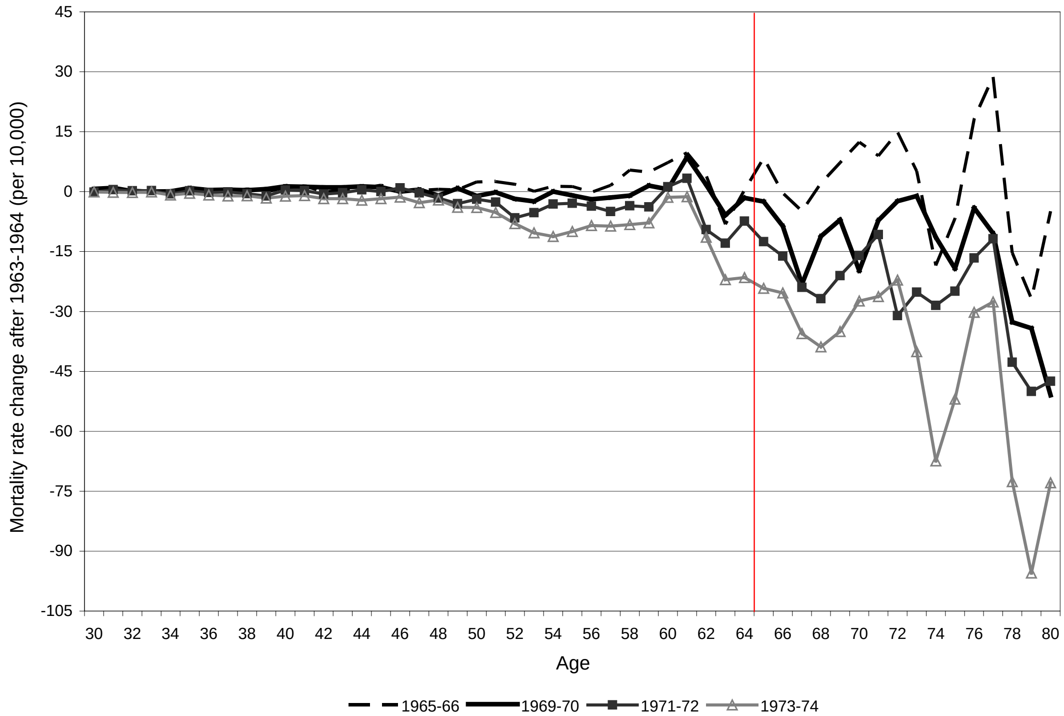
C. Difference in log-mortality between 65-to-69 and 60-to-64 year olds



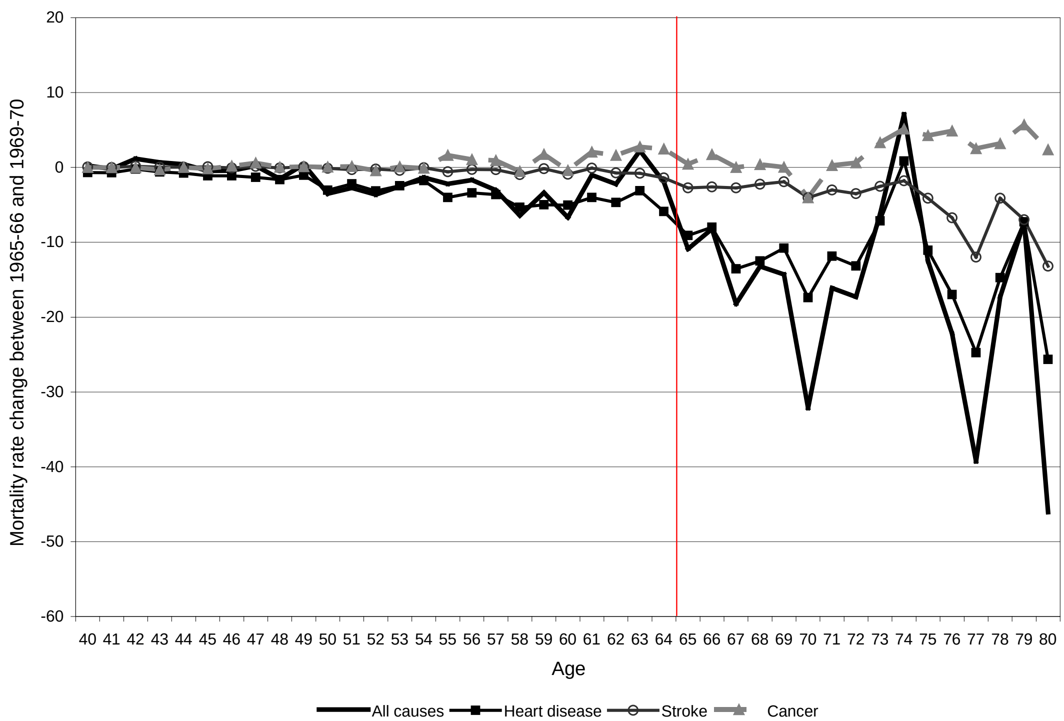
Notes: Data come from the *World Health Organization Mortality Files*.

Figure 1.6: Mortality rate changes by age and year, Whites only

A. Change in all-causes mortality rates relative to 1963-1964



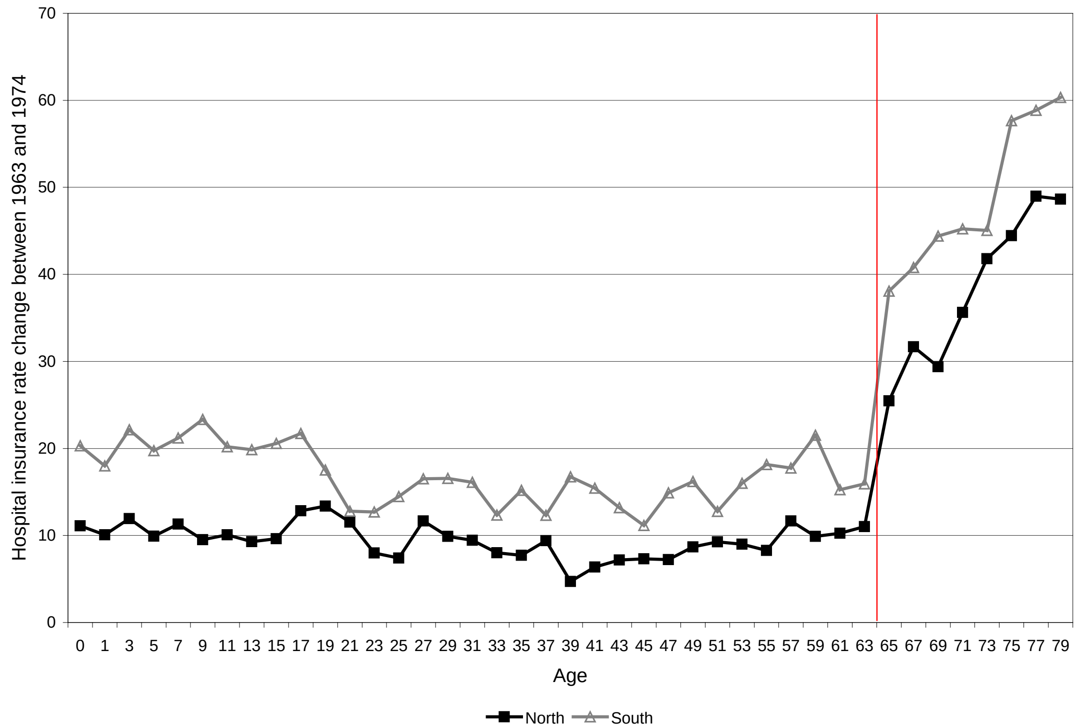
B. Change in mortality rate between 1965-1966 and 1969-1970, by cause of death



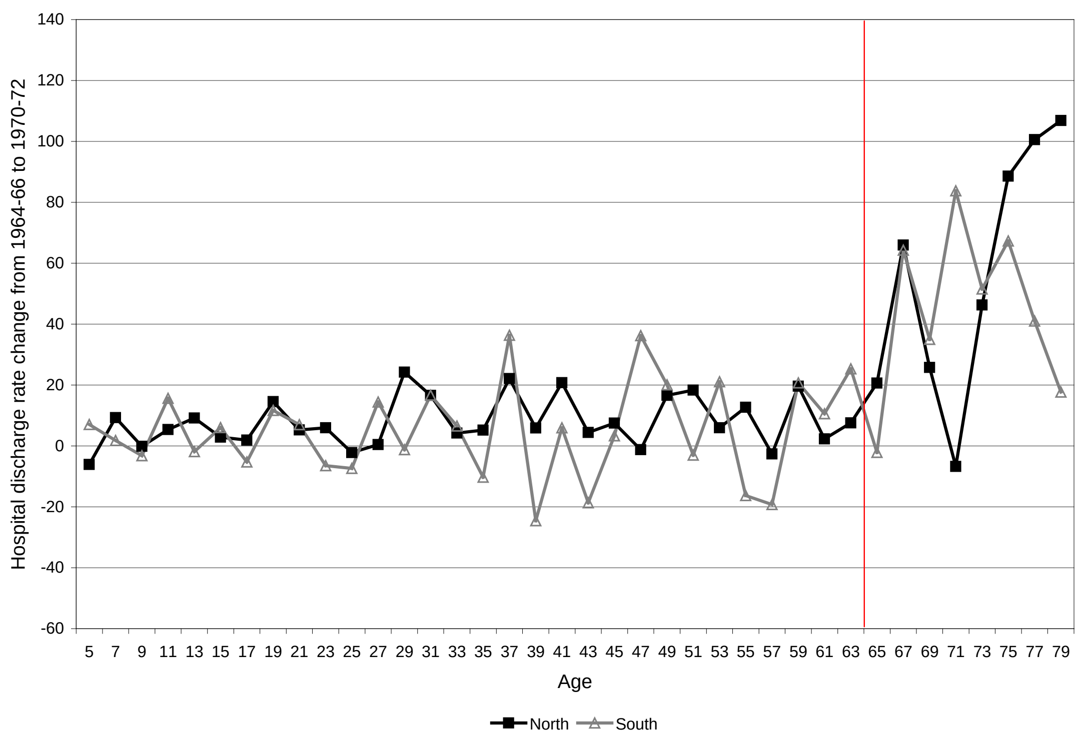
Notes: mortality counts come from the *Mortality Detail Files* and age-specific, population sizes come from the (unrevised) *Census* counts.

Figure 1.7: Growth in hospital insurance and discharge rates in the North and South

A. Growth in hospital insurance for whites between 1963 and 1974, North and South



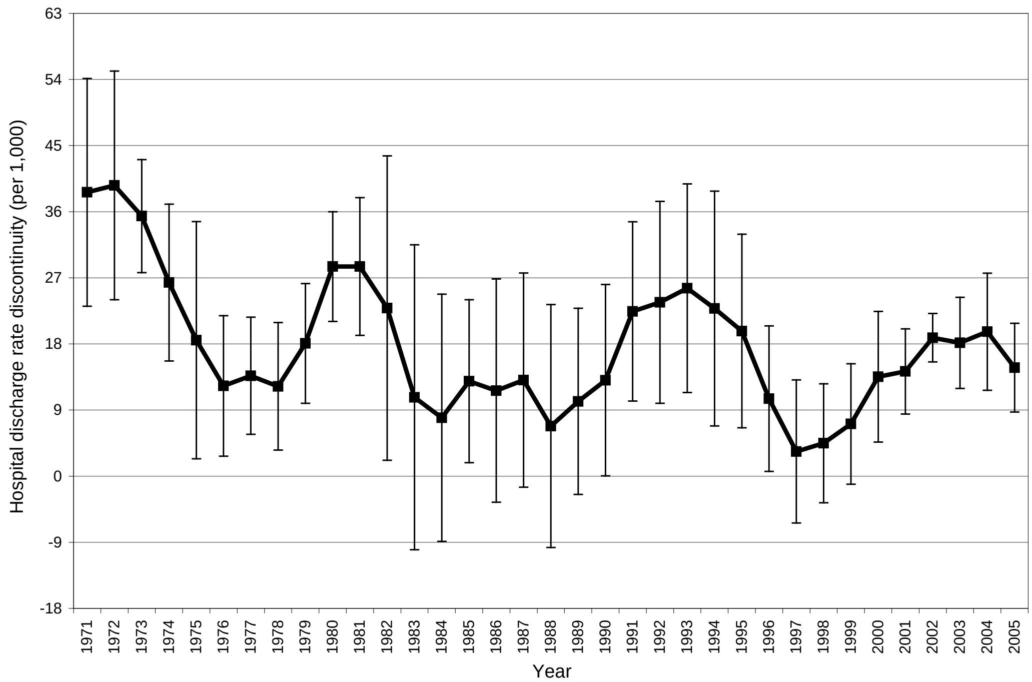
B. Growth in hospital discharge rate between 1964-1966 and 1970-1972, North and South



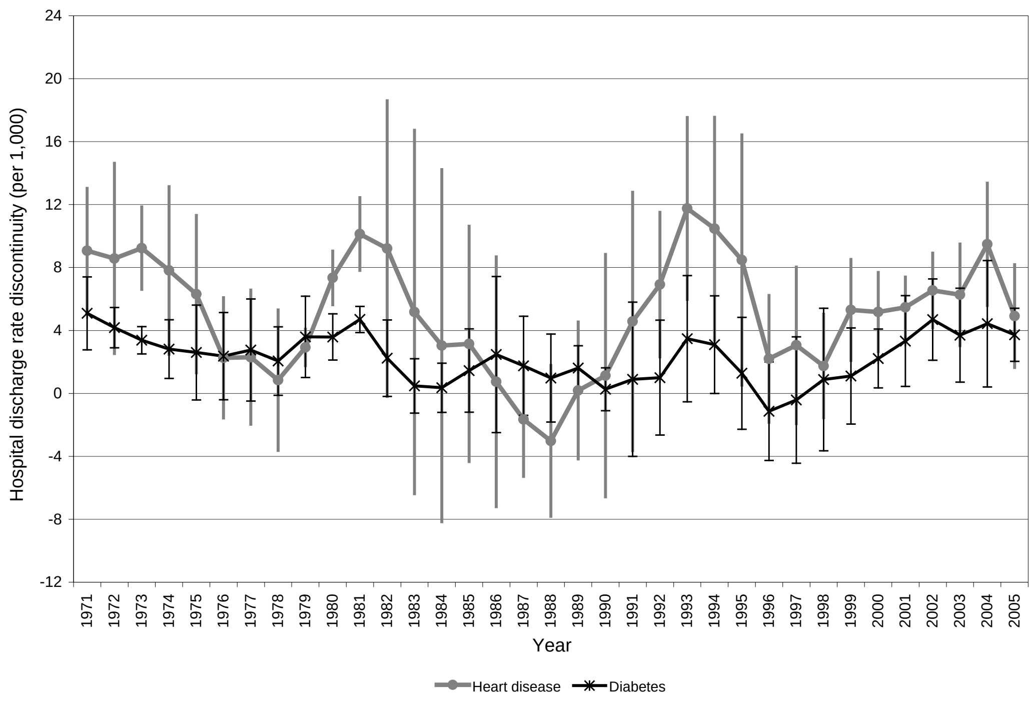
Notes: Data come from the *National Health Interview Surveys*.

Figure 1.8: Hospital discharge rate discontinuities at age-65 based on *NHDS*

A. All hospital discharges

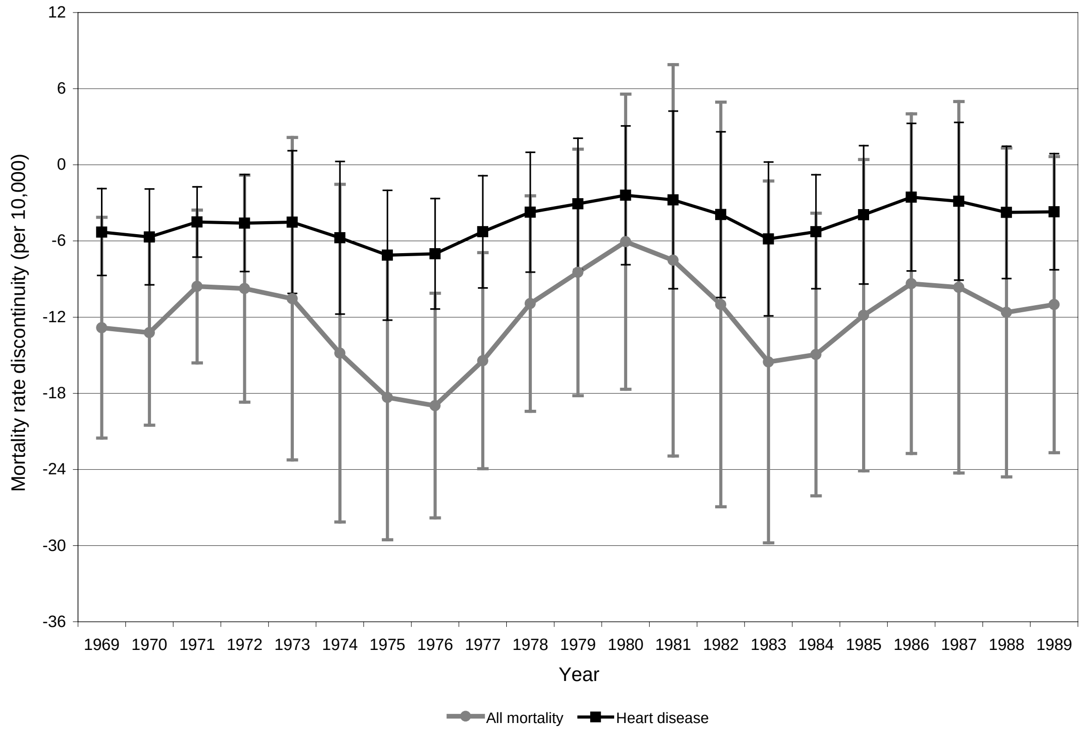


B. Heart disease and diabetes discharges



Notes: Data come from the National Hospital Discharge Surveys merged to population counts. Plots are of the estimated coefficient on an indicator for being aged 65-69 based on regressions for 50 to 69 year-olds with a quartic polynomial in age and using a moving sample of three years (with time effects). Regressions are weighted by cell population sizes and the (±) 2*s.e. bands shown have been corrected for age-level clustering and heteroskedasticity.

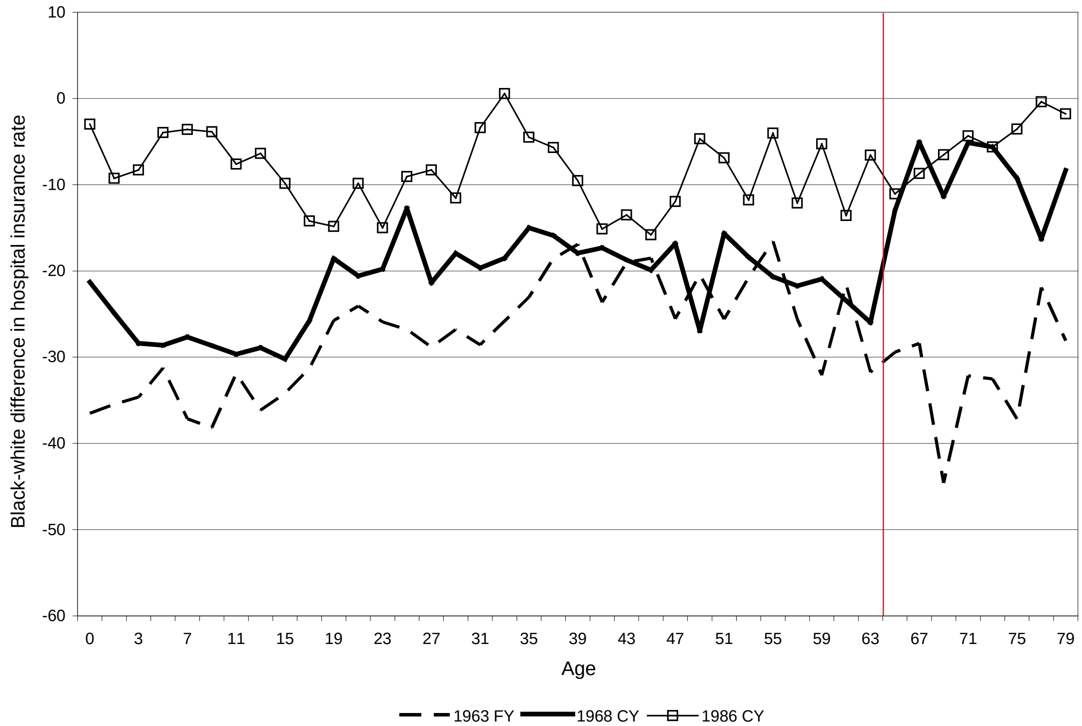
Figure 1.9: Age 65 to 69 discontinuities in change in mortality rates after 1964 to 1966



Notes: Data come from the *Mortality Detail Files* merged to population counts. The regressions that generate the plots are based on age-specific mortality rates for 50 to 69 year-olds, and estimate the change in the age-65 discontinuity relative to the baseline period of 1964 to 1966. Each regression contains six years of data (3 years baseline, 3 years after Medicare) and includes time effects, a quartic polynomial in age, and a cubic polynomial in age interacted with an indicator for post-Medicare years. Thus, each point represents a moving average of three years. Regressions are weighted by cell population sizes and the (±) 2*s.e. bands shown have been corrected for age-level clustering and heteroskedasticity.

Figure 1.10: Differentials in hospital insurance rates across time

A. Black-white difference in percent with hospital insurance



B. Insurance rate gap between persons with and without activity limitations (due to chronic conditions)

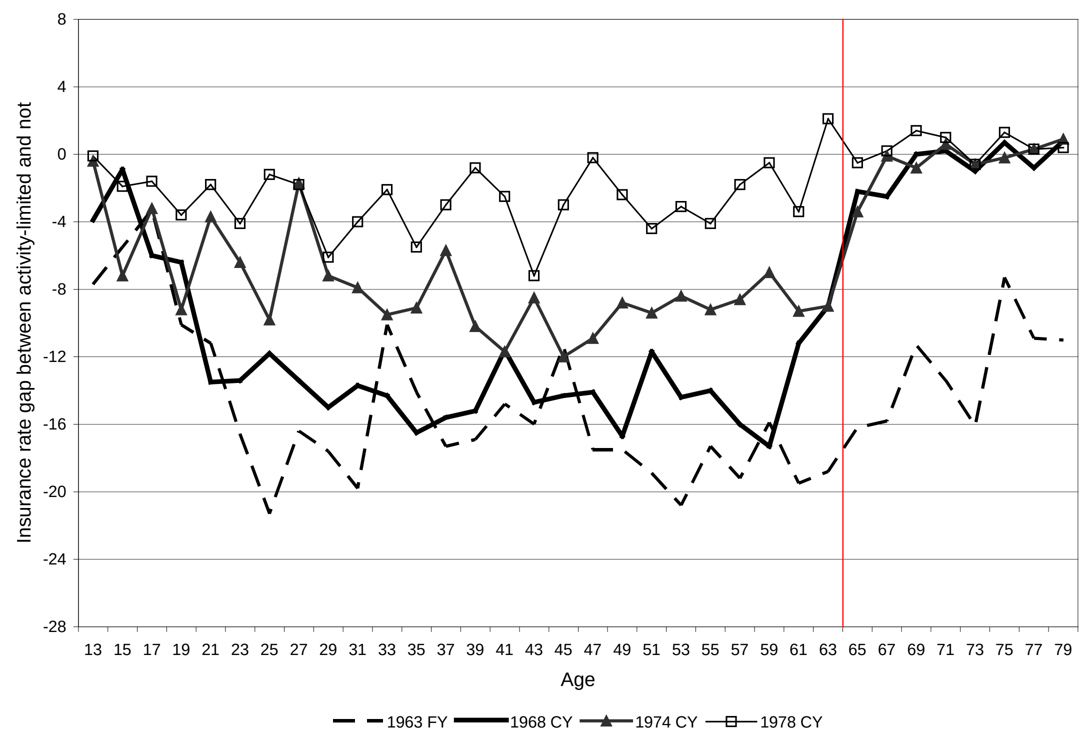
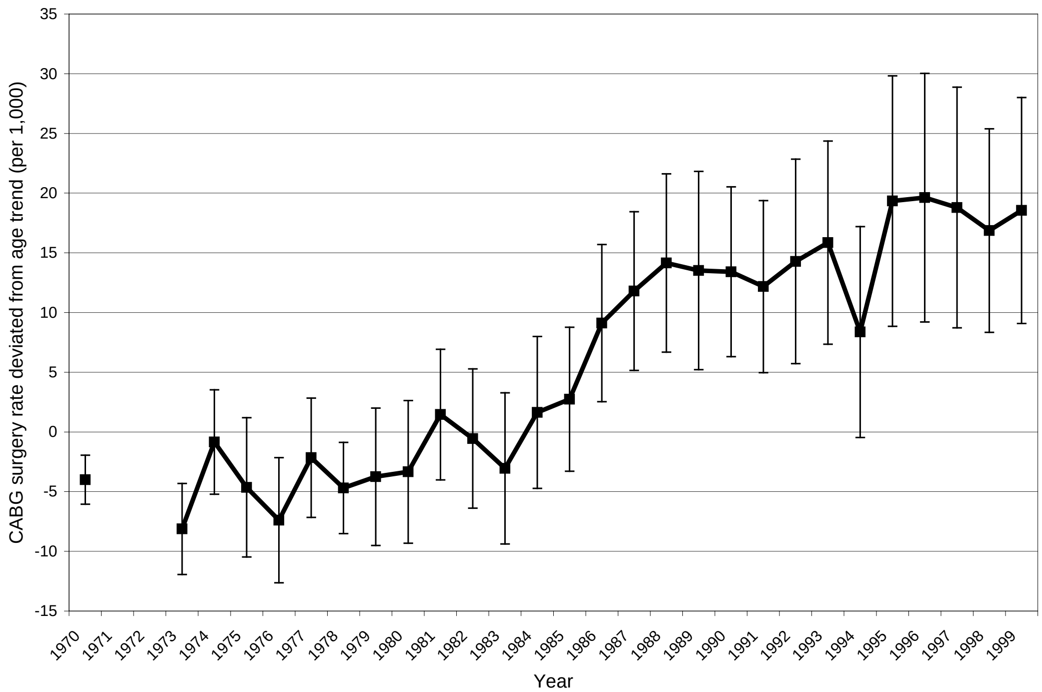
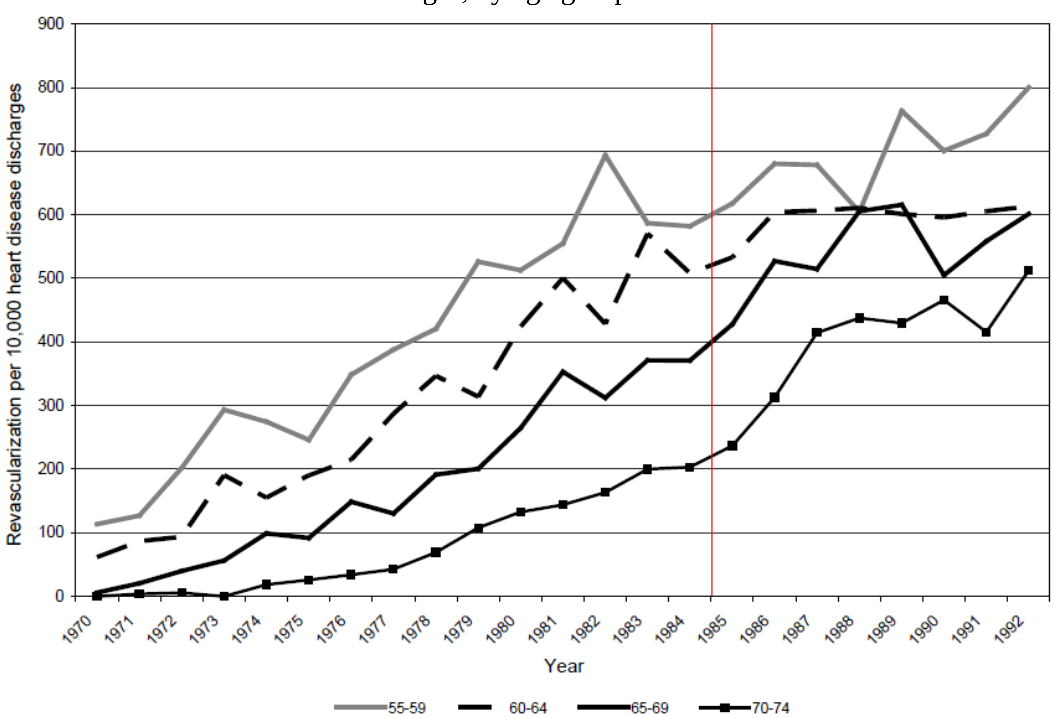


Figure 1.11: Age 65-and-over discontinuity in coronary artery bypass graft (CABG) surgery rate, among hospital discharges

A. Age 65-and-over CABG discontinuity deviated from age trend (ages 50-and-over)



B. CABG rates for heart disease discharges, by age group and over time



Notes: Data come from the *National Hospital Discharge Surveys*. Results are from year-specific, linear probability regressions that include age trends and use samples of discharges aged 50 and over. Vertical lines in Panel A represent (±) twice the standard error of the estimate, corrected for heteroskedasticity.

1.A Data Appendix

National Health Interview Survey (NHIS)

The National Health Interview Survey (NHIS) is a continuing nationwide sample survey of households conducted by National Center for Health Statistics (NCHS) to gather information on the health of the American people since July 1957. The NHIS utilizes a questionnaire which contains information on personal and socio-demographic characteristics, illnesses, injuries, chronic conditions, activity limitations, insurance coverage, hospital utilizations, personal health expenses, and other health topics. The population covered by the sample for the NHIS is the civilian, non-institutionalized population of the United States living at the time of the interview.[1] The NHIS includes about 75,000 to 100,000 individuals (35,000 to 40,000 household) in each survey year. The public-use microdata files are available starting from fiscal year 1963. From 1963 to 1967, the survey was based on fiscal year – e.g., the reference period for the fiscal year 1967 is July 1966 to June 1967. For the transition period of 1968, the interview was based both on fiscal and calendar year. From 1969 on, all interviews are based on calendar year.

Insurance Coverage

The NHIS contains information on health insurance coverage by types (i.e., hospital and surgical insurance) and payment sources (i.e., Medicare, Medicaid, other public, and private insurance). From 1959 to 1968, insurance coverage data were collected in 1959, 1963, and 1968. From 1968 to 1986, such data were generally collected every 2 years; and from 1989 on, data were collected every year. The sample sizes for the insurance questions were about 100,000 varying over the years. For 1970, 1983, 1986, 1993, and 1996, only a subset of the sample (e.g., a half-year sample) received the health insurance questions, resulting in sample sizes ranging 45,000 to 56,000.

From 1959 to 1980, NHIS asked questions about hospital and surgical insurance separately and it further provides information on Blue Cross and Blue Shield coverage among those covered by private insurance until 1980.[2] Questions about private insurance coverage were asked for persons of all ages for all years, while Medicare coverage was only asked of persons aged 65 years and over in 1968 – 1976. Direct questions about Medicare for persons of *all ages* and Medicaid were asked starting in 1978 and questions about military coverage starting in 1982.

Medicare coverage

To derive Medicare coverage for *all ages* in 1974 and 1976 including eligible persons under age 65 who had received the Social Security Disability Insurance (SSDI) as well as those diagnosed with end-stage renal disease (DSRD), we include persons who reported “received care through Social Security Medicare” as their reason for no private insurance.

Medicaid coverage

For Medicaid coverage in 1974 and 1976, we include i) persons who reported “receive care through Medicaid or welfare” as their main reason for not having private insurance; ii) persons who reported receipt of services paid by Medicaid during past year; or iii) those eligible for such payment under Aid to Families with Dependent Children (AFDC) or Supplemental Security Income (SSI).

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[1] It would be noted that data are not collected in the interview for persons who died during the reference period.

[2] In 1982, the separate associations for Blue Cross (covering hospitalizations) and Blue Shield (covering physician care) merged, making the separation between hospital and physician insurance less distinct.

Military coverage
Before 1982, we counted persons who report "receive care through military coverage or Veteran's benefits" as their main reason for no private insurance as covered under the military coverage. It includes the Civilian Health and Medical Program for Uniformed Services (CHAMPUS), the Civilian Health and Medical Program for Veterans Administration (CHAMP-VA), and Veterans Administration (VA) health care benefits.

Hospital Discharge
A hospital discharge from the short-stay hospital is the completion of any continuous period of stay of one or more nights in a hospital as an inpatient except the period of stay of a well newborn infant[3]. A hospital discharge is recorded whenever a present member of the household is reported to have been discharged from a hospital in the 12-month period prior to the interview week. The estimates in this paper are based on discharges which occurred the 6-month period prior to the interview to reduce the recall bias. From 1982 on, the reason for each hospitalization is no longer included because it is generally recognized that the National Hospital Discharge Survey (NHDS) obtains more complete and accurate hospital diagnosis information

Average Length of Stay per Discharge
The length of hospital stay is the duration in days (exclusive of the day of discharge) of a hospital discharge. The average length of stay per discharge is computed by dividing the total number of hospital days for a specific group by the total number of discharges for the same group.

Activity Limitation due to Chronic Conditions
Persons are classified into four categories according to the extent to which their activities are limited at present as a result of chronic conditions.[4]
1) Persons unable to carry on major activity. Major activity refers to ability to work, keep house, or engage in school or preschool activities.
2) Persons limited in amount or kind of major activity performed.
3) Persons not limited in major activity but otherwise limited
4) Persons not limited in activities
It is noteworthy that there was a significant change in questions on activity limitation, especially for the elderly in 1982 when the NHIS was redesigned. Before 1982, the question focused on the ability to "work" while beginning in 1982, it focuses ability to "usual activity." For example, the retirees who cannot work anymore but can do housekeeping, outside activity, etc might answer "Yes, limited" to the question before 1982, but they might answer "No, not limited" from 1982.

Number of Days with Restricted Activity
A day of restricted activity is one on which a person cuts down on his usual activities for the whole of that day because of an illness or an injury. Restricted activity covers the range from substantial reduction to complete inactivity for the entire day. Since the questionnaire asks for the respondent's experience over the 2 weeks prior to the week of interview, the estimated quarterly total is 6.5 times the average 2-week estimate produced by the 13 successive samples taken

[3] A short-stay hospital is one in which the type of service provided by the hospital is general; maternity; eye, ear, nose, and throat; children's; or osteopathic; or it may be the hospital department of an institution.
[4] A condition is considered to be chronic if (1) the condition is described by the respondent as having been first noticed more than 3 months before the week of the interview or (2) it is one of the conditions on the "Check List" provided by field interviewers.

during the that quarter (*each week* a probability sample of households is interviewed). Thus, we annualized the number of days by summing the four quarters estimates.[5]

Average costs per hospital discharge

Data were obtained from hospital bills for each person as an inpatient, doctors' bill, medicine costs, dentists' bills, and other medical expenses. The expenses included all bills paid (or to be paid) by the person himself, his family, or friends, and any part paid by insurance. It excludes health insurance premium, workmen's compensation, charitable or welfare organizations, military services, Veterans Administration, and Government.

Socio-demographic variables

The NHIS also contains respondent's socio-demographic information such as age, race (white, black, or other), region (Northeast, North Central, South, and West)[6], level of education (the highest grade of school completed), family income (the total of all income received by members of family in the 12-month period preceding the week of interview)[7], employment status, (paid work, self-employment in business, farming, or professional practice; and unpaid work), marital status (married, separated, widowed, divorced and never-married), veteran status (World War I, II, Korean War, Vietnam Era, Post-Vietnam, and Peace time veteran), and so on.

National Hospital Discharge Survey (NHDS)

The National Hospital Discharge Survey (NHDS) conducted by NCHS since 1965 is national sample of about 500 hospitals, which are non-federal, short-stay hospitals in the United States[8]. The NHDS sample contains about 75,000-100,000 individuals and about 200,000 inpatients hospital records per each survey year. It contains information on patient's age, gender, race, marital status, and geographic region of hospital's location; medical records for hospital admission, discharge, diagnosis, procedure, length of stay, and the patients' expected principal source of payment (Medicare, Medicaid, other public, or Private insurance; available in public-use data from 1979 on). All discharge diagnoses and procedures were listed on the medical record in the order of the principal, or the first-listed one, followed by the order in which all other diagnoses or procedures were entered on that record. From 1965 to 1978, a maximum of five diagnostic codes were assigned for each discharged patient, while this was increased to seven in 1979. If the medical information included surgical or nonsurgical procedures, a maximum of three codes for these procedures were assigned during the period 1965 – 1978, with the maximum increased to four in 1979. The diagnoses codes and procedure codes are based on the International Classification of Diseases (ICD) codes.

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[5] It would be noted that persons who have permanently reduced their usual activities because of a chronic condition might not report any restricted-activity days during a 2-week period. Therefore, absence of restricted-activity days does not imply normal health.

[6] The Northeast – Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania; the North Central – Michigan, Ohio, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, Nebraska, the South – Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Texas, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and the West – Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Alaska, Oregon, California, Hawaii.

[7] Income from all sources is included, e.g., wages, salaries, rents from property, pensions, and help from relatives. The income is categorized basically by increment of $1,000.

[8] Short-stay hospitals were defined in NHDS as hospitals with an average length of stay of fewer than 30 days are included. Also only hospitals with six beds or more for patient use are included.

Hospital Discharge
The number and rates of hospital discharge based on the NHDS is compatible with those based on the NHIS, except some differences in the definition of hospital utilization. Unlike the NHIS, the NHDS includes patients who die in the hospital as well as nursing homes. Also, the NHDS provides the detail ICD codes for individual hospital discharges.

Patients' Expected Principal Source of Payment
From 1968 to 1970, information on hospital charges and sources of payment was collected from a subsample of the NHDS. No information on charges or sources of payment was collected in the NHDS from 1971 to 1976. Beginning in 1977, data on patients' principal sources of payment (Medicare, Medicaid, other public, or private insurance) were collected in the NHDS sample. Estimated in this paper are based on what patients indicated as their *expected* principal source of payment.[9]

National Mortality Detail Files

The 1960-2006 National Mortality Detail Files are an annual census of deaths within the United States, derived from the standard Certificate of Death and processed by the NCHS. The data contain the universe of deaths and information on the deceased's age at death, race, gender, and underlying as well as multiple causes of deaths according to the International Classification of Diseases (ICD) codes. Deaths of foreign residents of the United States were excluded from 1970 because those were not uniquely identified before 1970. Even so, deaths of foreign residents before 1970 do not appear to affect our results because total deaths of foreign residents for aged 45 to 80 are 0.08%, on average for 1970 – 1974, relative to those of residents. For 1972, data files contain only 50 percent sample of deaths occurred in each states and thus we multiply the number of deaths for this year by 2 to get an annual number of deaths. Figures by race exclude data for New Jersey in 1962 and 1963 because this state omitted the item on race from its death certificates. In this paper, we use the following ICD codes for each cause of death:

ICD codes for Cause of Deaths

Cause of Death	1958 – 1967 (ICD-7)	1968 – 1978 (ICD-8)	1979 – 1998 (ICD-9)	1999 – (ICD-10)
Heart Disease	400-402, 410-443	390-398, 402, 404, 410-429	390-398, 402, 404, 410-429	I00-I09, I11, I13, I20-I51
Malignant Neoplasms (Cancer)*	140-205	140-209	140-208	C00-C97
Cerebrovascular Disease (stroke)**	330-334	430-438	430-434, 436-438	I60-I69
Diabetes Mellitus	260	250	250	E10-E14
Influenza and Pneumonia	480-483, 490-493	470-474, 480-486	480-487	J10-J18
Accidents	E810-E835, E800-E802, E840-E962	E810-E823, E800-E807, E825-E949	E810-E825, E800-E807, E826-949	V01-X59, Y85-Y86

* Including neoplasms of lymphatic and hematopoietic tissues
** For ICD-7, vascular lesions affecting central nervous system

[9] In some cases the expected source of payment may not have been the actual source of payment because it is recorded on time of admission.

For adequacy of cause-specific mortality discontinuity, we scrutinize the degree of comparability resulting from the introduction of the ICD-8 beginning in 1968. The comparability ratio was calculated as the ratio of the number of deaths due to a given cause in ICD-8 to those in ICD-7. A ratio of greater than one results from an increase in assignments of deaths to a cause in ICD-8 as compared with ICD-7. Based on the same deaths occurring in 1966 by both the ICD-7 and ICD-8, the published comparability ratios for Heart Disease, Cancer, Stroke, Diabetes Mellitus, and Influenza & Pneumonia are 1.0045, 1.0017, 0.9905, 0.9971, and 1.0440, respectively (DHEW 1975). This ratio implies that the change from ICD-7 to ICD-8 could result in an *underestimate* the decrease in deaths due to Heart Disease between 1965-66 and 1969-70.

World Health Organization (WHO) Mortality Database

The World Health Organization (WHO) Mortality data are official national statistics. The competent authorities of the countries have transmitted data to the World Health Organization. The WHO database comprises deaths registered in national vital registration systems with underlying cause of death as coded by the relevant national authority. The database contains population, live births, and number of deaths by country, year, sex, *age group* and cause of death as far back from 1950 (i.e., for U.S.). Data are included only for countries reporting data properly coded according to the International Classification of Diseases (ICD). The database is available at http://www.who.int/healthinfo/morttables/en/index.html

Population

To estimate mortality rates by single age, we use postcensal population estimates for the 1960s published in Current Population Reports Series P-20 and intercensal estimates for all other years from the Bureau of the Census in Current Population Report Series P-25. The most recent population information is available on the Census Bureau web site at www.census.gov. All populations are as of July 1st for each year.

Postcensal population estimates

For example, the postcensal population estimates for 1960s were produced by updating the population enumerated in the 1960 census by the estimates of the components of population change from April 1, 1960 to April 1, 1970 (+ births – death + net international migration).

Intercensal population estimates

Once the Bureau of the Census conducted the Census 1970, the postcensal population estimates are revised (called intercensal estimates) using difference between the Census counts and the postcensal estimate for 1970 – “the error of closure”. Then the intercensal population estimates for 1960s are derived from the postcensal estimates by distributing “the error of closure” over the decade by month. However, the method used for the 1960s for distributing the error of closure is different from that was used for the 1970s. For the 1960s, *the inflation-deflation method* which is a variant of the cohort-component method was used while *the straight-line interpolation procedure* was done for the 1970s (U.S. Bureau of Census 1974, 1982). In addition, the intercensal population estimates were adjusted by Medicare data (U.S. Bureau of Census 1970).

Chapter 2

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

2.1 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 , Center for Medicare and Medicaid Services). 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 reimburse-

[1]Under 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.

[2]Indeed, 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.

ment 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.

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

[3] Shleifer (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).

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.

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.

[4]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). 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.

[5]It 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; Hlatky et al., 1997; Hannan et al., 1999).

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 2.2 provides a brief background on the PPS and cardiac procedures. Section 2.3 lays out a simple model for hospital responses to PPS. Section 2.4 outlines an empirical strategy. Section 2.5 describes data. Section 2.6 presents empirical results, and Section 2.7 concludes.

2.2 Background

2.2.1 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, 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

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

[7]Also, 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).

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

[9]Four 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.

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 by[12]

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

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 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

[10]DRGs 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.

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

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

[13]The 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.

[14]Indeed, 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).

[15]Standardization 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.

[16]For 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).

equal to the national average cost of each DRG:

$$R_{d,h} = \left(\frac{\overline{AC}_d}{\overline{AC}}\right)\overline{AC} \times (1 + Adjust_h) \approx \overline{AC}_d. \tag{2.1}$$

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.

2.2.2 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 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

[17]As 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.

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

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 machine[20], 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 2.1). Second, for moderately-ill patients, the two procedures are medically substitutable (Hillis and Rutherford, 1994; Bypass Angioplasty Revascularization Investigation , BARI; 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]

2.3 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 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.

[19]Recently, 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.

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

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

[22]Using 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.

2.3.1 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, $s \in [0, \overline{s}]$, 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 $\overline{s}$. 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 functions[24]

$$b^0 = \alpha^0, \quad b^L(s) = \alpha^L + \beta^L s, \quad b^H(s) = \alpha^H + \beta^H s, \tag{2.2}$$

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 $\alpha^0 < \alpha^L + \beta^L \overline{s} < \alpha^H + \beta^H \overline{s}$ (Figure 2.14 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.

2.3.2 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]

$$U = U\big(\pi, B\big). \tag{2.3}$$

[23] It 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; Hlatky et al., 1997; Hannan et al., 1999).

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

[25] I 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).

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 $q^H(s^H) = \overline{s} - s^H$, $q^L(s^H, s^L) = s^H - s^L$, and $q^0(s^L) = s^L = \overline{s} - q^H - q^L$.[27] Given benchmark values of s^H and s^L, the patients' benefit is given by[28]

$$B(s^H, s^L) = \alpha^H \overline{s} + \frac{1}{2}\beta^H \overline{s}^2 + (\alpha^L - \alpha^H)s^H - \frac{1}{2}(\beta^H - \beta^L)(s^H)^2 + (\alpha^0 - \alpha^L)s^L - \frac{1}{2}\beta^L (s^L)^2. \quad (2.4)$$

2.3.3 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.

2.3.4 Use of Cardiac Procedures Prior to PPS

The hospital's optimization problem prior to PPS is

$$\max_{s^H, s^L} U\left[\pi\Big(q^H(s^H), q^L(s^H, s^L), q^0(s^L)\Big), B\Big(s^H, s^L\Big)\right], \quad (2.5)$$

[26] In other words, the hospital chooses benchmark values of (s^L, s^H) such that:
(1) $b^H(s) > b^L(s) > b^0(s), \forall s \in (s^H, \overline{s}]$; (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 $b^L(s^L) = b^0(s^L)$.

[27] Note 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 Figure 2.14).

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

subject to $\overline{s} \geq s^H > s^H \geq 0$. 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 (2.4), 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

$$q_{pre}^{H^*} = \overline{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L}, \quad q_{pre}^{L^*} = \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} - \frac{\alpha^0 - \alpha^L}{\beta^L}, \quad \text{and} \quad q_{pre}^{0^*} = \frac{\alpha^0 - \alpha^L}{\beta^L}. \tag{2.6}$$

2.3.5 Use of Cardiac Procedures Under PPSss

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 (2.5), the hospital chooses s^H and s^L to satisfy two first-order conditions that can be simplified to be

$$B_{s^H} - \left(\pi_{q^H} - \pi_{q^L}\right) \frac{U_\pi}{U_B} = 0 \tag{2.7}$$

$$B_{s^L} - \left(\pi_{q^L} - \pi_{q^0}\right) \frac{U_\pi}{U_B} = 0 \tag{2.8}$$

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 (2.7), the number of patients who receive CABG is given by

$$q_{post}^{H^*} = \overline{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L} + \left\{ \left(\overline{AC}^H - MC^H(q^H) \right) - \left(\overline{AC}^L - MC^L(q^L) \right) \right\} \frac{U_\pi}{U_B} \frac{1}{(\beta^H - \beta^L)} \tag{2.9}$$

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 (2.9)), then the hospital has an incentive to increase CABG use more than its pre-PPS level ($\overline{s} - \frac{\alpha^L - \alpha^H}{\beta^H - \beta^L}$). 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

$$TC^H(q^H) = c^H \cdot q^H + F \quad \text{and} \quad TC^L(q^L) = c^L \cdot q^L, \tag{2.10}$$

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] Figure 2.15 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

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

[30] Of 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.

[31] Note 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.

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 (2.8), the angioplasty use is given by

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

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).

2.4 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

$$Y_{it} = \alpha + f(age_{it}; \lambda) + \gamma \cdot \mathbf{1}\left\{age_{it} \geq 65\right\} + \varepsilon_{it}, \tag{2.11}$$

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

$$Y_{it} = \alpha + f(age_{it}; \lambda) + \gamma \cdot \mathbf{1}\left\{age_{it} \geq 65\right\} + \delta \cdot Post_t + f(age_{it}; \lambda) \cdot Post_t + \theta \cdot \mathbf{1}\left\{age_{it} \geq 65\right\} \cdot Post_t + \varepsilon_{it} \tag{2.12}$$

where δ allows for the time effects, $f(age_{it}; \lambda) \cdot Post_t$ 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

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

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 (2.12).[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-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

$$\begin{aligned} Y_{it} &= \alpha + \gamma_1 \cdot T_{it}^{65} + \gamma_1 \cdot T_{it}^{70} + \gamma_1 \cdot T_{it}^{75} \\ &+ \lambda_1 age_{it} + \lambda_2 age_{it}^2 + \lambda_3 age_{it}^3 + \lambda_4 age_{it}^4 + \lambda_5 age_{it}^5 + \delta \cdot Post_t \\ &+ \theta_1 \cdot T_{it}^{65} \cdot Post_t + \theta_2 \cdot T_{it}^{70} \cdot Post_t + \theta_3 \cdot T_{it}^{75} \cdot Post_t + \kappa \cdot age_{it} \cdot Post_t + \varepsilon_{it}, \end{aligned} \tag{2.13}$$

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.

2.5 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]

2.5.1 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

[32] I 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.

[33] See the Data Appendix for details.

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]

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.

2.5.2 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.

2.5.3 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.

[34]Medicare 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.

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.

2.5.4 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]

2.6 Empirical Results

2.6.1 Profit Margins for the Use of CABG and Angioplasty

Panel A of Figure 2.1 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.

[35] To 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).

[36] Indeed, 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.

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)

$$AC_{ht} = \alpha + \theta \cdot \ln(q_{ht}) + X_h'\beta + \mu_t + \varepsilon_{ht}, \tag{2.14}$$

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 (2.14), 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 2.1 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, 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 2.1 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.

2.6.2 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.

[37]Included 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.

[38]PPS 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.

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

Figure 2.2 plots the age profiles of changes in CABG and angioplasty discharge rates.[40] The data come from the NHDS. Panel A of Figure 2.2 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 (2.13) 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 2.2 presents the results. The data come from the NHDS as for Figure 2.2. Panel A shows the impact of PPS on the use of CABG. Column (1) ensures that before PPS there is no change 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 2.2. 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 2.1), the estimate of 18 per 10,000 persons (the first row of Column (2) of Table 2.2) shows that the PPS induced 50 percent increase in CABG use within its four years of implementation. Column (3) and (4) of Table 2.2 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

[40] PPS-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.

[41] Figure 2.16 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 Figure 2.16 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 2.2.

69. The RD estimate for aged 70 to 74 does not support this delaying effect. Panel B of Table 2.2 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.

2.6.3 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; 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 2.3, 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 2.3 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.

[42] Panel B of Figure 2.16 ensures no change in angioplasty use.

[43] The marginal cost of CABG is shown to decrease in its use (Panel B of Figure 2.1).

[44] Unfortunately, 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.

[45] The 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).

[46] Waldhausen 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.

To ensure the results of graphical analysis, I estimate the pre-post RD model with the same specification used in the previous analysis. Table 2.3 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.

2.6.4 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 the number of grafts used in CABG and the indication of comorbidity[47] 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 2.4 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

[47] I 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).

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 2.4 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 2.5 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 2.4 confirm these patterns. Panel A of Table 2.4, corresponding to Panel A in Figure 2.5, ensures that there is no changes in CABG use at age-65 prior to PPS across patients' severity levels. Panel B of Table 2.4 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) 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 2.2), 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).

[48]To 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. Figure 2.17 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.

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.

2.6.5 Effects of Increased CABG Use on Health Outcomes

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 2.6 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 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

[49]Indeed, I use the in-hospital CABG mortality rate from the NHDS data. Figure 2.18 suggests no changes in the in-hospital CABG mortality at age-65 before and after the PPS reform.

[50]Another 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.

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

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 2.5 shows the estimates of discontinuity in IHD mortality rate at age-65. First, the year effects confirm overall time trends shown in Figure 2.6. 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 2.6. During all the post-PPS periods, the IHD mortality rate does not change at the age-65 threshold. Overall, the RD estimates in Table 2.5 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 2.7 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 2.6 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) 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.

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

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

[53] I 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 Table 2.13).

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 2.8 (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):

$$h_i^* = \alpha + \gamma d_i + X_i'\beta + \varepsilon_i. \tag{2.15}$$

I assume that self-reported health status represent h_i^* and ε_i follows the logistic distribution. Then I estimate equation (2.15) by ordered logit regression.[55]

I report the results of this estimation, along with imputed QALY weights in Table 2.7. 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 row of Column (4)).[57] For the cost-per-QALY estimation, I use the imputed QALY wights from the interaction term of IHD dummy with indicator for ages of 65 to 69.

Table 2.8 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

[54]The results are shown graphically in Figure 2.19. It plots the survival curve for IHD. Similar to Figure 2.6, 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.

[55]I 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.

[56]These two values are indicated as Cut 4 and Cut 1 under the "Cut points" Panel in Table 2.7.

[57]Indeed, 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.

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.

2.6.6 Competing Hypotheses

In this section, I examines a number of possible competing hypotheses that may explain my finings. 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.

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; 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

[58] Heidenreich 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).

[59] Medicare 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.

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 2.8 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 2.9, 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 ate age-65 before PPS.

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 2.9, 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 2.9 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.

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 1980s, many states repealed their CON programs.[61] If some states repealed their CON programs for CABG around

[60] Before 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.

[61] States 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).

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 2.10 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 2.10, presenting the RD estimates, confirms no effect of hospital entry on the change in CABG use. The first columns of each panel of Table 2.10 replicate my baseline results from Table 2.2 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.

[62] Indeed, I find suggestive evidence that there was an increase in hospital entry into the provision of CABG after the repeal of CON program. Figure 2.20 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, Figure 2.21 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.

A falsification check

I examine changes in the use of CABG and angioplasty in PPS-waiver states as a falsification check. Figure 2.11 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 2.11, 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 2.11 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.

2.6.7 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 2.12 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 2.13 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 2.12 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.

[63] Note 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.

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.

2.7 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.

Table 2.1: Hospital discharge rate 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	Post-PPS 1988-89	Changes between pre-and post-PPS	Marginal costs 1988-92	PPS reimbursements 1988-92	Profit margins 1988-92
	(1)	(2)	(3)	(4)	(5)	(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 the non-elderly Medicare beneficiaries (i.e., aged under 65 disabled and/or those with end-stage renal disease). ICD-9-CM codes for CABG and Angioplasty are 36.1x and 36.0x, respectively. Marginal costs are based on the estimation of equation (15) in the text, weighted by number of discharges; marginal costs and PPS reimbursement 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*, and Healthcare Cost and Utilization Project (HCUP)

Table 2.2: Discontinuity in hospital discharge rates at age 65 and over
[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	17.72***	20.64***	13.45**
	[1.33]	[3.38]	[3.40]	[2.43]
Ages 70 to 74	-2.66	19.62***	26.75***	26.92***
	[0.59]	[4.68]	[3.28]	[4.38]
Ages 75 to 80	-4.31	7.92	8.28	32.05***
	[0.82]	[1.31]	[1.35]	[4.06]
Year effect	7.25**	4.60	6.90**	3.57
	[2.52]	[1.65]	[2.52]	[1.24]
B. Angioplasty				
Ages 65 to 69	-0.55	2.78	-9.03**	-1.38
	[0.50]	[1.38]	[2.50]	[0.27]
Ages 70 to 74	-2.44*	-3.73	-10.67**	-4.62
	[1.84]	[1.33]	[2.43]	[0.72]
Ages 75 to 80	-2.28	-14.08***	-36.17***	-28.45***
	[1.49]	[3.91]	[7.19]	[3.62]
Year effect	2.37***	20.48***	43.45***	46.81***
	[3.39]	[13.86]	[22.06]	[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 (i.e., Massachusetts, New York, New Jersey, and Maryland) are excluded. All analysis 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 2.3: Discontinuity in CABG discharge rate at age 65 and over, by hospital volume
[absolute value of t-ratio]

	Discontinuity in CABG discharge rate (per 10,000)		
	All hospitals (Panel hospitals) (1)	High-volume hospitals (annual volume >=200) (2)	Low-volume hospitals (annual volume < 200) (3)
	Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983		
Ages 65 to 69	-6.76**	-3.08	-3.69*
	[2.24]	[1.38]	[1.91]
Ages 70 to 74	-4.61	-1.39	-3.22
	[1.16]	[0.52]	[1.37]
Ages 75 to 80	-4.87	-1.09	-3.78
	[1.07]	[0.33]	[1.26]
Year effect	7.51***	3.50**	4.01***
	[3.06]	[2.14]	[2.98]
	Panel B. Post-PPS: changes from 1982-1983 to 1986-1987		
Ages 65 to 69	17.82***	15.02***	2.80
	[4.55]	[5.95]	[1.16]
{mean of 1982-1983}	{26.60}	{15.87}	{11.65}
Ages 70 to 74	16.53***	10.57***	5.96***
	[4.81]	[3.07]	[2.90]
Ages 75 to 80	9.16**	6.90*	2.26
	[2.23]	[1.84]	[0.90]
Year effect	-0.27	-2.00	1.73
	[0.14]	[1.03]	[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. PPS-waiver states (i.e., Massachusetts, New York, New Jersey, and Maryland) are excluded. Included are panel hospitals that had been contained in sample during the entire time period from 1980 to 1987 during which the same hospital ID format had been consistently used. All analysis 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 2.4: Discontinuity in CABG discharge rate at age 65 and over, by number grafts
[absolute value of t-ratio]

	Discontinuity in CABG discharge rate (per 10,000)		
	CABG with		CABG with
	1or 2 grafts	3+ grafts without cormorbidity	3+ grafts with cormorbidity
	(1)	(2)	(3)
	Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983		
Ages 65 to 69	-1.99	-1.1	0.53
	[0.97]	[0.42]	[0.29]
Ages 70 to 74	0.81	-0.61	-0.12
	[0.37]	[0.24]	[0.08]
Ages 75 to 80	-0.62	-2.38	-1.72
	[0.23]	[0.97]	[0.93]
Year effect	0.36	3.43**	2.14**
	[0.28]	[2.56]	[2.57]
	Panel B. Post-PPS: changes from 1982-1983 to 1988-1989		
Ages 65 to 69	7.82***	9.70***	-0.07
	[3.18]	[3.27]	[0.02]
Ages 70 to 74	-1.52	10.58***	2.67
	[0.36]	[3.13]	[0.65]
Ages 75 to 80	-18.07***	12.34***	-3.31
	[4.01]	[4.45]	[0.85]
Year effect	20.61***	-5.12***	9.17***
	[15.51]	[4.03]	[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 comorbidity is based on patients' diagnoses at admission; acute myocardial infarction (or heart attack), diabetes mellitus, chronic renal disease, cardiac arrhythmias, congestive heart failure, and history of previous CABG surgery. All analysis 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 2.5: 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 Files. All analysis 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 2.6: 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 analysis 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 2.7: Ordered logit estimates and implied quality-adjusted life year (QALY) weights
[absolute value of t-ratio]

	Pre-PPS 1982-83		Post-PPS *Changes* after 1982-83 by 1988-89	
	Estimates	QALY weights	Estimates	QALY weights
	(1)	(2)	(3)	(4)
Ischemic Heart Disease (IHD)	-1.38***	0.66	0.18**	0.04
	[19.04]		[2.09]	
IHD × Ages 65 to 69	0.25***	0.06	-0.04	-0.01
	[2.58]		[0.20]	
IHD × Ages 70 to 74	0.52***	0.13	-0.05	-0.01
	[3.05]		[0.23]	
IHD × Ages 75 to 80	0.94***	0.23	-0.55**	-0.13
	[6.37]		[2.30]	
Other circulatory disease	-1.31***	0.68	0.18***	0.04
	[44.70]		[3.91]	
Respiratory disease	-1.43***	0.65	0.15***	0.04
	[29.44]		[4.00]	
Digestive disease	-1.74***	0.58	0.21***	0.05
	[51.50]		[4.75]	
Skin/musculoskeletal disease	-1.31***	0.68	0.19***	0.05
	[34.67]		[4.69]	
Impairments	-1.39***	0.66	0.15***	0.04
	[28.76]		[2.88]	
Other chronic disease	-1.69***	0.59	0.23***	0.06
	[39.98]		[6.16]	
Year effect	---	---	0.08***	0.02
			[2.64]	
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”. Age, age squared, and indicators for ages 65-69, 70-74, 75-80 are not shown. 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.
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 2.8: Cost-per-QALY of the increased use of CABG relative to 1982, ages 65 to 69

	Post-PPS	
	1986	1988
	(1)	(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 2.9: 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	1984	1986	1989
	(1)	(2)	(3)	(4)
A. Hospital insurance rate (per 100)				
Ages 65 to 69	0.38	-1.00	-0.62	-0.85
	[0.57]	[1.08]	[0.55]	[1.01]
Ages 70 to 74	0.66	-1.56	-1.00	-0.44
	[0.69]	[1.28]	[0.67]	[0.39]
Ages 75 to 80	0.20	-2.31	-1.05	-0.86
	[0.16]	[1.54]	[0.54]	[0.60]
Year effect	-0.14	0.99	0.44	0.04
	[0.26]	[1.26]	[0.46]	[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	3.47	22.01	-44.73*
	[0.30]	[0.11]	[0.62]	[1.92]
Ages 70 to 74	-64.65*	30.04	67.76	16.26
	[1.90]	[0.73]	[1.51]	[0.49]
Ages 75 to 80	-8.44	-48.83	77.16	-11.26
	[0.19]	[1.02]	[1.43]	[0.34]
Year effect	19.84	33.08	-21.28	16.12
	[0.94]	[1.50]	[0.87]	[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 adjust for a fifth-order polynomial in age, year effects, and year effects interacted with age, and are weighted by NHIS annual sampling weights. 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 2.10: 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)	States repealed CON before 1989	States maintained CON
	(1)	(2)	(3)
	Panel A. Pre-PPS: changes from 1980-1981 to 1982-1983		
Ages 65 to 69	-4.78	-1.61	-3.98
	[1.33]	[0.19]	[0.63]
Ages 70 to 74	-2.66	-6.90	2.18
	[0.59]	[0.68]	[0.30]
Ages 75 to 80	-4.31	-14.77	2.66
	[0.82]	[1.27]	[0.32]
Year effect	7.25**	11.17*	4.76
	[2.52]	[1.93]	[1.07]
	Panel B. Post-PPS: changes from 1982-1983 to 1988-1989		
Ages 65 to 69	20.64***	10.77	20.27***
	[3.40]	[0.87]	[3.41]
Ages 70 to 74	26.75***	28.91***	26.66***
	[3.28]	[2.74]	[3.39]
Ages 75 to 80	8.28	24.63*	6.92
	[1.35]	[1.79]	[0.80]
Year effect	6.90**	-9.89	8.04*
	[2.52]	[1.50]	[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. All analysis 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 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. *** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 2.11: 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	1.87	10.35	9.31
	[0.45]	[0.17]	[0.88]	[1.33]
Ages 70 to 74	1.27	0.09	8.91	24.30*
	[0.15]	[0.01]	[0.71]	[1.99]
Ages 75 to 80	-5.36	7.80	16.51	28.12***
	[0.52]	[0.68]	[1.04]	[2.74]
Year effect	5.88	-1.18	3.53	-0.24
	[1.01]	[0.20]	[0.44]	[0.05]
B. Angioplasty				
Ages 65 to 69	-0.44	-8.40**	-6.67	2.86
	[0.72]	[2.23]	[1.30]	[0.40]
Ages 70 to 74	-0.58	-11.05***	-8.89	-4.30
	[0.76]	[3.50]	[1.33]	[0.58]
Ages 75 to 80	-0.73	-14.17***	-5.27	-20.49**
	[0.79]	[3.22]	[0.55]	[2.63]
Year effect	0.39	16.41***	20.17***	26.47***
	[0.70]	[8.85]	[4.85]	[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. All analysis 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 2.12: 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)
Cataract surgery				
Ages 65 to 69	2.93	-30.23***	-31.43***	-32.61***
	[0.61]	[4.59]	[5.39]	[5.21]
Ages 70 to 74	18.32**	-76.21***	-72.37***	-75.54***
	[2.28]	[7.03]	[7.13]	[7.28]
Ages 75 to 80	62.70***	-156.96***	-154.34***	-159.56***
	[7.47]	[12.63]	[11.82]	[11.76]
Year effect	2.84	-44.63***	-45.66***	-47.94***
	[1.08]	[11.99]	[12.41]	[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. All analysis 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 2.13: Discontinuity in percent of being in good health at age 65 (persons with IHD) [absolute value of t-ratio]

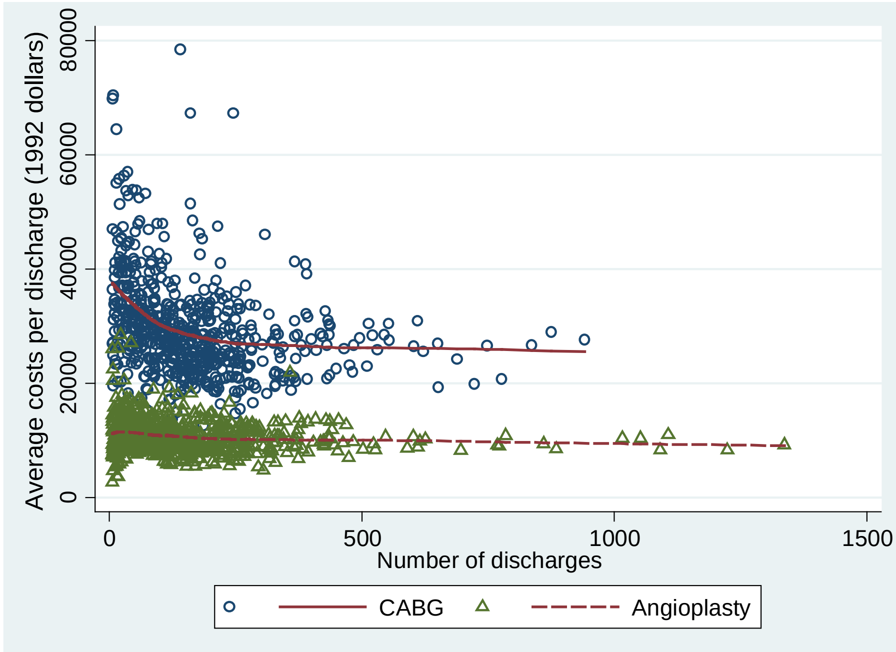
	Discontinuity in percent of being in good health among persons with IHD (%)			
	Pre-PPS	Post-PPS		
	Change after 1976-77 by	Change after 1981-1982 by		
	1981-1982	1986-1987	1988-1989	1990-1991
	(1)	(2)	(3)	(4)
Good health (%)				
Ages 65 to 69	-1.97	13.60*	9.05	9.49
	[0.26]	[1.81]	[1.43]	[1.55]
Ages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

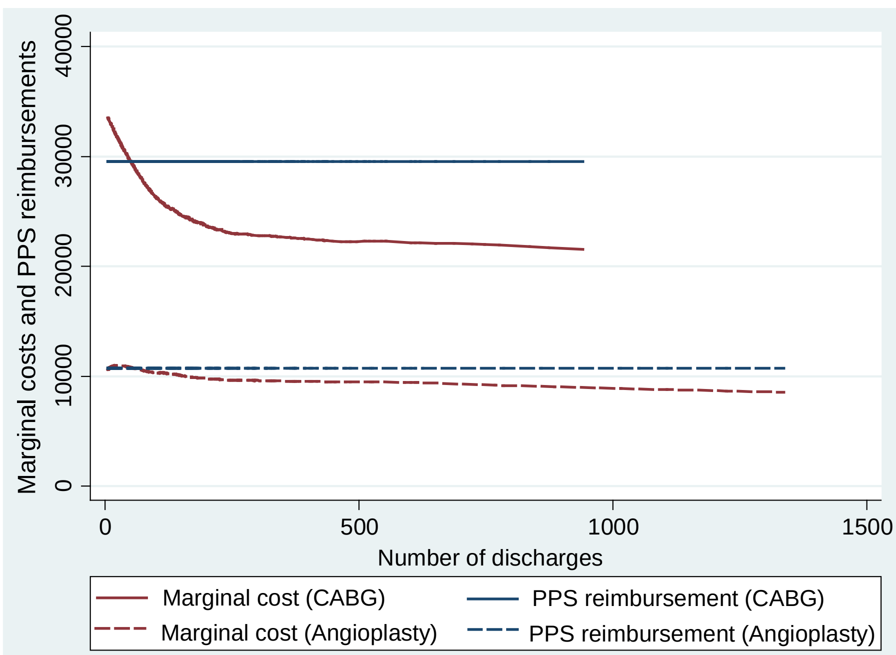
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Figure 2.1: Costs and PPS prices 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, 1988-1992

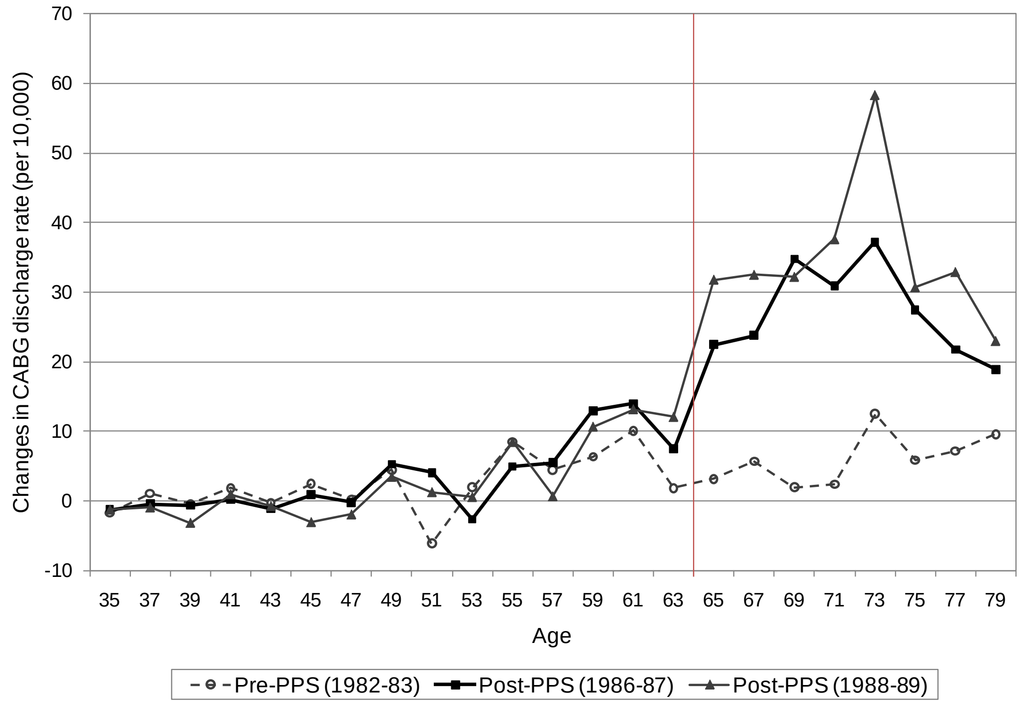


Notes: Figures include CABG and angioplasty performed to Medicare beneficiaries ages 65 and over. Any hospitals that performed five or more procedure annually are included. Average cost lines are derived from local linear regressions. Marginal cost lines come from the estimation of equation (15), controlling for hospital's locations at four Census regions (Northeast, Northwest, South, and West), teaching status nested in urban-rural classification (rural, urban-nonteaching, urban-teaching), bed sizes, and ownership. DRG codes used for CABG are 106 and 107, and the code used for Angioplasty is 112.

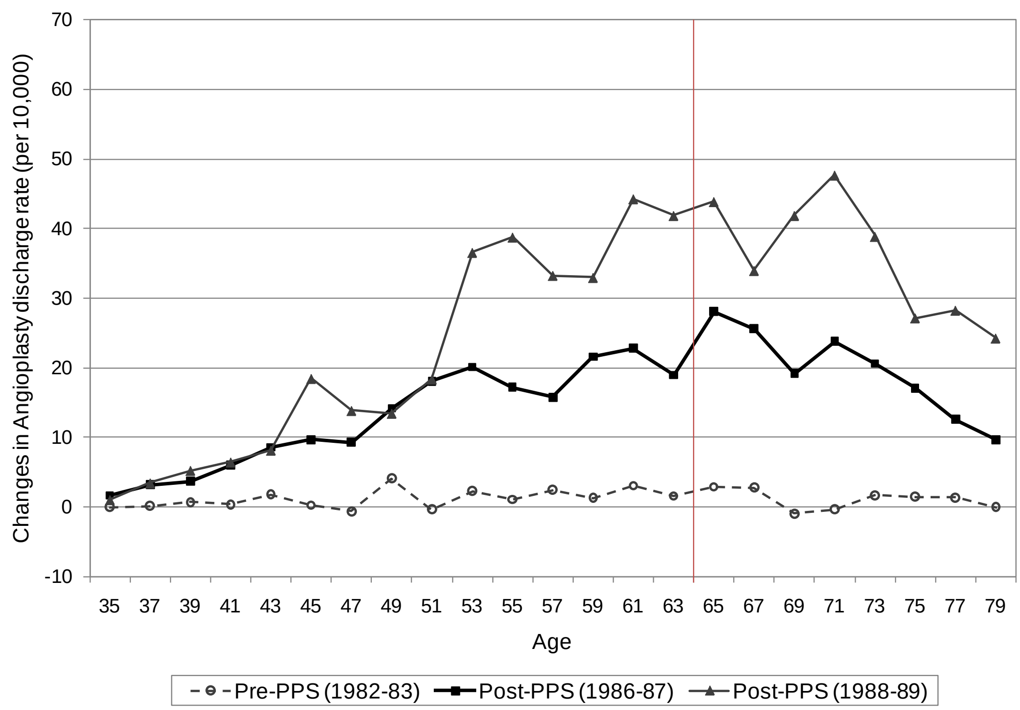
Source: Healthcare Cost and Utilization Project (HCUP) and Medicare Cost Reports.

Figure 2.2: Changes in hospital discharge rate, PPS states

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



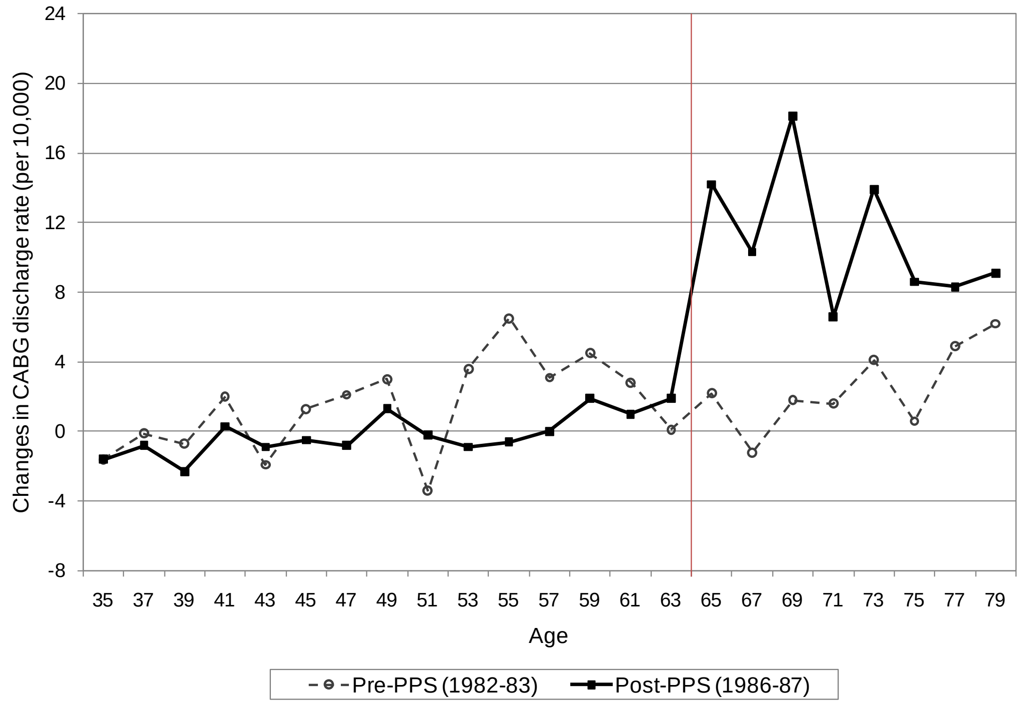
B. Changes in Angioplasty discharge rate relative to 1980-1981



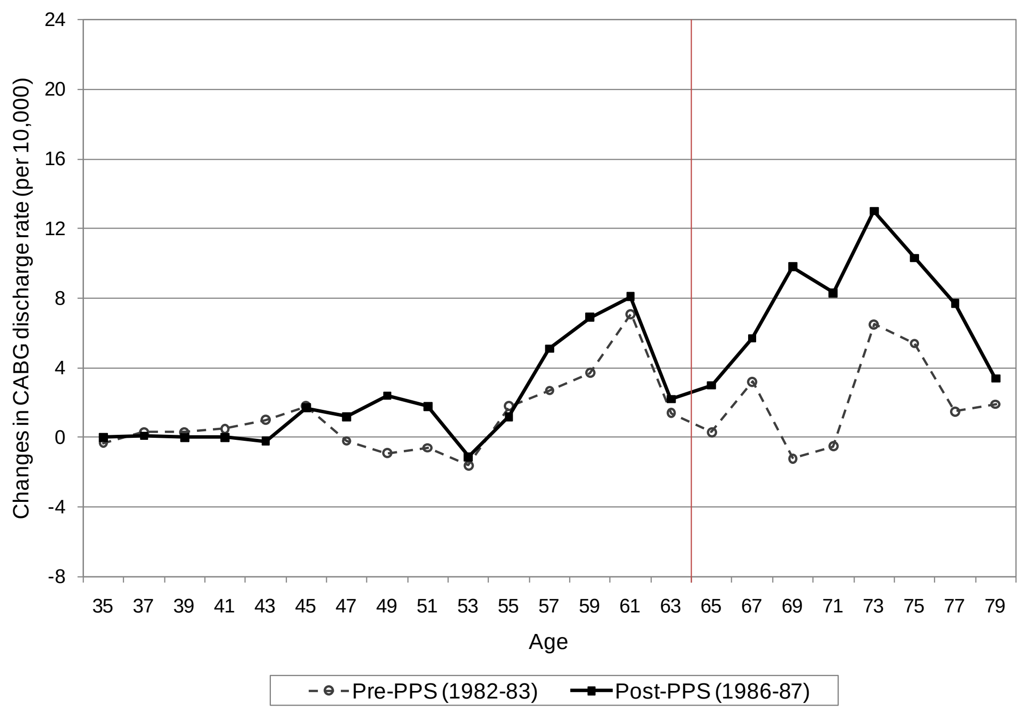
Notes: Figures exclude the non-elderly Medicare beneficiaries (i.e., aged under 65 disabled and/or those with end-stage renal disease), and PPS-waiver states (i.e., Massachusetts, New York, New Jersey, and Maryland). The ICD-9-CM codes used for CABG and Angioplasty are 36.1x and 36.0x, respectively.
Source: National Hospital Discharge Survey

Figure 2.3: Changes in CABG discharge rate, by hospital volume

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



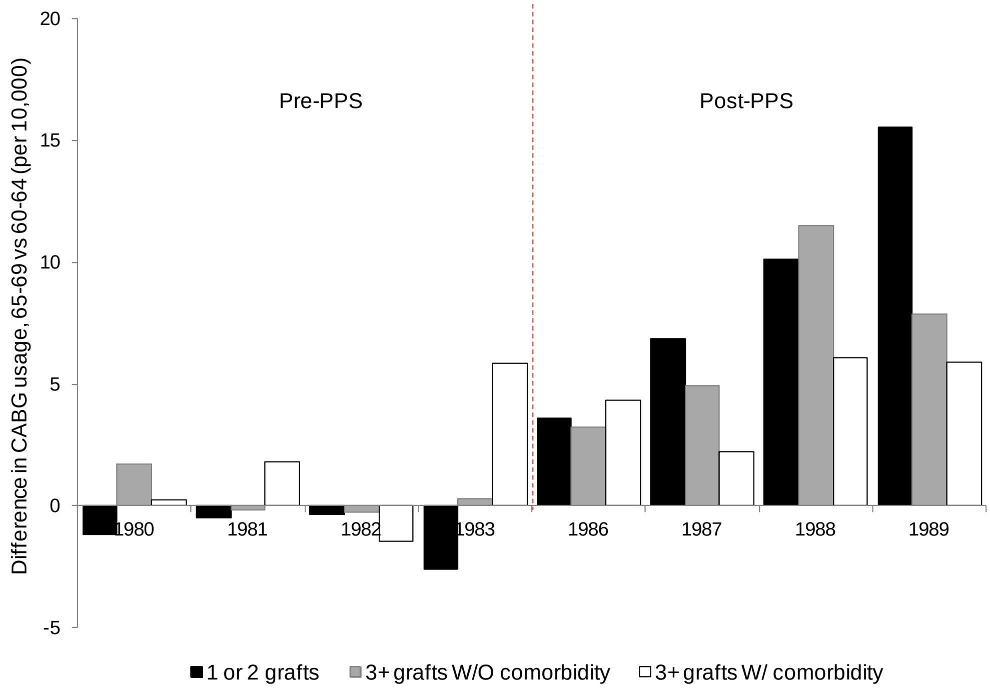
B. Changes in CABG discharge rate relative to 1980-1981, low-volume hospitals



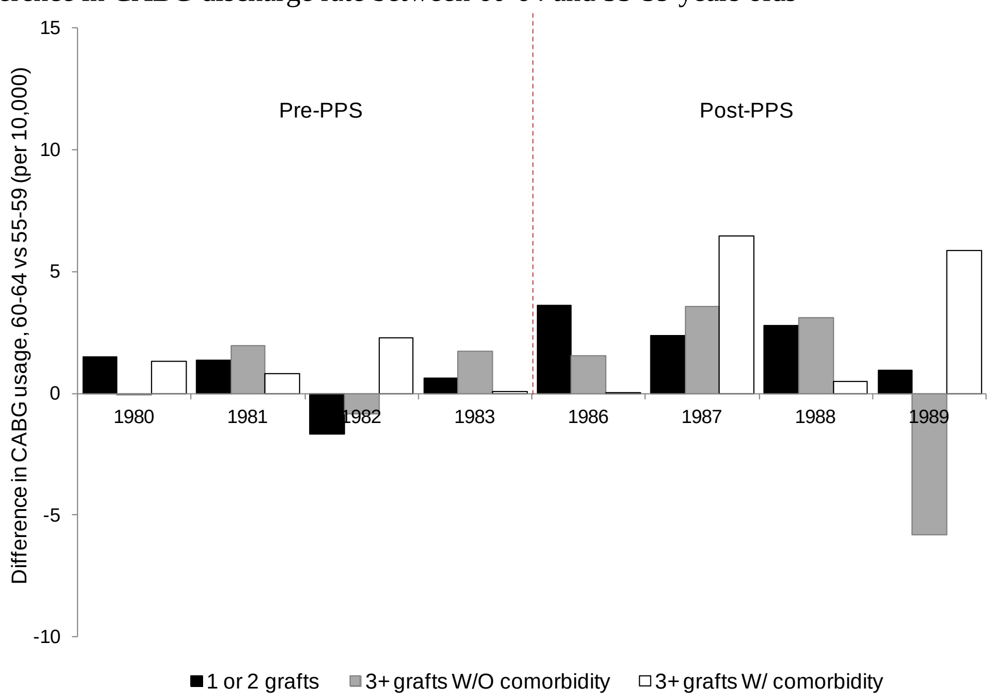
Notes: Figures exclude PPS-waiver states and the non-elderly Medicare beneficiaries. Hospitals that had provided 200 or more CABGs annually during 1980-82 (i.e., pre-PPS period) are categorized as high-volume hospitals. ICD-9-CM codes for CABG and Angioplasty are 36.1x and 36.0x, respectively.
Source: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

Figure 2.4: Difference in CABG discharge rate between age-groups, by number of grafts

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

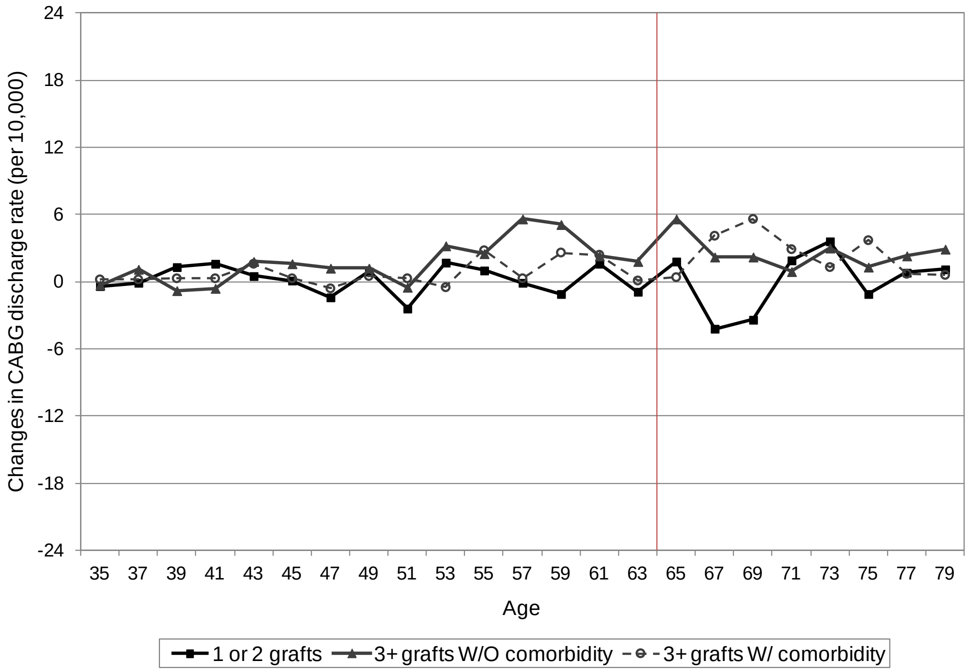


Notes: Figures exclude PPS-waiver states (i.e., MA, NY, NJ, and MD) and the non-elderly Medicare beneficiaries. The ICD-9-CM codes used for CABG with one or two grafts are 36.11-36.12, 36.15-36.16; three or more grafts are 36.13-36.14. The comorbidity is based on patients' seven diagnoses at admission;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

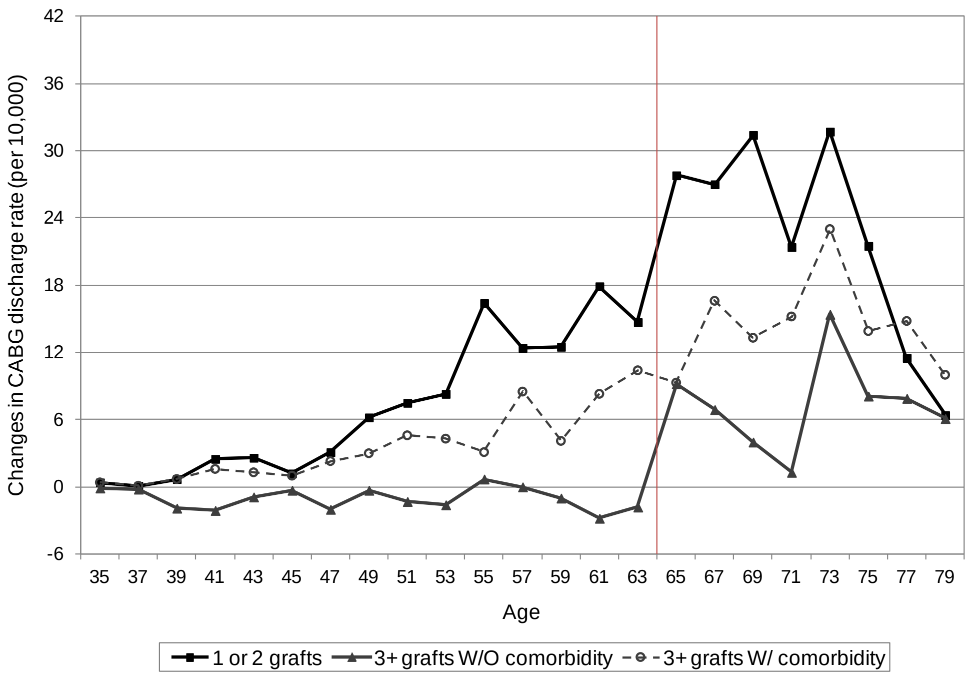
Source: National Hospital Discharge Survey

Figure 2.5: Changes in CABG discharge rate, by number of grafts

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



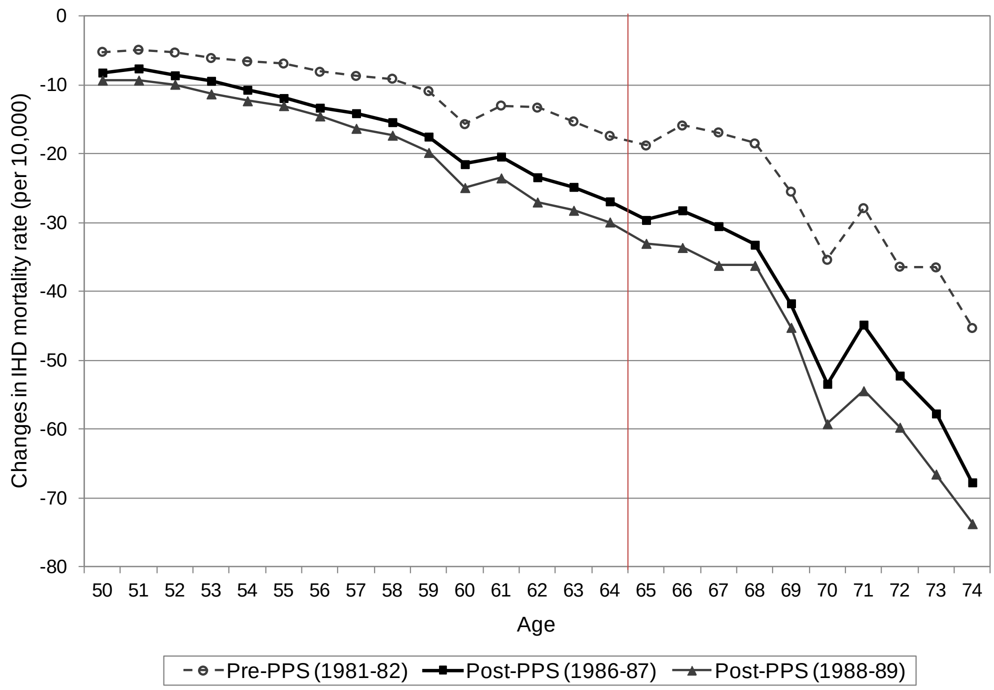
B. Changes in CABG discharge rate from 1980-1981 to 1988-1989 (Post-PPS)



Notes: Figures exclude the 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 comorbidity is based on patients' seven diagnoses at admission; acute myocardial infarction (or heart attack), diabetes mellitus, chronic renal disease, cardiac arrhythmias, congestive heart failure, and history of previous CABG surgery.

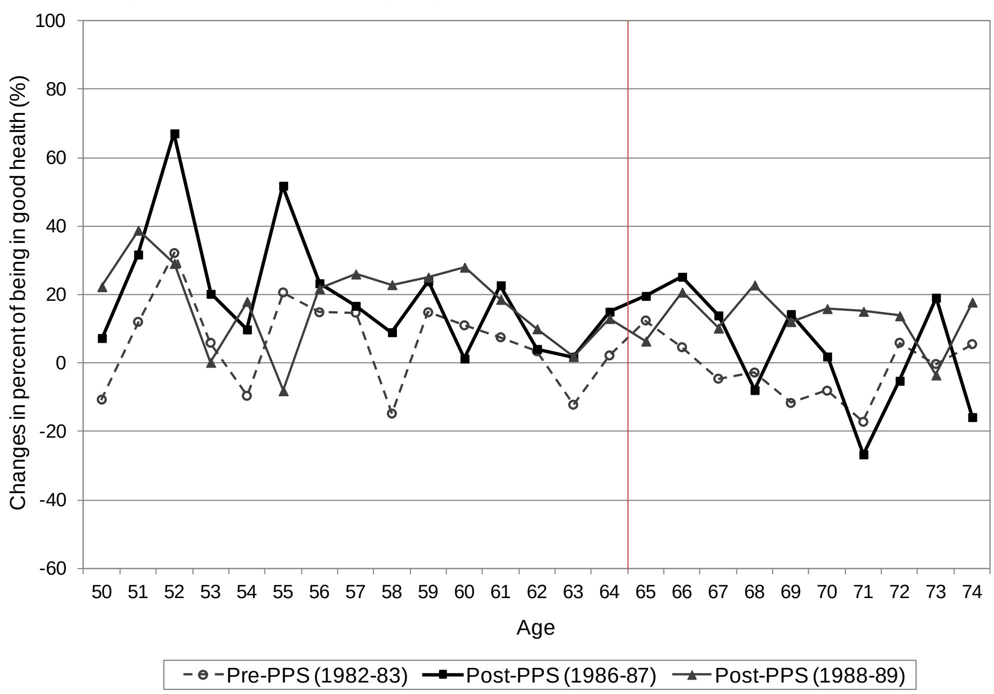
Source: National Hospital Discharge Survey

Figure 2.6: Changes in Ischemic Heart Disease (IHD) mortality rate relative to 1976-1977



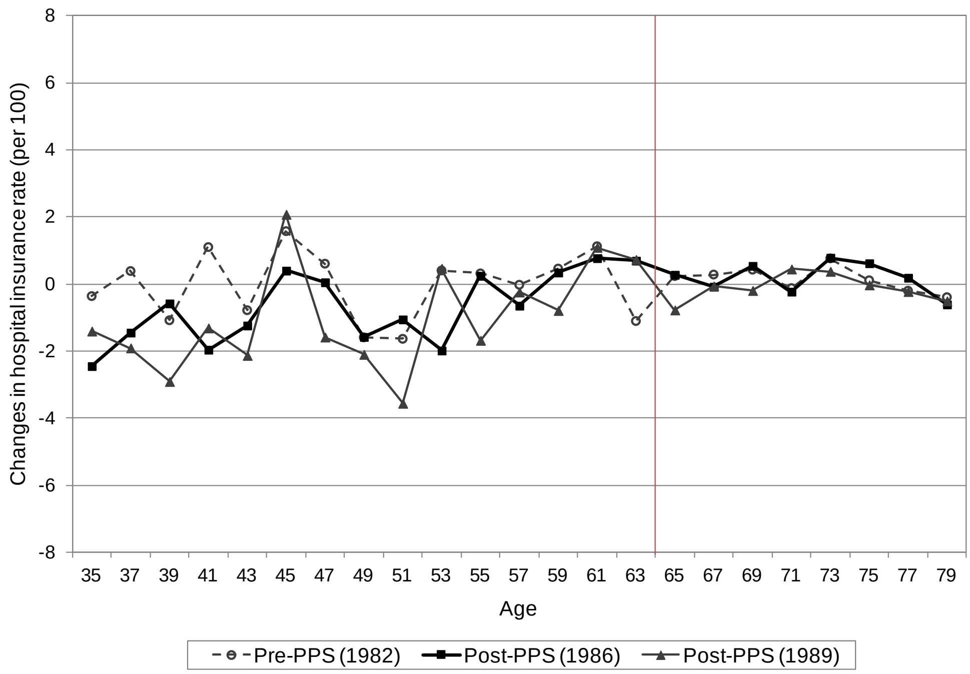
Note: The ICDA-8 (1976-1977) and ICD-9 (1981-1989) codes used for IHD mortality rate are 410-414.
Source: Multiple Cause-of-Death Files

Figure 2.7: Changes in percent of being in good health (persons with IHD) relative to 1976-1977



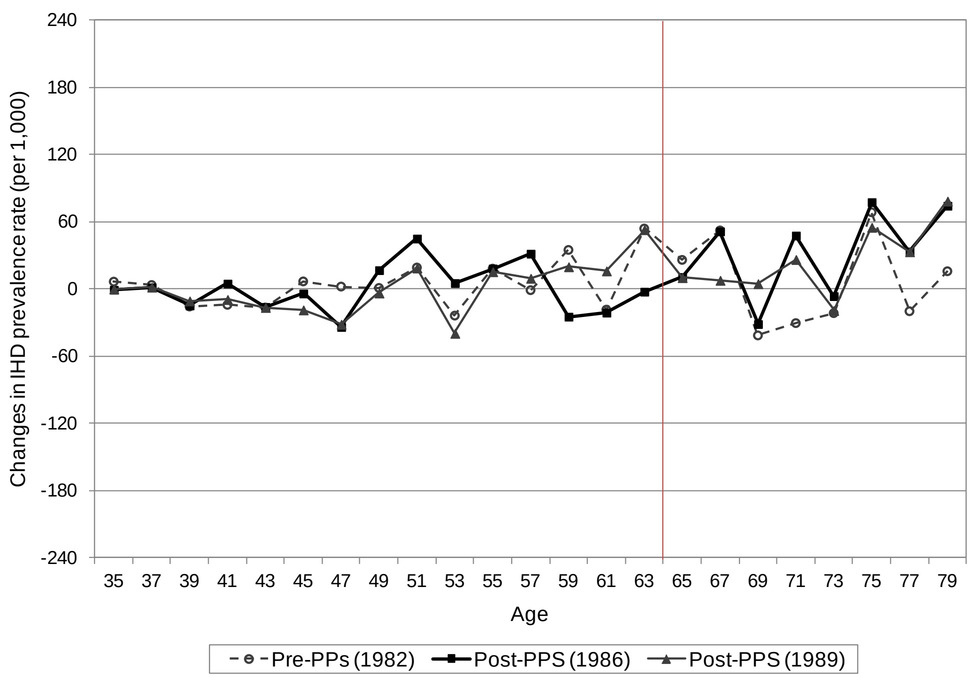
Notes: Percent of being in "good" health is based on the share of people with IHD reporting "excellent," "very good," or "good" to the question on their health status. The ICDA-8 (1976-1977) and ICD-9 (1982-1989) codes used for IHD conditions are 410-414.
Source: National Health Interview Survey

Figure 2.8: Changes in hospital insurance rate relative to 1980 (per 100 persons)



Notes: Figure excludes the non-elderly Medicare beneficiaries. Hospital insurance covers Medicare, Medicaid, private insurance, and any public assistance program that paid for health care.
Source: National Health Interview Survey

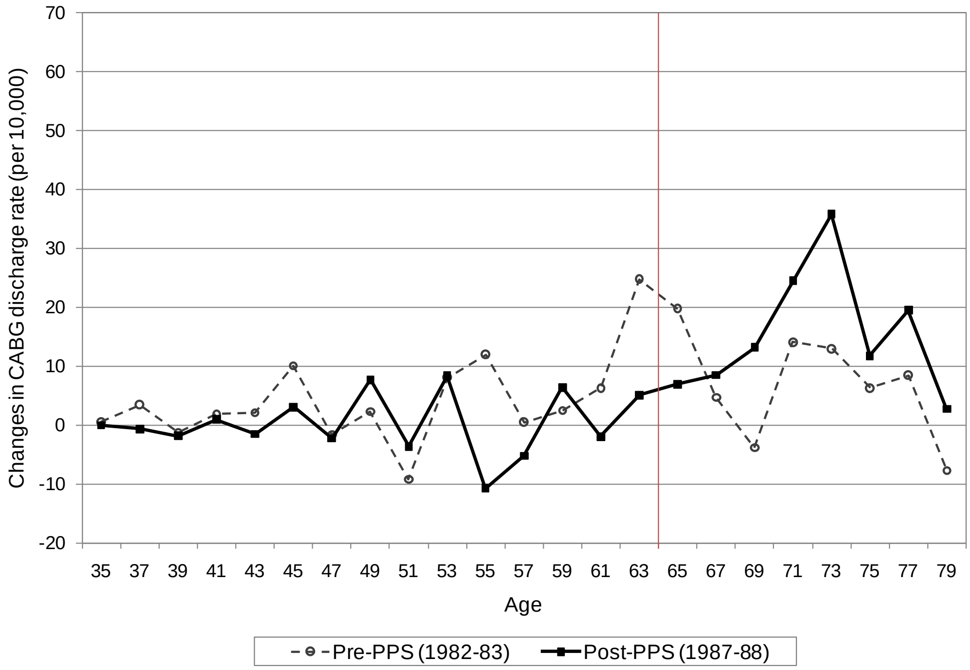
Figure 2.9: Changes in Ischemic Heart Disease prevalence rate relative to 1980 (per 1,000 persons)



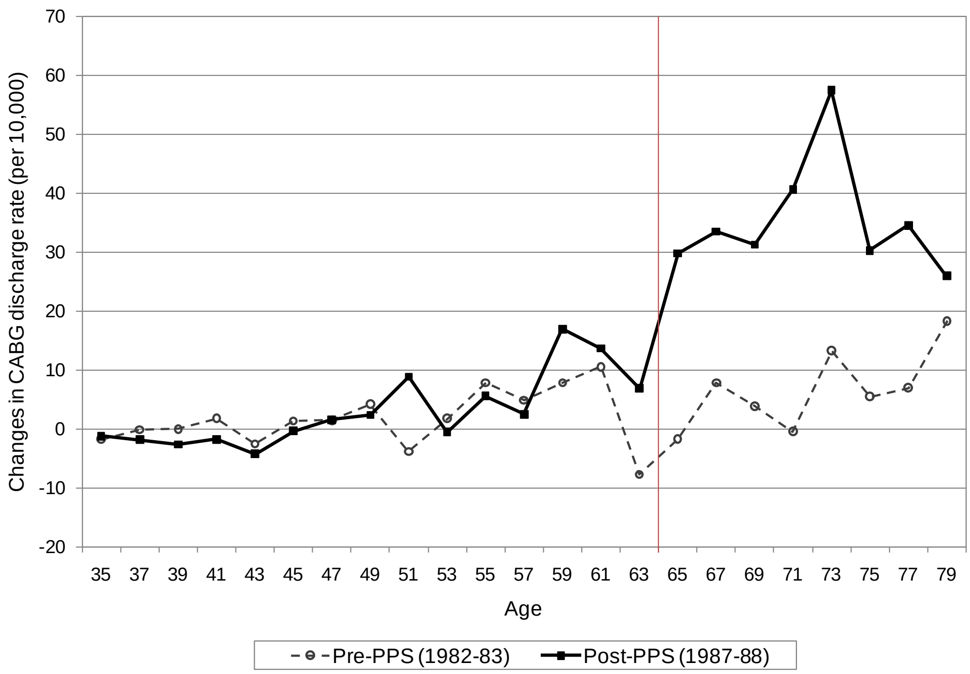
Notes: Figure excludes the non-elderly Medicare beneficiaries. The ICD-9-CM diagnosis codes used for Ischemic Heart Disease (IHD) are 410-414.
Source: National Health Interview Survey

Figure 2.10: 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

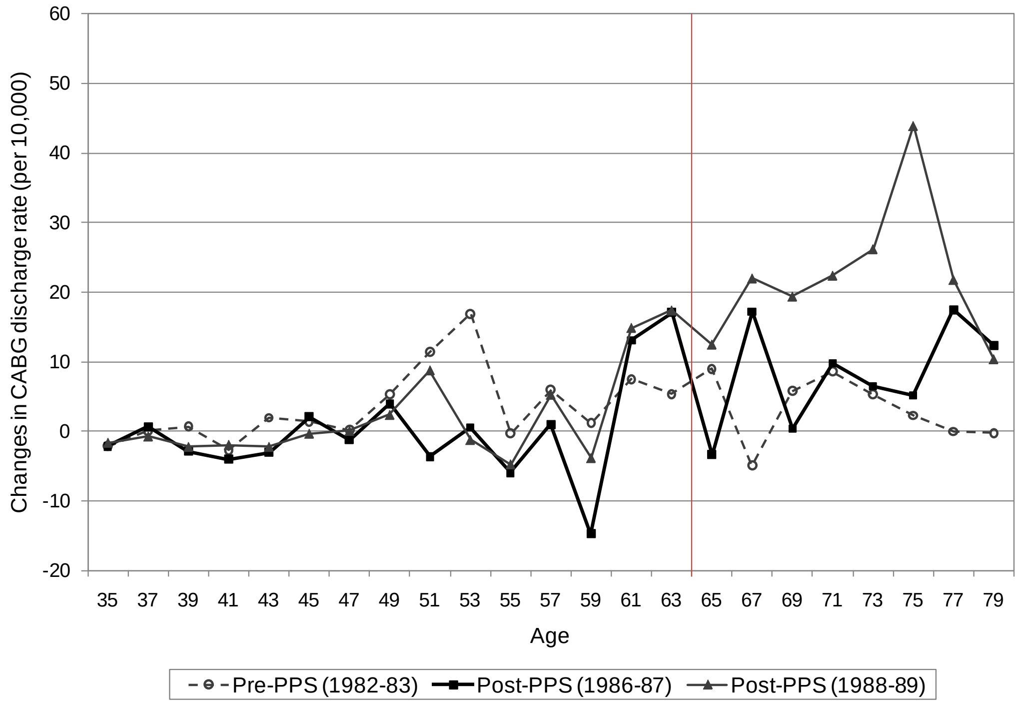


Notes: Figures exclude the non-elderly Medicare beneficiaries (i.e., aged under 65 disabled and/or those with end-stage renal disease), and PPS-waiver states (i.e., Massachusetts, New York, New Jersey, and Maryland). The ICD-9-CM code used for CABG is 36.1x. States that repealed CON for open-heart surgery (i.e., CABG) before 1989 are Idaho, New Mexico, Minnesota, Utah, Arizona, Kansas, Texas, Wyoming, California, Colorado, and South Dakota.

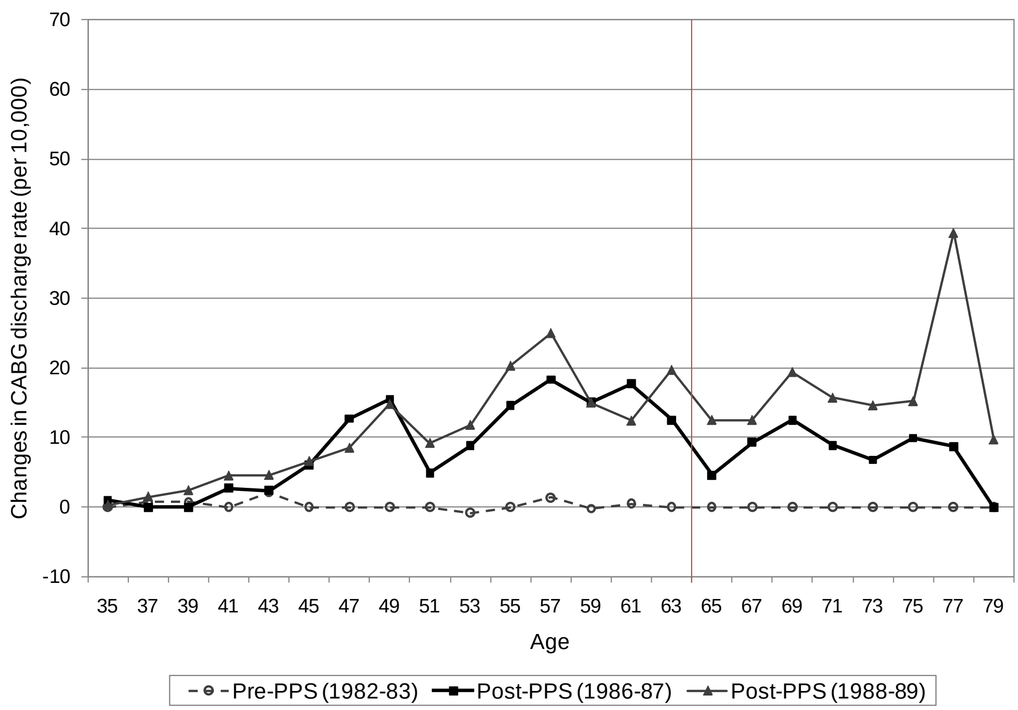
Source: National Hospital Discharge Survey

Figure 2.11: Changes in hospital discharge rate, PPS-waiver states

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

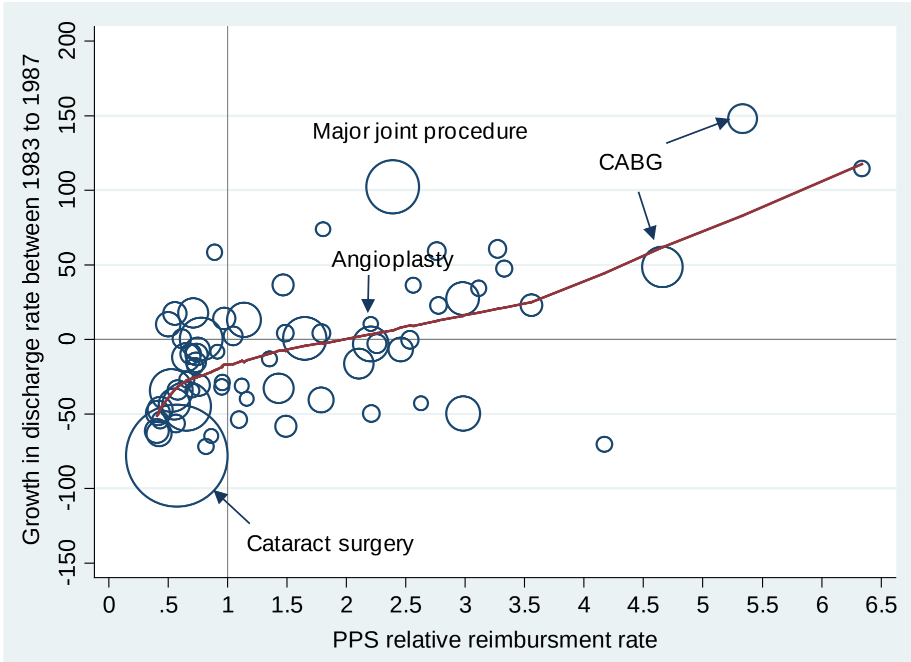


B. Changes in Angioplasty discharge rate relative to 1980-1981



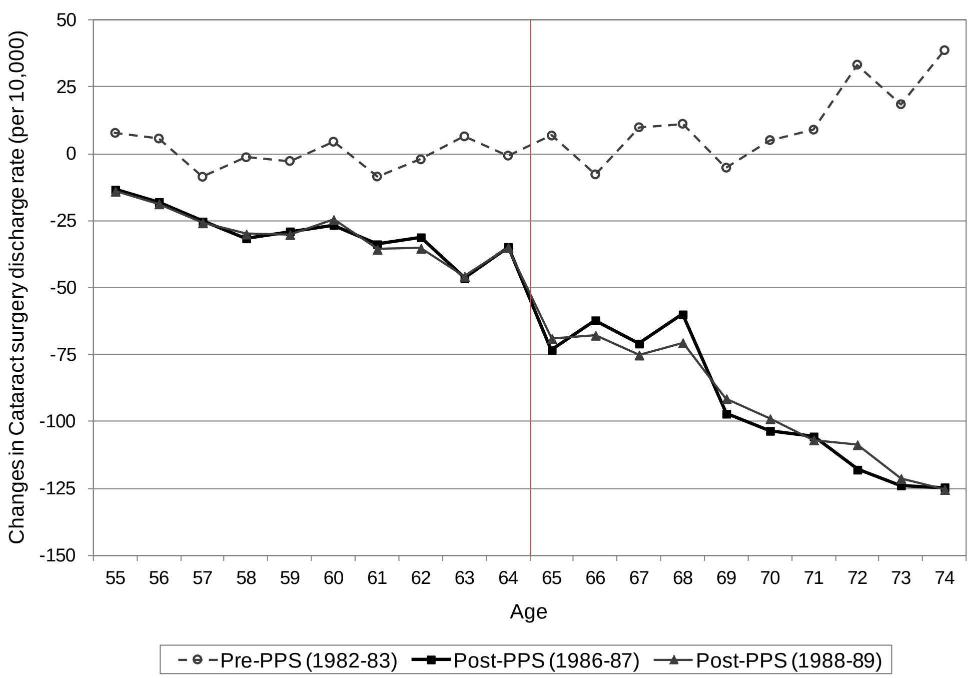
Notes: Figures exclude the non-elderly Medicare beneficiaries (i.e., aged under 65 disabled and/or those with end-stage renal disease). PPS-waiver states include Massachusetts, New York, New Jersey, and Maryland. The ICD-9-CM codes used for CABG and Angioplasty are 36.1x and 36.0x, respectively. Source: National Hospital Discharge Survey

Figure 2.12: Growth in discharge rate by PPS relative reimbursement rate, 65-74 year olds



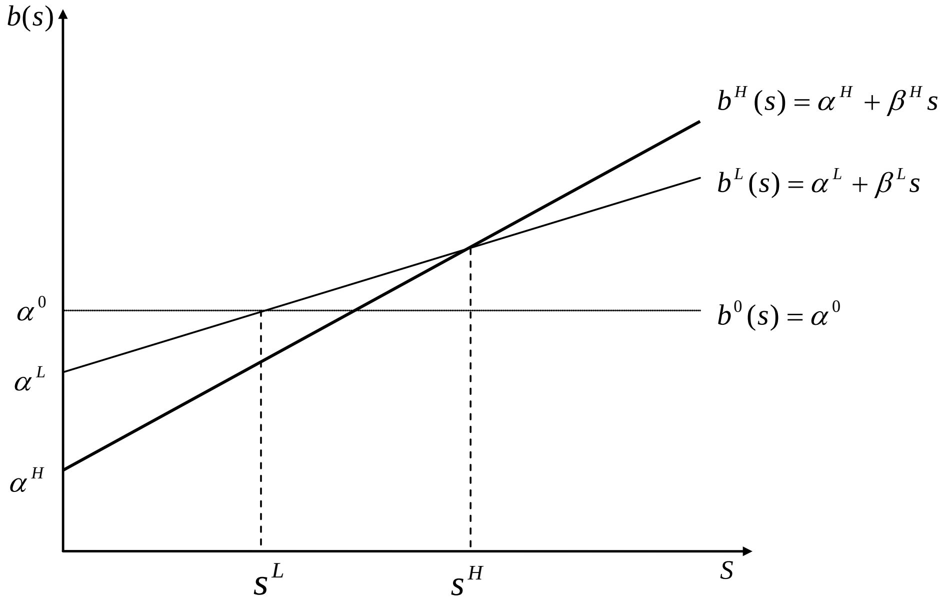
Notes: Figure includes surgical procedures among 250 most frequent DRGs for aged 65-74 in 1987. The PPS relative reimbursement rates are DRG weights in 1987. The line is estimated from the local linear regression. Growth in discharge rate is weighted by the number of discharges in 1983 (the size of circles).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

Figure 2.13: Changes in Cataract surgery discharge rate relative to 1980-1981



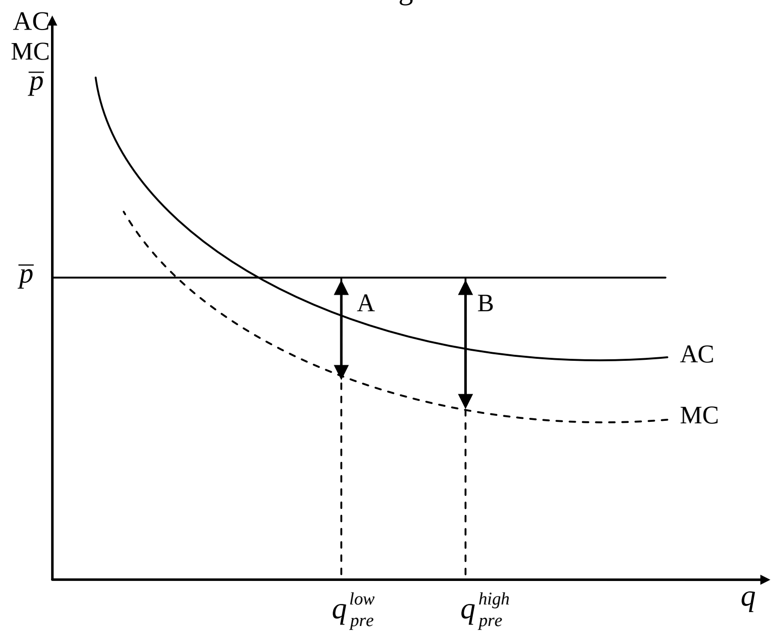
Notes: Figures excludes the non-elderly (i.e., aged under 65) disabled and/or those with end-stage renal disease. The ICD-9-CM codes used for Cataract surgery are 13.1-13.6.
Source: National Hospital Discharge Survey

Figure 2.14: The benefits function of each medical treatment for ischemic heart disease



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 medical management (i.e., drug therapy), respectively. s^H and s^L are benchmark values that hospital choose to provide CABG for patients whose severity of illness is larger than s^H; angioplasty for those whose severity is between s^H and s^L and ; medical management for those whose severity is less than s^L.

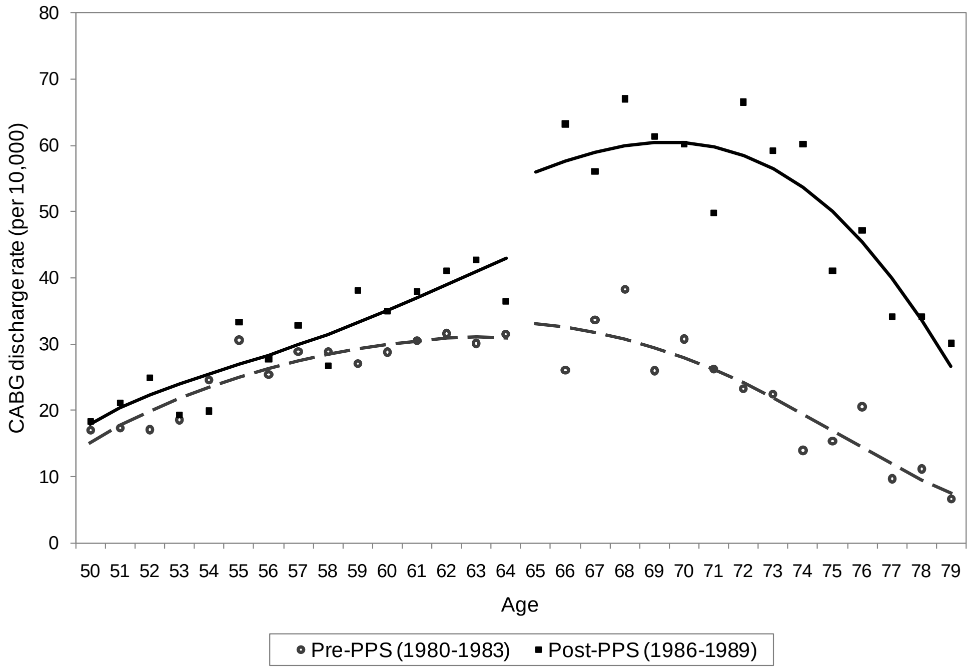
Figure 2.15: Financial incentives under the average cost reimbursement of Medicare PPS



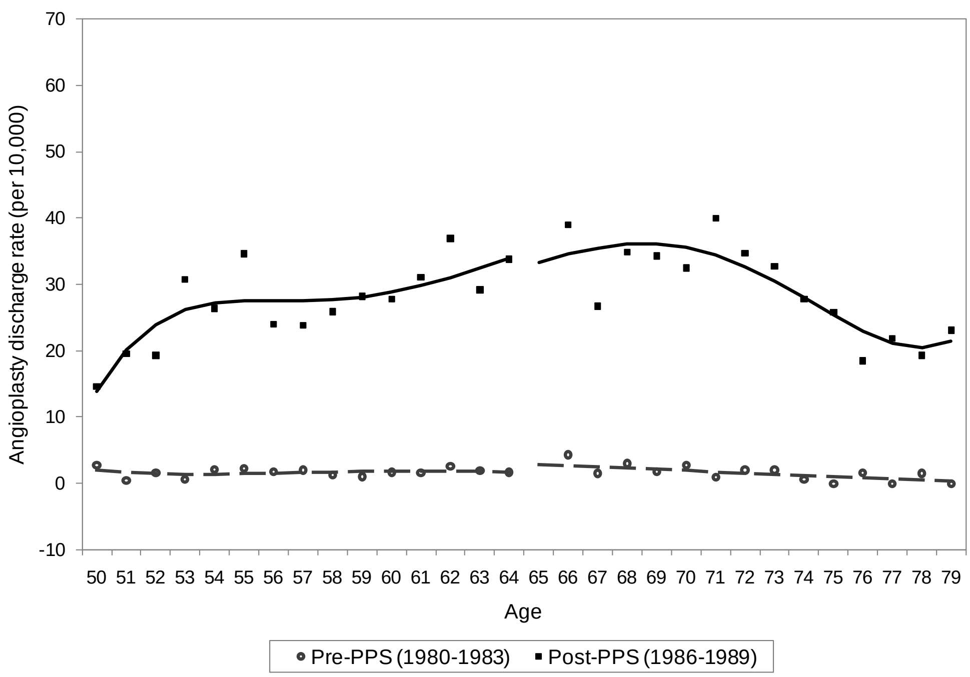
Notes: $\bar{p}$ indicates the average cost reimbursement under Medicare PPS. AC and MC are average costs and marginal costs, respectively.

Figure 2.16: CABG discharge rate, pre- and post-PPS periods

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

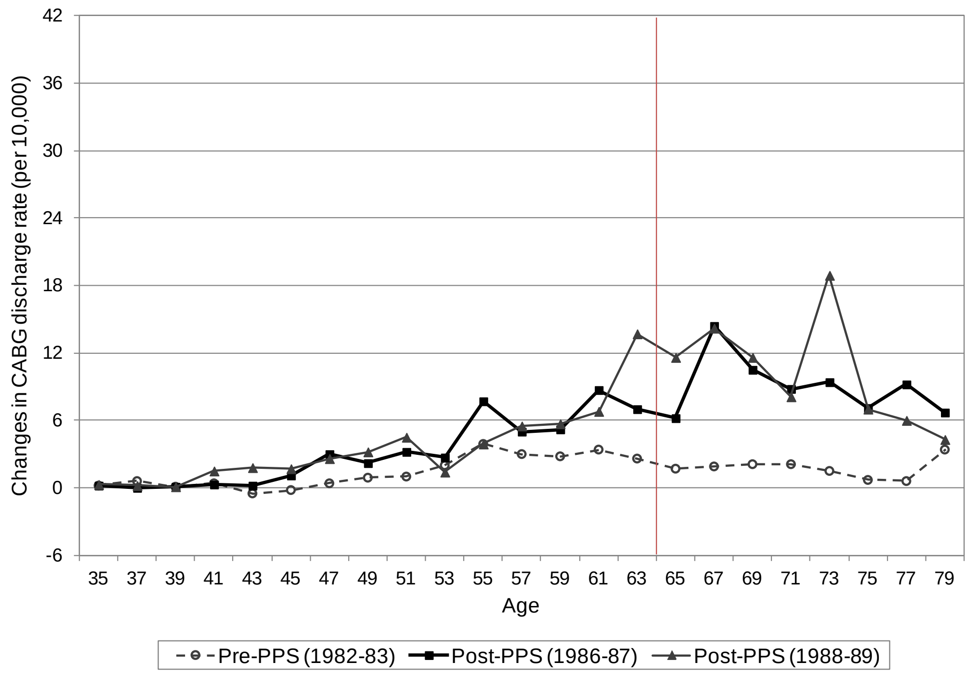


B. Angioplasty discharge rates pre- and post-PPS periods



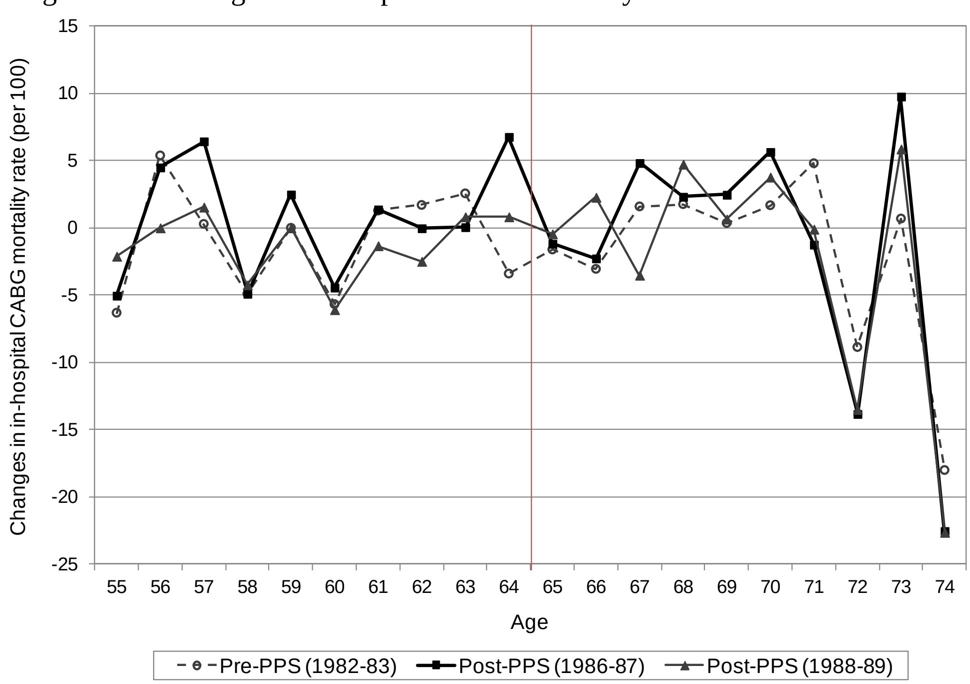
Notes: Figures excludes the non-elderly (i.e., aged under 65) disabled and/or those with end-stage renal disease. Points represent means for discharge rate in each age cell. Points for people age 65 are not shown in the figure. Fitted lines are adjusted for fifth-order polynomial in age and a dummy for age greater than or equal to 65. The ICD-9-CM codes used CABG and Angioplasty are 36.1x and 36.0x, respectively. The PPS-waiver states include MA, NY, NJ, and MD (see text for details).
Source: National Hospital Discharge Survey

Figure 2.17: Changes in CABG discharge rates relative to 1980-1981, heart attack patients



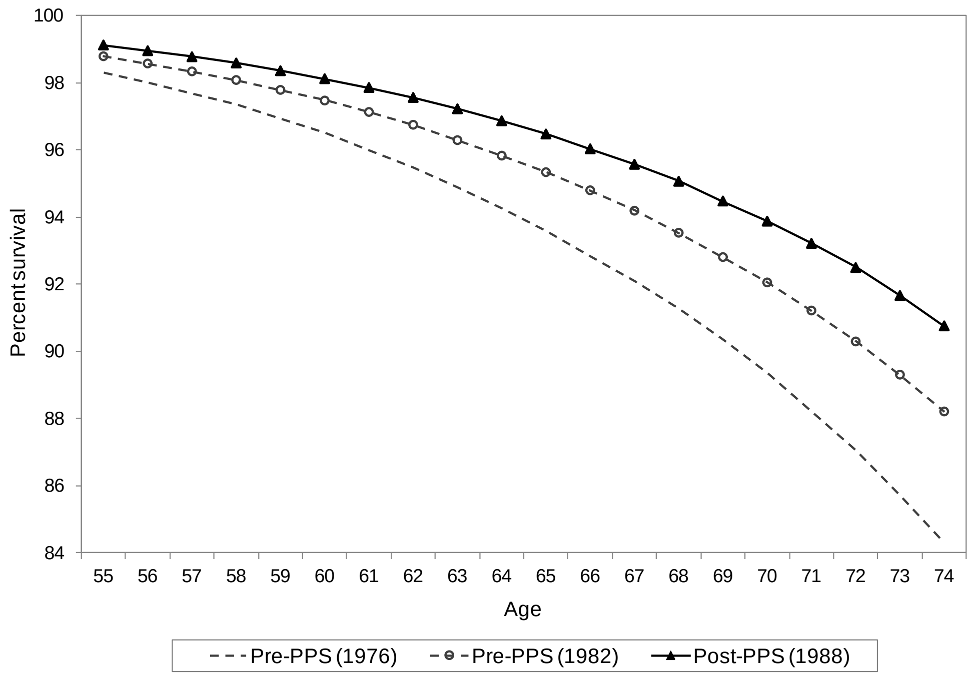
Notes: Figure excludes non-elderly Medicare beneficiaries aged under 65 (disabled and/or those with end-stage renal disease). The ICD-9-CM codes used for CABG are 36.1x. And ICD-9 code used for heart attack (AMI: Acute Myocardial Infarction) is 410.
Source: National Hospital Discharge Survey

Figure 2.18: Changes in in-hospital CABG mortality rate relative to 1980-1981



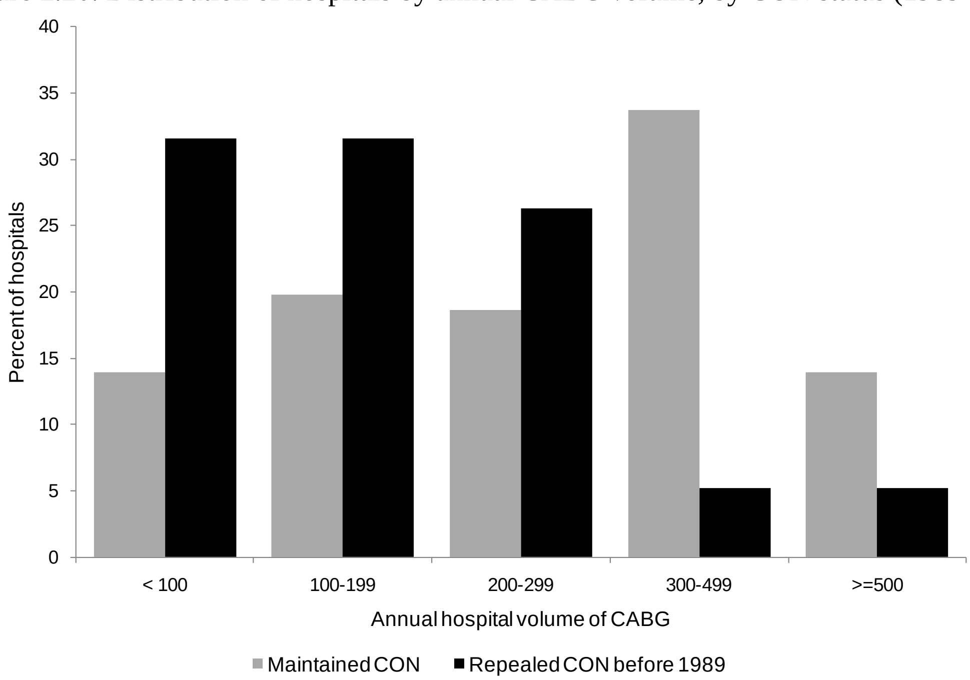
Notes: Figure excludes non-elderly Medicare beneficiaries aged under 65 (disabled and/or those with end-stage renal disease). The ICD-9-CM code used for CABG is 36.1x.
Source: National Hospital Discharge Survey

Figure 2.19: Survival Curve for Ischemic Heart Disease mortality, survivors to age 45



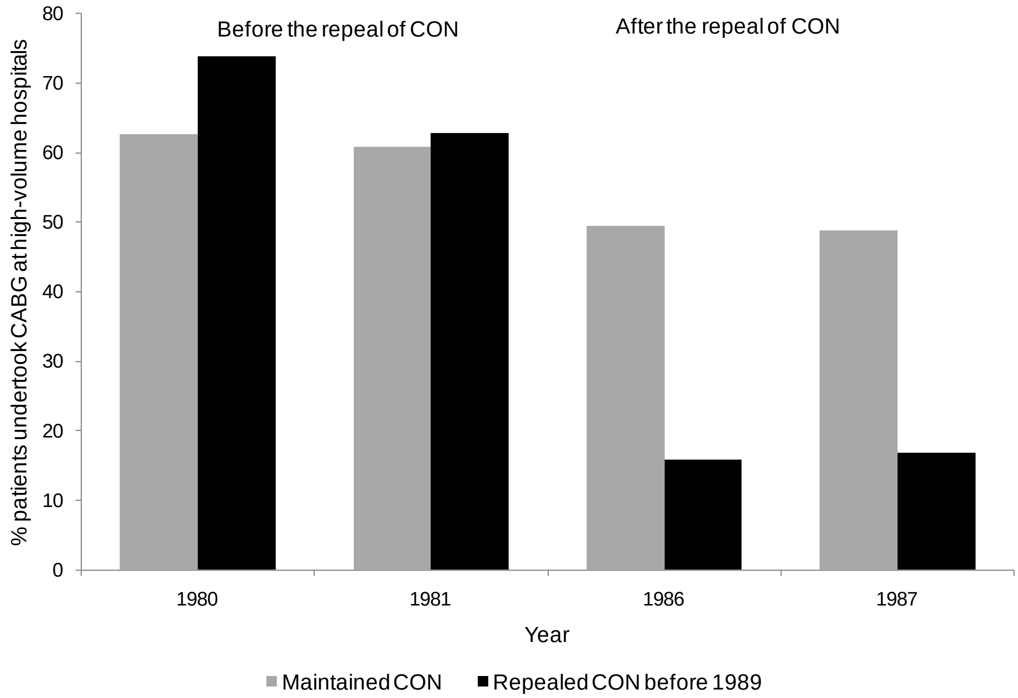
Note: Survival rates for Ischemic Heart Disease are calculated conditional on survival to age 45.
Source: Multiple Cause-of-Death Files

Figure 2.20: Distribution of hospitals by annual CABG volume, by CON status (1989-92)



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 programs before 1989 included in the data are AZ, CA, and CO. DRG codes of 106 and 107 are used for CABG volume.
Source: Healthcare Cost and Utilization Project

Figure 2.21: Proportion of patients undergo CABG at high-volume hospitals, by CON status



Notes: Hospitals are categorized as high-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

2.A 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
CABG by number of grafts	
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
Indication of comorbidity	
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 dortro/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)

The1988-1992 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.

Chapter 3

The Black-White Gap in Educational Attainment: The Role of the Hospital Desegregation

3.1 Introduction

Almost four decades have passed after federal efforts had been put to end the racial segregation in hospitals mainly through two legislations, the Civil Right Acts of 1964 and the Social Security Amendment of 1965 (Medicare). Those were the landmark policies that turned the long-lasting divided health care system into an integrated one in the United States. Under this hospital desegregation, more access to and better treatment from hospitals were provided to black patients, especially in the South, who previously had limited access and treatment. However, the effect of this hospital integration through the improved health on the education attainment (i.e., formal schooling) is an open question.

Not much attention on the effect of hospital desegregation has been paid by economists although a couple of studies explore those effects. Almond et al. (2008) show that the hospital integration in the South improved black infant health measured by post-neonatal mortality rates. They also show that, after integration, access to hospital care increased significantly for blacks in the South. Chay et al. (2008) present evidence that improved access to hospital care due to the integration described above may have long-run effects on human capital accumulation, measured by remarkable reduction in black-white gap in AFQT (Armed Forced Qualifying Test) scores. They demonstrate that the timing of the cohort-based AFQT score convergence tracks the convergence in black-white mortality gap for those cohorts very closely. Almond and Chay (2005) argue that infant health improvement due to the hospital desegregation had long-run and intergenerational health benefits. They show that black women born in the late 1960s are much less likely to give birth to an infant with low birth weight and APGAR scores than black women born in the early 1960s.[1]

To my knowledge, however, no study has been done to assess the effect of the hospital desegregation on formal schooling, i.e., being in the modal grade, high school dropout rate, high school completion rate, or college enrollment rate. Although a large literature documents the substantial narrowing of the black-white gap in educational attainment during 1980s, it does not focus on the hospital desegregation as an underlying force[2]. In addition, most previous studies use the NLSY79 (National Longitudinal Survey of Youth) mainly because it includes the measured cognitive skills, such as AFQT scores.[3] Thus, the scope of those studies are limited to the cohort born between 1957 and 1964, before the hospital integration.[4] However, as seen in Figure 3.1, there has been a substantial narrowing of the black-white gap in college enrollment rate among cohorts born between 1964 and 1968 in the South, who mostly benefited from the hospital desegregation relative to those in the North.

By focusing on the cohort who had been exposed to hospital desegregation in the South, especially those born between 1966 and 1968, this study explores the effects of hospital desegregation on educational attainment. The study may shed an important light on the effects of health care accessibility or health care in early life on educational attainment. It could also provide one of the underlying reasons why the convergence in black-white skill gap has stopped in the 1990s[5].

The analysis compares the South-North differences in black-white gap in educational attainment for those born before and after hospital desegregation. Using the cohort-region-race variations contained in the Current Population Survey (CPS) October Supplement, this study documents that the black-white gap in educational attainment among post-desegregation cohorts (born between 1966 and 1968) was much more narrowed than among pre-desegregation cohorts (born between 1961 and 1963). For example, the black-white gap in high school dropout rate was narrowed by 7 percentage points among post-desegregation cohorts relative to pre-desegregation cohorts. The black-white gap in high school completion rate was reduced by 7 to 8 percentage points among post-desegregation

[1] Almond et al. (2005) find evidence that the five-minute APGAR score is a better predictor of infant health and mortality than birth weight. The five component factors are (1) Skin Color, (2) Heart Rate, (3) Reflex Irritability, (4) Muscle Tone, and (5) Respiratory Effort.

[2] Hauser (1993) and Kane (1994) focuses the effect of credit constraint on black-white gap in college enrollment rate for cohorts born between the mid 1950s and 1970.

[3] Cameron and Heckman (1998), Cameron and Heckman (2001), Carneiro and Heckman (2002), and Cameron and Taber (2004) among others.

[4] NLSY79 represents young men and women who were 14-22 years old when they first interviewed in 1979 while respondents for the NLSY97 were ages 12-17 when they first interviewed in 1997 (birth cohort from 1980 to 1984.

[5] Neal (2006) raised three possible explanations for the stagnant trend for black-white skill gap, which could be corresponding to time period after the early 1990s in Figure 3.1.

cohorts. The gap in college enrollment rate was also decreased by 4 to 7 percentage points.

I examine alternative hypotheses which may have explained the reduction of black-white gap in educational attainment. Of particular hypotheses are Medicaid, Head Start, and the school desegregation. However, any of these social programs or policies does not seem to match with the timing of reduction in cohort-based black-white gap in educational attainment.

The rest of this paper is organized as follows. Section 3.2 reviews the background of hospital desegregation. Section 3.3 describes the data. Section 3.4 presents a conceptual framework. In Section 3.5, I present the empirical results, and Section 3.6 examines alternative hypotheses. Section 3.7 concludes.

3.2 Background on the Hospital Desegregation

Before 1965, the health care system among other aspect in Southern area was distinctively segregated based on race. In 1956 and 1956, among 523 general hospitals, only 10 percent of hospitals in the South had integration policy compared with 87 percent in the North (Cornely, 1957). Chay et al. (2008) also documents that, in segregated hospitals, there were separate waiting rooms for black and white patients, and in many cases black patients who came to the emergency room for treatment were forced to wait until all white patients were treated, regardless of the severity or urgency of the patients' condition. In other cases, care was refused to black patients outright. Especially, the Hospital Survey and Construction Act (or Hill-Burton Act) of 1946 explicitly allowed the construction of racially *separated* hospitals using federal funds (Smith, 1999)[6].

Almost two decades later from the national struggle, two landmark legislations induced Southern hospitals to integrate for both legal and economic reasons. The first was Title VI of the Civil Rights Act of 1964, which banned discrimination in any activities that used federal funds for training, employment, or construction (Smith, 1999). The second was Title XVIII of the Social Security Amendments of 1965 (Medicare), which was the first major test of Title VI enforcement. Medicare was effectively implemented on July 1, 1966. It provided financial support to hospitals for providing medical care to elderly patients aged 65 and older – i.e., medical costs that would have been otherwise uncompensated. More importantly hospitals had to be in compliance with Title VI of the Civil Rights Act in order to receive cost reimbursement from Medicare. The requirement of Title VI certification for all participating hospitals to be eligible for Medicare reimbursement and Medicare's

[6]The passage was inserted in sec. 622(f): ... but an exception shall be made in cases where separate hospital facilities are provided for separate population groups, if the plan makes equitable provision on the basis of need for facilities and services of like quality for each such group...

generous reimbursement formula provided strong and unambiguous financial incentives for hospitals to become racially integrated (Smith, 2005). Thus, Medicare program combined with Office of Equal Health Opportunity (OEHO)'s aggressive approach to auditing hospitals in the South had been driving forces in the dramatic integration of Southern hospitals in the last half of 1966 (Almond and Chay, 2005).

3.3 Conceptual Framework

This section provides a simple model to explore the effect of hospital integration on the educational attainment through the improvement in health. The utility function is assumed to be non-additive and non-separable for consumption goods (and services) and health status because total utility which people could enjoy from consumption goods and services depends on their health status itself. For example, some people who have relatively weak health status would have less utility than those have strong health status even from the exactly same amount of consumption goods. In other words, the health status developed from health care inputs plays a role as a utility shifter, as opposed to one of the arguments in the utility function. Thus, the utility function at age t can be deposited as follows

$$U = [U(X_t)] \cdot h_t \tag{3.1}$$

where X_t is the consumption goods and services other than health care inputs, and importantly h_t denotes the health status at age t. The health status is defined by the ratio of the health stock at age t (H_t) to the hypothetical maximum health stock ($\overline{H}$),

$$h_t \equiv \frac{H_t}{\overline{H}} \tag{3.2}$$

The health stock at age t (health production function) can be described as a function of health care inputs (m_t) and the health stock at age $t-1$ (H_{t-1}).

$$H_t = q \cdot m_t^{\phi} + (1-\delta) \cdot H_{t-1} \tag{3.3}$$

where q is the quality of health care ($q > 0$), ϕ is the effectiveness of the health care input, and δ is the depreciation rate of the previous health stock.[7] The initial (innate) health stock (H_0) is given and the marginal product of health stock diminishes as health care inputs increase, $0 < \phi < 1$.

[7] ϕ is the degree of effectiveness of health care inputs and δ captures the fact that the initial stock of health depreciates with age. Both parameters can be generalized to be a function of age, i.e., $\phi = \phi(t)$ and $\delta = \delta(t)$.

If utility function follows the logarithm of X_t, then individual's maximization problem becomes

$$\max_{\{X_t, m_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty} (1-\rho)^t \log(X_t) \cdot \frac{H_t}{\overline{H}} \tag{3.4}$$

$$\text{s.t} \quad \sum_{t=1}^{\infty} \left(\frac{1}{1+r}\right)^t (p_m \cdot m_t + X_t) = Y \tag{3.5}$$

where ρ is the discount rate, r is interest rates, p_m is the relative price of health care inputs, and Y is the expected total life-time income.[8]

Once one knows the optimal health stock at time τ, then the optimal health care input at time τ is determined given initial health stock, H_0. Thus, by substituting for health care inputs (m_t) from Equation (3.3) into Equation (3.5), individual's problem becomes

$$\max_{\{X_t, H_t\}_{t=1}^{\infty}} \sum_{t=1}^{\infty} (1-\rho)^t \log(X_t) \cdot \frac{H_t}{\overline{H}} \tag{3.6}$$

$$\text{s.t} \quad \sum_{t=1}^{\infty} \left(\frac{1}{1+r}\right)^t \left(p_m \left[\frac{H_t - (1-\delta)H_{t-1}}{q}\right]^{\frac{1}{\phi}} + X_t\right) = Y \tag{3.7}$$

Hence, the optimal health care inputs at a given time τ can be described as follows.

$$m_\tau^* = m(q, \phi, p_m, X_\tau, m_{\tau-s}^*), \quad s = 1, \ldots, \tau - 1 \tag{3.8}$$

Given that hospital integration could be reflected as the increase in quality of health care inputs as well, the effect of hospital integration on the optimal health care inputs is positive and that effect on other consumption goods is negative.[9]

$$\frac{\partial m_\tau^*}{\partial q} > 0, \quad \frac{\partial X_\tau^*}{\partial q} < 0 \tag{3.9}$$

This implies that people exposed to the hospital integration tend to increase their health care input (i.e., hospital utilization) but reduce other consumption goods because they would enjoy the same level of utility even with less consumption of other goods due to the increased health status from those increased health care input, shifting the utility upwards.

The educational attainment can be described as a function of health stock

$$S_t = f(H_t, Z_t) \tag{3.10}$$

[8] The price of other goods and services (X_t) is normalized to 1.
[9] See Appendix 3.A for the proof.

where S_t denotes the level of educational attainment and Z_t indicates other factors, including unobservables (e.g., ability, motivation, etc). Also, educational attainment can be assumed as a positive function of the health stock, $\frac{\partial S_t}{\partial H_t} > 0$.[10] From Equation (3.3), (3.9), and (3.10), one can easily see the effect of hospital integration reflected as an increase in health care quality on educational attainment at time τ;

$$\frac{\partial S_\tau^*}{\partial q} = \frac{\partial S_\tau^*}{\partial H_\tau^*}\frac{\partial H_\tau^*}{\partial m_\tau^*}\frac{\partial m_\tau^*}{\partial q} > 0 \tag{3.11}$$

It holds because $\frac{\partial S_\tau^*}{\partial H_\tau^*} > 0$ and $\frac{\partial H_\tau^*}{\partial m_\tau^*} > 0$.

3.4 Data Description

In this study, I use the Current Population Survey (CPS hereafter) October Supplement from 1972 to 2007.[11] Even though the CPS data has some weak properties, I can take a couple of advantages from it for the purpose of this study[12]. First, unlike the NLSY, it provides information on birth cohorts including those born between 1964 and the early 1970s, cohorts of interest in this study. Second, it gives a trend of racial differences in the educational attainment for a relatively long horizon, which allows the comparison of cohort born before and after the hospital desegregation. Third, it provides a nationally representative sample for whites and blacks in all regions, especially the North and the South, the regions that this paper focuses as the hospital desegregation affected mostly the South as opposed to the North. Finally, unlike the population estimates produced by Census Bureau, it records a family home address as state of residence, in preference to the address of dormitory where some students might live (U.S. Census Bureau, 2006).

As seen in Table 3.1, there was substantial black-white gap in educational attainment. On average from 1972 to 1992, corresponding to the cohorts born between 1956 and 1973, black youths (18 and 19 years old) enrolled college less than their white counterparts by 20% points. Other dimensions of educational attainment show similar patterns. During the same time period, high school graduates among black were less than white by 21% points, and high school dropout rates of black is higher than white by 8% points. Those gaps look same across regions, i.e., the South and the North, respectively. However, different cohorts had achieved educational attainment differentially across the regions, depending upon their exposure to hospital desegregation. Figure 3.1 shows the black-

[10] There is some evidence that healthier children are more better to get schooling because of the reduction in absenteeism (Bleakley, 2007; Miguel and Kremer, 2004).

[11] From 1972 on, the racial group is mutually exclusive. Before 1972, Hispanic origin could be classified either as whites or as blacks.

[12] Cameron and Heckman (1993) points that the CPS-based studies tend to underestimate the contribution of family income to college attendance decisions because dependency status (dependent family members of students) is positively related to family income.

white gap in college enrollment rates among 18-19 years old. The gap in the South was improved much more than in the North for cohorts born after the hospital desegregation.

Especially for the purpose of this paper, the black youths born between 1964 and 1968 in the South, who were mainly exposed to the hospital integration, relative to the North counterparts narrowed those gaps by 10% points, compared with previous cohorts who did not have exposure to the integrated hospital. In terms of the appropriateness on the schooling track, Figure 3.2 depicts the black-white gap in the proportion of students being on the modal grade. The gap was narrowed for the same cohort exposed to the hospital integration in the South relative to the North by 5% points.[13] These cohort-based aggregate trends suggest that the accessibility of health care, affecting birth cohorts differentially, could possibly explain the improvement in educational attainment.

3.5 Empirical Results

To explore the effects of hospital integration, I estimate the linear probability model, difference-in-difference-in-differences model, and ordered logit model as described below.

3.5.1 Linear Probability Model

I first estimate the following equations

$$Y_{icat}^W = \alpha_t^W + \gamma_c^W + \delta_a^W + X_{ict}\beta^W + U_{icat}^W \tag{3.12}$$

$$Y_{icat}^B = \alpha_t^B + \gamma_c^B + \delta_a^B + X_{ict}\beta^B + U_{icat}^B \tag{3.13}$$

where i indexes individuals, c indexes year of birth, a indexes the age, and t indexes the calendar year in which the survey was implemented. Y_{icat} are the outcome variables; the proportion of students being on the modal grade; high school dropout rates; high school completion rates; and college enrollment rates, and X_{ict} denotes the control variables, which include householders' education levels and their marital status. Both equations above can be estimated as follows.

$$\begin{aligned} Y_{icat} &= \alpha_t^W + \gamma_c^W + \delta_a^W + X_{ict}\beta^W \\ &+ (\alpha_t^B - \alpha_t^W)B_{ict} + (\gamma_c^B - \gamma_c^W)B_{ict} + (\delta_a^B - \delta_a^W)B_{ict} + X_{ict}(\beta^B - \beta^W)B_{ict} + \varepsilon_{icat} \end{aligned}$$

[13]The modal grade measures the degree of appropriateness in the school track. For example, if some students were 9th grade or over at age 15, they were regarded as being on the modal grade, which means that they were less likely to be on the retard in grades.

where B_{ict} is binary variable equal to one for black and zero for white.

I estimate $\gamma_c^B - \gamma_c^W$, the black-white gap in educational attainment for cohorts born between 1956 and 1977, separately for the South and the North. The cohort effects are estimated conditional on year effects, age effects, householders' education levels, and their marital status. Panel A and B of Figure 3.3 show the estimates of the proportion of students being on the modal grade with linear time trend and quadratic time trend, respectively. As seen in those Figures, for cohorts born between 1966 and 1971, the South-North differences in the black-white gap in the proportion of being on the modal grade is higher than for cohort born before 1964 by about 10% points. This implies that black cohorts (relative to white counterparts) born between 1966 and 1971 in the South (compared with those in the North) were much more likely to be on the appropriate track in school given their age than cohorts born before 1964. The column (1) and (2) of Table 3.2 show those cohort effects by every single cohort. The effects of cohort born in 1967, 1970, and 1971 are marginally significant in the estimation with linear time trends.

The same estimates for the different measure of educational attainment are plotted in Figure 3.4, 3.5, and 3.6. Figure 3.4 shows the estimates for the black-white gap in the high school dropout rates. The cohorts born between 1966 and 1968 reduced high school dropout rates by around 5% points relative to the cohorts born before 1964. As seen in columns (3) and (4) of Table 3.2, the cohort born in 1966 and 1967 reduced the high school dropout rates by 10% points, which is moderately significant with linear time trends. Figure 3.5 and 3.6 show the similar pattern of the cohort effect for high school completion rates and college enrollment rates - e.g., the black cohort in the South born after hospital desegregation improved high school completion rate and college enrollment rate. More interestingly, columns (7) and (8) of Table 3.2 show that the black cohorts born between 1965 and 1968 in the South substantially improved the college enrollment rates by 14 to 24% points according the estimates with linear time trends.

3.5.2 Difference-in-Difference-in-Differences

Given that the cohort effects on each measure of educational attainment are imprecisely estimated mainly due to the small sample of black students, I combined cohorts born between 1966 and 1968 (post-desegregation cohorts) as a treatment group while cohort born between 1961 and 1963 (pre-desegregation cohorts) as a control group, and then estimate a difference-in-differences estimator separately for the South and the North from an equation below.

$$
\begin{aligned}
Y_{iat} &= \alpha_t^W + \gamma^W Post + \delta_a^W + X_{ict}\beta^W \\
&+ (\alpha_t^B - \alpha_t^W)B_{it} + (\gamma^B - \gamma^W)Post \cdot B_{it} + (\delta_a^B - \delta_a^W)B_{it} + X_{ict}(\beta^B - \beta^W)B_{it} + \varepsilon_{iat}
\end{aligned}
$$

where $Post = 1$ for cohorts born between 1966 and 1968 while $Post = 0$ for cohorts born between 1961 and 1963, and $B = 1$ for black while $B = 0$ for white.

Table 3.3 shows the estimates of $\gamma^B - \gamma^W$ separately for the South and the North (difference-in-differences estimator), conditional on year effects, age effects, householders' educational attainment, and their marital status. With linear time trends, column (9) to (10), and (15) to (16) of Table 3.3 show that the black post-desegregation cohorts in the South reduced high school dropout rates while increased high school completion rates, relative to their white counterparts. Columns (21) to (22) of Table 3.3 highlight that the same cohorts in the North, not much affected by desegregation, reduced the college enrollment rates. This implies that those cohorts in the South, mostly benefited from the hospital desegregation, increased the college enrollment rate relative to those in the North.

To see the differential effects across regions, i.e, the South and the North, I estimate a difference-in-difference-in-differences estimator derived from an equation below.

$$
\begin{aligned}
Y_{iat} &= \alpha_t + \gamma Post + \delta_a + X_{it}\beta \\
&+ \alpha_t^B B + \gamma^{PB} Post \cdot B + \delta_a^B B + X_{it} \cdot B\beta^B + \alpha_t^S S + \gamma^{PS} Post \cdot S + \delta_a^S \cdot S + X_{it} \cdot S\beta^S \\
&+ \alpha_t^{BS} B_{it} \cdot S + \gamma^{PBS} Post \cdot B_{it} \cdot S + \delta_a^{BS} B \cdot S + X_{it} \cdot B \cdot S\beta^{BS} + \varepsilon_{iat}
\end{aligned}
$$

where $Post = 1$ for cohorts born between 1966 and 1968 while $Post = 0$ for cohorts born between 1961 and 1963, $B = 1$ for black while $B = 0$ for white, and $S = 1$ if live in the South while $S = 0$ if live in the North. The parameter of interest is $\gamma^{PBS} = [(\gamma^{BS} - \gamma^{WS}) - (\gamma^{BN} - \gamma^{WN})]_{P=1} - [(\gamma^{BS} - \gamma^{WS}) - (\gamma^{BN} - \gamma^{WN})]_{P=0}$.

Table 3.4 provides the results. For the estimation with linear time trends, column (2) shows that the post-desegregation cohorts of black in the South had improved the proportion of being on the modal grade by 7% points compared to the pre-desegregation cohorts (born between 1961 and 1963). Similarly, column (5) of Table 3.4 indicates that the South-North differences in black-white gap in high school dropout rates with post-desegregation cohorts are narrowed by 7% points relative to pre-desegregation cohorts. For high school completion rates, as can be seen in column (8) of Table 3.4, the post-desegregation cohorts improve the black-white gap by 7% points. Although marginally significant without time effects or insignificant with time effects, the post-desegregation cohort effect on college enrollment rate is 4 to 7% points.

3.5.3 Ordered Logit Model

Finally, I estimate the ordered logit model with 3 and 4 categories of outcome, respectively. Four categories include high school dropout, still in school, high school graduate, and college enrollment in an order. Three categories exclude a "still in school" category. I estimate the ordered logit model separately for the South and the North as follows

$$\begin{aligned}\log\left[\frac{P(Y_{iat}\leq j)}{1-P(Y_{iat}\leq j)}\right] &= \alpha_t^W+\gamma^W Post+\delta_a^W+X_{it}\beta^W\\ &+ (\alpha_t^B-\alpha_t^W)B+(\gamma^B-\gamma^W)Post\cdot B+(\delta_a^B-\delta_a^W)B+X_{it}(\beta^B-\beta^W)B+\varepsilon_{iat}\\ j&=1,\ldots,J-1\end{aligned}$$

where J denotes number of categories which are 3 or 4 in this paper. $Post=1$ for post-desegregation cohorts while $Post=0$ for pre-desegregation cohorts, and $B=1$ for black, $B=0$ for white.

In column (2), (4), and (6) of Table 3.5, the post-desegregation cohorts in the North have 0.25 to 0.31 decrease in the log odds ratio of getting more education, given all other variables are being constant. As indicated in the curly brackets, the odds ratio of getting more education for the post-desegregation cohorts in the North are 0.74, 0.77, and 0.78 without, with linear, and with quadratic time effects, respectively. It implies that those cohorts in the South are more likely to get additional education relative to those in the North. To see the South-North differences, I combine the regions and then estimate following ordered logit model.

$$\begin{aligned}\log\left[\frac{P(Y_{iat}\leq j)}{1-P(Y_{iat}\leq j)}\right] &= \alpha_t+\gamma Post+\delta_a+X_{it}\beta+\alpha_t^B B+\gamma^{PB}Post\cdot B+\delta_a^B B+X_{it}\cdot B\beta^B\\ &+ \alpha_t^S S+\gamma^{PS}Post\cdot S+\delta_a^S\cdot S+X_{it}\cdot S\beta^S\\ &+ \alpha_t^{BS}B_{it}\cdot S+\gamma^{PBS}Post\cdot B_{it}\cdot S+\delta_a^{BS}B\cdot S+X_{it}\cdot B\cdot S\beta^{BS}+\varepsilon_{iat}\\ j&=1,\ldots,J-1\end{aligned}$$

where J denotes number of categories of which are 3 or 4 in this paper. $Post=1$ for post-desegregation cohorts while $Post=0$ for pre-desegregation cohorts, $B=1$ for black, $B=0$ for white, and $S=1$ if live in the South while $S=0$ if live in the North. The parameter of interest is γ^{PBS}.

Columns (1) to (3) in Table 3.6 show the results for outcome with 4 categories (i.e., high school dropout, still in school, high school graduate, and college enrollment), and columns (4) to (6) for outcome with 3 categories (i.e., high school dropout, high school graduate, and college enrollment). The post-desegregation cohort effects are positive and significant in either 4 or 3 category-outcome. As shown in curly brackets, the odds of attaining more education for the post-desegregation cohorts are 1.39 to 1.62, relative to pre-desegregation cohorts, given that all other variables are being constant. These results are consistent with previous results, which suggest that the hospital desegregation may play an important role on the increase in educational attainment.

The results derived from the ordered logit model above are based on the proportional odds assumption or the parallel regression assumption, which stipulates that the relationship between each pair of outcome groups is the same. For example, $\gamma_j^{PBS} = \gamma$ for all j. If this assumption holds, then the odds ratio of college enrollment (category 3) is the same as the odds ratio of high school graduation or college enrollment (category 2 or 3). This assumption can be tested by the Brant (1990) test. The row of "proportional odds test for post cohort" in Table 3.6 shows the results. Given the chi-square statistics, the null hypothesis of the proportional odds assumption cannot be rejected.[14]

3.6 Alternative Hypotheses

In this section, I examine the alternative hypotheses which could explain the narrowed black-white gap in educational attainment. Those alternative hypotheses include some of the social program of War on Poverty (e.g., Medicaid and Head Start) and the school desegregation.

3.6.1 Medicaid

Medicaid was enacted in 1965 for providing the health services mainly to welfare recipients while Medicare was for the aged. Thus, one might expect that Medicaid could increase hospital access of poor people, inducing the improvement in educational attainment of those cohorts born after 1965. Note that, for Medicaid to be the main deriving forces of the results of this paper, the timing of implementation of Medicaid in the South should be matched with that of hospital integration in the South. However, Medicaid was implemented around 1969 in most states in the South while the most states in the North implemented much earlier than the South. Half of states (8 out of 16 states) in the

[14]Even under the non-parallel regression assumption, the generalized ordered logit gives the similar results (not shown).

South introduced Medicaid after July 1968 (Gruber, 2007)[15]. To the extent that implementation of Medicaid in the South occurred mostly after 1968, post-integration cohorts (especially born between 1966 and 1968) could not be mainly affected by Medicaid program. Considering the timing of implementation, one should expect that the reduction in black-white gap in educational attainment would be greater in the North than South if Medicaid affected cohort born between 1966 and 1968. Thus, the findings of this paper can put Medicaid effect aside from the hospital integration effects for the post-integration cohorts.

3.6.2 Head Start

The Head Start was established in 1965 as an eight-week summer program for poor children age 3 to 5 in the United States. This program would provide poor children and their families with comprehensive services, including education. If the participation rates in 1965 (birth cohorts born between 1960 and 1962) and in 1972 (cohorts born between 1967 and 1969) are not different, then the Head Start program cannot explain the educational attainment for cohorts born between 1967 and 1969 compared with for those born between 1960 and 1962.

Also, if Head Start spending per 4-year-old in the South as of 1968 (cohorts born in 1964) are *not different* from those as of 1972 (cohorts born in 1968), then the Head Start cannot explain the cohort-based educational attainment. Data from Ludwig and Miller (2007) show that Head Start spending per 4-year-old in the South as of 1968 ($315) is not different from those as of 1972 ($308), rather it actually decreased for cohorts born in 1968 relative to those born in 1964.

3.6.3 School Desegregation

First, Coleman (1975) shows that the degree of the school desegregation in 1968 in the U.S. was quite low. In the South region (Southeast and West South), black-white segregation was 0.77, compared with 0.67 and 0.70 in the East North and the West North, respectively.[16] Thus, it could not be the case in which the reduction in black-white gap in educational attainment for cohorts born between 1966 and 1968 is driven by the school desegregation.

Guryan (2004) also estimates the effect of school desegregation using cohorts born between 1963 and 1965 as a treatment group and cohorts born after 1965 (and before 1963) as control group. He argues that the school desegregation has reduced high school dropout rate of cohorts born during 1963-65 compared with those cohort born after 1965. Since the control group in his study were

[15] Eight states are South Carolina, Tennessee, Virginia, Alabama, Arkansas, Florida, Mississippi, and North Carolina

[16] Overall segregation in U.S. was 0.72.

exposed to the hospital integration, his results indirectly supports the fact that school desegregation could not fully explain the increase in the educational attainment of post-integration cohorts born between 1966 and 1968.[17]

Also, Chay et al. (2008) show that black-exposure-to-whites of students (commonly used measure of school desegregation) began to increase among cohorts born in 1958 and continued increasing, but it began to stabilize by the 1967 or 1968 cohort. These patterns of the school desegregation do not match with those of reduction in black-white gap in educational attainment.

3.7 Conclusion

The Civil Rights Acts of 1964 and the implementation of Medicare in 1966 forced the end of racial segregation in hospitals. The effects of this effort – to eliminate the racial separation and unequal access to health care – on educational attainment, however, has not been fully understood.

This paper explores the effects of the hospital desegregation on educational attainment using cohort-based analysis. The results show that black cohorts born after the hospital desegregation have substantially increased the attainment in formal schooling, relative to those cohorts born before the hospital desegregation, arguably through the health improvement in early life. Those cohorts born after the desegregation reduced the high school dropout rate by 7 percentage point while increased high completion rate and college enrollment rate by 7 percentage points and 4 to 7 percentage points, respectively.

Given that hospital desegregation was not the only policy aimed to reduce the racial differences in the Southern area during the mid- and late 1960s, some of other social programs or policies may have affected the reduction in black-white gap in educational attainment – i.e., Medicaid, Head Start, or school desegregation. Any of these alternative explanations, however, does not match with the timing of reduction in cohort-based black-white gap in educational attainment.

Future work will need more information to fully utilize the differential timing of hospital desegregation even within the South – i.e., county-level data on the hospital desegregation and educational attainment within the South. In addition, investigation of the impacts on labor market productivity of individuals measured by wages will be an important area of the future research.

[17]For the purpose of comparison, the effect of hospital integration for cohorts born between 1966 and 1968 (7 percentage points) is bigger than Guryan (2004)'s estimates for the effect of school desegregation for cohorts born between 1963 adn 1965 (3.8 percentage points).

Table 3.1: Summary Statistics

	Black			White		
	All regions	South	North	All regions	South	North
	(1)	(2)	(3)	(1)	(2)	(3)
Educational attainment (fraction)						
High School Dropout	0.17	0.18	0.17	0.09	0.12	0.07
	(0.38)	(0.38)	(0.38)	(0.28)	(0.32)	(0.26)
High School Completion	0.59	0.58	0.59	0.80	0.77	0.82
	(0.49)	(0.49)	(0.49)	(0.40)	(0.42)	(0.38)
College Enrollment	0.28	0.27	0.28	0.48	0.46	0.49
	(0.45)	(0.44)	(0.45)	(0.50)	(0.50)	(0.50)
Householder's education (fraction)						
0-4 years of schooling	0.07	0.09	0.03	0.01	0.02	0.01
	(0.25)	(0.29)	(0.18)	(0.11)	(0.14)	(0.08)
5-6 years of schooling	0.07	0.09	0.05	0.02	0.03	0.01
	(0.25)	(0.28)	(0.21)	(0.12)	(0.16)	(0.11)
7-8 years of schooling	0.11	0.14	0.10	0.07	0.08	0.08
	(0.32)	(0.34)	(0.30)	(0.26)	(0.27)	(0.27)
9 years of schooling	0.07	0.08	0.07	0.03	0.04	0.03
	(0.26)	(0.27)	(0.25)	(0.18)	(0.20)	(0.18)
10 years of schooling	0.10	0.10	0.10	0.05	0.05	0.05
	(0.30)	(0.30)	(0.30)	(0.22)	(0.22)	(0.23)
11-12 years of schooling (no diploma)	0.09	0.08	0.10	0.04	0.04	0.04
	(0.28)	(0.28)	(0.30)	(0.19)	(0.19)	(0.19)
High school graduate	0.30	0.27	0.35	0.38	0.35	0.41
	(0.46)	(0.44)	(0.48)	(0.49)	(0.48)	(0.49)
1-3 years of college	0.12	0.10	0.13	0.17	0.17	0.15
	(0.33)	(0.30)	(0.34)	(0.37)	(0.37)	(0.35)
Bachelor's degree and more	0.06	0.05	0.07	0.23	0.23	0.21
	(0.25)	(0.22)	(0.26)	(0.42)	(0.42)	(0.41)
Householder's marital status						
Married	0.47	0.50	0.44	0.82	0.82	0.84
	(0.50)	(0.50)	(0.50)	(0.38)	(0.39)	(0.37)
Sample size	11,370	6,422	4,138	64,364	16,842	36,128

Notes: Data consist of cohorts born between 1956 and 1973 and aged between 18 and 19 who were dependent family members only. The South consists of Alabama, Mississippi, Kentucky, Tennessee, Arkansas, Louisiana, Oklahoma, Texas, Virginia, West Virginia, North/South Carolina, Georgia, Florida, Delaware, and Maryland. The North consists of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North/South Dakota, Nebraska, and Kansas. The standard deviations are in the parentheses.
Sources: Current Population Survey (CPS), October Supplement from 1972 to 1992.

Table 3.2: Estimates of the South-North differences in black-white gap

	Modal Grade		HS Dropout Rates		HS Completion Rates		College Enrollment Rates	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Householder's education								
5-6 years of schooling	0.03	0.02	0.09	0.09	0.01	0.01	0.03	0.03
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)
7-8 years of schooling	-0.08	-0.08	0.10	0.10	-0.12*	-0.12*	-0.01	-0.01
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.05)	(0.05)
9 years of schooling	-0.02	-0.02	0.11	0.11	-0.16**	-0.16**	-0.06	-0.06
	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.06)	(0.06)
10 years of schooling	-0.09	-0.09	0.08	0.08	-0.12	-0.11	-0.05	-0.05
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)
11-12 years of schooling (no diploma)	-0.15**	-0.15**	0.11	0.11	-0.10	-0.10	-0.06	-0.06
	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.06)	(0.06)
High school graduate	-0.10	-0.10	0.13**	0.13**	-0.16**	-0.16**	-0.03	-0.03
	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.05)	(0.05)
1-3 years of college	-0.09	-0.09	0.13**	0.13**	-0.18**	-0.18**	-0.03	-0.03
	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)
Bachelor's degree and more	-0.04	-0.04	0.17***	0.17***	-0.21***	-0.21***	-0.06	-0.06
	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)
Householder's marital status								
Married	-0.01	-0.01	0.03	0.03	-0.04*	-0.04*	0.01	0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Age effects								
16 years old	0.03*	0.03*						
	(0.02)	(0.02)						
19 years old			0.03	0.03	-0.01	-0.01	-0.02	-0.02
			(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Table 3.2: Estimates of the South-North differences in black-white gap (continued)

	Modal Grade		HS Dropout Rates		HS Completion Rates		College Enrollment Rates	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Birth cohort effects								
1961	-0.01	-0.13	0.00	0.03	0.09	0.23	0.17**	0.36*
	(0.06)	(0.14)	(0.06)	(0.16)	(0.07)	(0.20)	(0.07)	(0.19)
1962	0.09	-0.06	-0.03	0.01	0.16**	0.31	0.13*	0.33
	(0.06)	(0.16)	(0.06)	(0.16)	(0.07)	(0.21)	(0.07)	(0.20)
1963	-0.06	-0.22	-0.02	0.01	0.13*	0.28	0.04	0.24
	(0.06)	(0.17)	(0.05)	(0.17)	(0.07)	(0.21)	(0.07)	(0.21)
1964	0.02	-0.15	-0.07	-0.03	0.14*	0.29	0.11	0.31
	(0.06)	(0.18)	(0.06)	(0.17)	(0.07)	(0.22)	(0.07)	(0.21)
1965	0.07	-0.11	-0.02	0.02	0.14*	0.29	0.14**	0.34*
	(0.06)	(0.19)	(0.05)	(0.17)	(0.08)	(0.21)	(0.07)	(0.21)
1966	0.01	-0.17	-0.10*	-0.06	0.19**	0.33	0.13*	0.33
	(0.07)	(0.19)	(0.05)	(0.16)	(0.08)	(0.21)	(0.07)	(0.20)
1967	0.16**	-0.03	-0.10*	-0.06	0.26***	0.40**	0.15**	0.34*
	(0.07)	(0.19)	(0.06)	(0.16)	(0.08)	(0.20)	(0.08)	(0.20)
1968	0.10	-0.08	0.02	0.06	0.16*	0.29	0.24***	0.41**
	(0.07)	(0.19)	(0.05)	(0.15)	(0.09)	(0.19)	(0.08)	(0.19)
1969	0.11	-0.07	0.05	0.08	0.08	0.20	0.09	0.25
	(0.07)	(0.19)	(0.06)	(0.14)	(0.09)	(0.18)	(0.08)	(0.17)
1970	0.13*	-0.04	0.04	0.07	0.18**	0.28*	0.22***	0.35**
	(0.07)	(0.18)	(0.06)	(0.12)	(0.09)	(0.16)	(0.08)	(0.15)
1971	0.13*	-0.03	-0.06	-0.04	0.27***	0.35**	0.24***	0.36**
	(0.07)	(0.17)	(0.06)	(0.11)	(0.09)	(0.14)	(0.08)	(0.14)
1972	0.10	-0.04	-0.01	0.01	0.16*	0.23*	0.08	0.17
	(0.08)	(0.16)	(0.06)	(0.09)	(0.09)	(0.13)	(0.09)	(0.12)
1973	0.03	-0.10	0.05	0.06	0.11	0.16	0.17*	0.23**
	(0.08)	(0.15)	(0.06)	(0.08)	(0.10)	(0.11)	(0.09)	(0.10)

Table 3.2: Estimates of the South-North differences in black-white gap (continued)

	Modal Grade		HS Dropout Rates		HS Completion Rates		College Enrollment Rates	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Birth cohort effects								
1974	0.09	-0.01	0.04	0.04	0.17*	0.18*	0.13	0.15
	(0.08)	(0.13)	(0.06)	(0.07)	(0.10)	(0.10)	(0.09)	(0.09)
1975	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	(0.08)	(0.11)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
1976	-0.07	-0.11						
	(0.09)	(0.10)						
1977	0.13	0.11						
	(0.09)	(0.09)						
1978	0.00	0.00						
	(0.00)	(0.00)						
Time effects								
Linear	-0.01**	0.03	-0.01*	-0.01	-0.00	-0.03	0.00	-0.04
	(0.00)	(0.04)	(0.00)	(0.03)	(0.01)	(0.04)	(0.00)	(0.04)
Quadratic		-0.00		0.00		0.00		0.00
		(0.00)		(0.00)		(0.00)		(0.00)
R-squared	0.09	0.09	0.09	0.09	0.14	0.15	0.18	0.18
Sample size	81,115	81,115	63,530	63,530	63,530	63,530	63,530	63,530

Notes: The modal grade is the year of school in which the largest proportion of students of a given age is enrolled. The Baseline group is the birth cohort born in 1956 (for column 1 and 2) and 1953 (for column 3 to 8), age of 15 (for column 1 and 2) or 18 (for column 3 to 8), and whose householders are unmarried (including the case in which spouse was absent) and have 0 to 4 years of education. Estimated standard errors are corrected for heteroskedasticity.

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

Table 3.3: Difference-in-differences estimates of black-white gap

	Modal Grade						High School Dropout Rates					
	South	North	South	North	South	North	South	North	South	North	South	North
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Householder's education												
5-6 years of schooling	-0.02	-0.04	-0.01	-0.04	-0.01	-0.04	0.06	-0.02	0.06	-0.02	0.06	-0.02
	(0.04)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)
7-8 years of schooling	-0.12***	-0.03	-0.12***	-0.03	-0.12***	-0.03	0.16***	0.07	0.16***	0.07	0.16***	0.07
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
9 years of schooling	-0.11***	-0.09	-0.11***	-0.09	-0.11***	-0.09	0.19***	0.09	0.20***	0.09	0.20***	0.09
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)
10 years of schooling	-0.16***	-0.05	-0.15***	-0.05	-0.15***	-0.05	0.16***	0.09	0.17***	0.09	0.17***	0.09
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
11-12 years of schooling	-0.22***	-0.04	-0.19***	-0.05	-0.19***	-0.05	0.17***	0.07	0.17***	0.07	0.17***	0.07
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)
High school graduate	-0.17***	-0.04	-0.14***	-0.04	-0.14***	-0.04	0.20***	0.08	0.21***	0.08	0.21***	0.08
	(0.03)	(0.06)	(0.03)	(0.06)	(0.03)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
1-3 years of college	-0.13***	0.01	-0.09**	0.00	-0.09**	0.00	0.18***	0.08	0.20***	0.08	0.20***	0.08
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
BAs degree and more	-0.10***	-0.02	-0.07*	-0.03	-0.08*	-0.03	0.19***	0.04	0.20***	0.05	0.21***	0.05
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
Householder's marital status												
Married	-0.00	0.00	-0.00	0.01	-0.00	0.01	0.01	-0.02	0.01	-0.02	0.01	-0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Age effects												
16 years old	-0.02	-0.05***	-0.02	-0.05***	-0.02	-0.05***						
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)						
19 years old							0.05***	0.03**	0.05***	0.03**	0.05***	0.03**
							(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Birth cohort effects												
Post cohort (1966-68)	0.02	-0.03	0.03	-0.05*	0.02	-0.04	-0.05**	0.02	-0.04**	0.03	-0.04**	0.02
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Time effects												
Linear			-0.00**	0.00***	0.00	-0.00			-0.00*	-0.00	-0.00	-0.00
			(0.00)	(0.00)	(0.00)	(0.01)			(0.00)	(0.00)	(0.00)	(0.01)
Quadratic					-0.00	0.00					0.00	0.00
					(0.00)	(0.00)					(0.00)	(0.00)
Observations	30,997	50,118	30,997	50,118	30,997	50,118	23,264	40,266	23,264	40,266	23,264	40,266
R-squared	0.08	0.06	0.09	0.07	0.09	0.07	0.10	0.07	0.10	0.07	0.10	0.07

Table 3.3: Difference-in-differences estimates of black-white gap (continued)

	High School Completion Rates						College Enrollment Rates					
	South (13)	North (14)	South (15)	North (16)	South (17)	North (18)	South (19)	North (20)	South (21)	North (22)	South (23)	North (24)
Householder's education												
5-6 years of schooling	-0.04	-0.05	-0.04	-0.05	-0.04	-0.05	0.01	-0.02	0.01	-0.03	0.01	-0.03
	(0.05)	(0.07)	(0.05)	(0.07)	(0.05)	(0.07)	(0.03)	(0.06)	(0.03)	(0.06)	(0.03)	(0.06)
7-8 years of schooling	-0.13***	-0.01	-0.13***	-0.01	-0.13***	-0.01	-0.02	-0.01	-0.02	-0.01	-0.02	-0.01
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
9 years of schooling	-0.19***	-0.04	-0.19***	-0.04	-0.20***	-0.04	-0.08**	-0.02	-0.08**	-0.02	-0.08**	-0.02
	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
10 years of schooling	-0.16***	-0.05	-0.16***	-0.05	-0.17***	-0.05	-0.09***	-0.05	-0.09***	-0.05	-0.09***	-0.05
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
11-12 years of schooling	-0.18***	-0.09	-0.18***	-0.08	-0.18***	-0.08	-0.11***	-0.05	-0.11***	-0.05	-0.11***	-0.05
	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
High school graduate	-0.20***	-0.04	-0.20***	-0.04	-0.20***	-0.04	-0.15***	-0.12***	-0.15***	-0.11**	-0.15***	-0.12**
	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.02)	(0.05)	(0.02)	(0.05)	(0.02)	(0.05)
1-3 years of college	-0.18***	-0.01	-0.18***	-0.00	-0.18***	-0.00	-0.18***	-0.17***	-0.19***	-0.15***	-0.19***	-0.15***
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
BAs degree and more	-0.18***	0.03	-0.18***	0.03	-0.18***	0.03	-0.25***	-0.21***	-0.25***	-0.19***	-0.25***	-0.19***
	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)
Householder's marital status												
Married	0.01	0.06***	0.01	0.06***	0.01	0.06***	0.03**	0.02	0.03**	0.02	0.03**	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Age effects												
19 years old	0.04**	0.04***	0.04**	0.04***	0.04**	0.04***	-0.01	0.01	-0.01	0.01	-0.01	0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Birth cohort effects												
Post cohort (1966-68)	0.06**	-0.02	0.05*	-0.02	0.05*	-0.02	-0.03	-0.09***	-0.03	-0.07**	-0.03	-0.07**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Time effects												
Linear			0.00	0.00	0.00	0.00			0.00	-0.00***	0.00	-0.00
			(0.00)	(0.00)	(0.01)	(0.01)			(0.00)	(0.00)	(0.01)	(0.01)
Quadratic					-0.00	-0.00					-0.00	-0.00
					(0.00)	(0.00)					(0.00)	(0.00)
Observations	23,264	40,266	23,264	40,266	23,264	40,266	23,264	40,266	23,264	40,266	23,264	40,266
R-squared	0.15	0.12	0.15	0.13	0.15	0.13	0.20	0.16	0.20	0.16	0.20	0.16

Notes: See notes to Table 3.2.
***significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 3.4: Difference-in-difference-differences estimates of black-white gap

	Modal Grade			HS Dropout Rates			HS Completion Rates			College Enrollment Rates		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Householder's education												
5-6 years of schooling	0.02	0.03	0.03	0.08	0.08	0.08	0.01	0.01	0.01	0.04	0.04	0.04
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.07)
7-8 years of schooling	-0.09	-0.09	-0.09	0.09	0.09	0.09	-0.12*	-0.12*	-0.12*	-0.01	-0.01	-0.01
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.05)	(0.05)	(0.05)
9 years of schooling	-0.03	-0.02	-0.02	0.10	0.10	0.10	-0.15*	-0.15**	-0.15**	-0.06	-0.06	-0.06
	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.06)	(0.06)	(0.06)
10 years of schooling	-0.11	-0.09	-0.10	0.08	0.08	0.08	-0.11	-0.12	-0.12	-0.04	-0.04	-0.04
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)
11-12 years of schooling	-0.17**	-0.15**	-0.15**	0.09	0.10	0.10	-0.10	-0.10	-0.10	-0.06	-0.06	-0.06
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.06)	(0.06)	(0.06)
High school graduate	-0.13**	-0.10	-0.10	0.12*	0.13**	0.13**	-0.16**	-0.16**	-0.16**	-0.02	-0.03	-0.03
	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.05)	(0.05)	(0.05)
1-3 years of college	-0.14*	-0.09	-0.09	0.11*	0.12*	0.12*	-0.17**	-0.17**	-0.17**	-0.01	-0.03	-0.03
	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)
BAs degree and more	-0.07	-0.04	-0.04	0.15**	0.16**	0.16**	-0.20***	-0.21***	-0.21***	-0.04	-0.06	-0.06
	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)
Householder's marital status												
Married	-0.00	-0.01	-0.01	0.03	0.03	0.03	-0.05**	-0.04*	-0.04*	0.01	0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Age effects												
16 years old	0.03*	0.03*	0.03*									
	(0.02)	(0.02)	(0.02)									
19 years old				0.02	0.02	0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
				(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Birth cohort effects												
Post cohort (1966-68)	0.05	0.07*	0.06	-0.07**	-0.07**	-0.07**	0.08*	0.07*	0.07*	0.07*	0.04	0.04
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
	[1.27]	[1.96]	[1.57]	[2.36]	[2.15]	[2.13]	[1.88]	[1.74]	[1.74]	[1.74]	[1.10]	[1.09]
Time effects												
Linear		-0.01***	0.01		-0.00	0.00		0.00	0.00		0.00***	0.01
		(0.00)	(0.01)		(0.00)	(0.01)		(0.00)	(0.01)		(0.00)	(0.01)
Quadratic			-0.00*			-0.00			-0.00			-0.00
			(0.00)			(0.00)			(0.00)			(0.00)
Observations	81,115	81,115	81,115	63,530	63,530	63,530	63,530	63,530	63,530	63,530	63,530	63,530
R-squared	0.08	0.08	0.08	0.09	0.09	0.09	0.14	0.14	0.14	0.18	0.18	0.18

Notes: Absolute value of t-ratios are in square brackets. ***significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Table 3.5: Ordered-logit estimates of black-white gap

	Educational Choice (4 categories)					
	South	North	South	North	South	North
	(1)	(2)	(3)	(4)	(5)	(6)
Householder's education						
5-6 years of schooling	-0.20	-0.10	-0.21	-0.10	-0.20	-0.10
	(0.19)	(0.27)	(0.19)	(0.27)	(0.19)	(0.27)
7-8 years of schooling	-0.59***	-0.12	-0.60***	-0.12	-0.60***	-0.12
	(0.16)	(0.24)	(0.16)	(0.24)	(0.16)	(0.24)
9 years of schooling	-0.86***	-0.26	-0.86***	-0.26	-0.87***	-0.26
	(0.18)	(0.25)	(0.18)	(0.25)	(0.18)	(0.25)
10 years of schooling	-0.78***	-0.31	-0.79***	-0.29	-0.80***	-0.30
	(0.17)	(0.24)	(0.17)	(0.24)	(0.17)	(0.24)
11-12 years of schooling	-0.86***	-0.35	-0.87***	-0.33	-0.87***	-0.33
	(0.18)	(0.24)	(0.18)	(0.24)	(0.18)	(0.24)
High school graduate	-1.03***	-0.45**	-1.05***	-0.42*	-1.05***	-0.42*
	(0.15)	(0.22)	(0.15)	(0.23)	(0.15)	(0.23)
1-3 years of college	-1.16***	-0.59**	-1.17***	-0.54**	-1.18***	-0.54**
	(0.17)	(0.24)	(0.17)	(0.24)	(0.17)	(0.24)
Bachelor's degree and more	-1.55***	-0.82***	-1.57***	-0.78***	-1.57***	-0.78***
	(0.19)	(0.26)	(0.20)	(0.26)	(0.20)	(0.26)
Householder's marital status						
Married	0.02	0.15**	0.03	0.14**	0.03	0.14**
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Age effects						
19 years old	-0.07	0.06	-0.07	0.07	-0.07	0.07
	(0.06)	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)
Birth cohort effects						
Post cohort (1966-68)	0.10	-0.31**	0.07	-0.26**	0.08	-0.25**
	(0.11)	(0.12)	(0.11)	(0.12)	(0.11)	(0.12)
	[0.89]	[2.55]	[0.66]	[2.07]	[0.70]	[2.02]
	{1.10}	{0.74}	{1.08}	{0.77}	{1.08}	{0.78}
Time effects						
Linear			0.00	-0.01*	0.02	0.00
			(0.01)	(0.01)	(0.02)	(0.03)
Quadratic					-0.00	-0.00
					(0.00)	(0.00)
Observations	23,264	40,266	23,264	40,266	23,264	40,266
Pseudo R-squared	0.10	0.08	0.10	0.08	0.10	0.08

Note: See notes to Table 3.2. Baseline group is the birth cohorts born between 1961 and 1963, age of 18, and whose householders are unmarried (spouse being absent) and have 0 to 4 years of education. Dependent variable has four categories: "high school dropout"; "still in school"; "high school graduates"; and "college enrollment". Estimated standard errors in parentheses are corrected for heteroskedasticity. Absolute values of t-ratios are in square brackets, and odds ratios are in curly brackets.
***significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

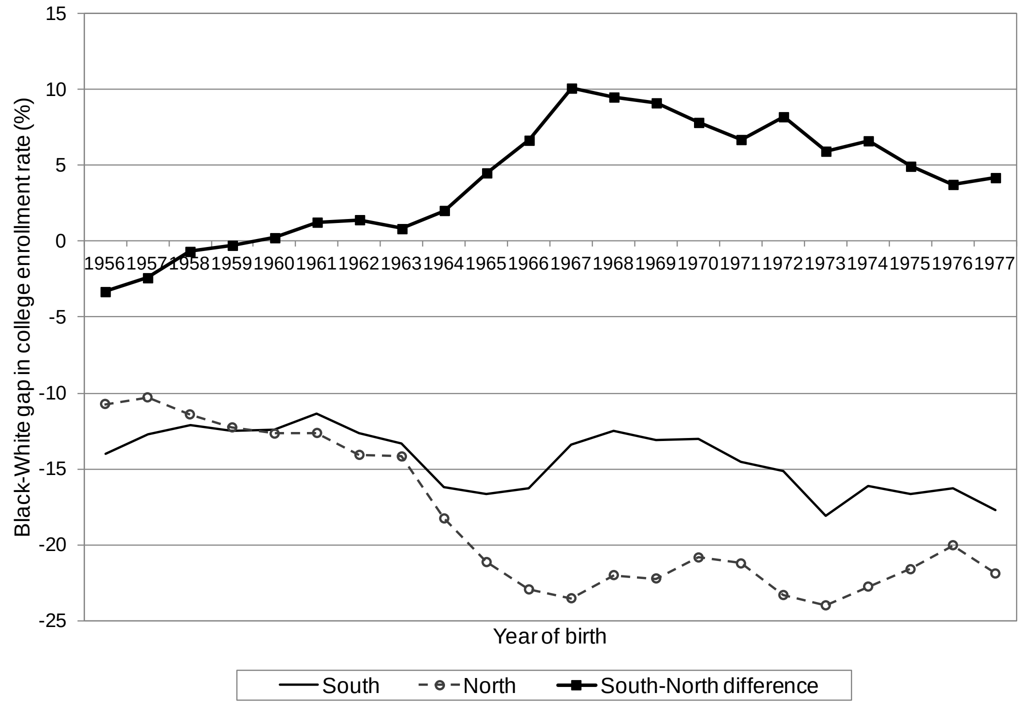
Table 3.6: Ordered-logit estimates of the South-North differences in black-white gap

	Educational Choice (4 categories)			Educational Choice (3 categories)		
	(1)	(2)	(3)	(4)	(5)	(6)
Householder's education						
5-6 years of schooling	-0.12	-0.12	-0.11	-0.02	-0.03	-0.01
	(0.33)	(0.33)	(0.33)	(0.46)	(0.46)	(0.46)
7-8 years of schooling	-0.49*	-0.50*	-0.50*	-0.31	-0.30	-0.30
	(0.29)	(0.29)	(0.29)	(0.38)	(0.38)	(0.38)
9 years of schooling	-0.63**	-0.64**	-0.64**	-0.51	-0.52	-0.52
	(0.31)	(0.31)	(0.31)	(0.41)	(0.41)	(0.41)
10 years of schooling	-0.51*	-0.53*	-0.53*	-0.38	-0.41	-0.42
	(0.29)	(0.29)	(0.29)	(0.39)	(0.39)	(0.39)
11-12 years of schooling	-0.55*	-0.58*	-0.58*	-0.55	-0.60	-0.61
	(0.30)	(0.30)	(0.30)	(0.40)	(0.40)	(0.40)
High school graduate	-0.63**	-0.67**	-0.67**	-0.53	-0.60*	-0.60*
	(0.27)	(0.27)	(0.27)	(0.36)	(0.36)	(0.36)
1-3 years of college	-0.62**	-0.68**	-0.68**	-0.43	-0.54	-0.54
	(0.29)	(0.30)	(0.30)	(0.38)	(0.38)	(0.38)
Bachelor's degree and more	-0.76**	-0.82**	-0.82**	-0.63	-0.73*	-0.73*
	(0.32)	(0.32)	(0.32)	(0.41)	(0.41)	(0.41)
Householder's marital status						
Married	-0.12	-0.10	-0.10	-0.10	-0.07	-0.08
	(0.10)	(0.10)	(0.10)	(0.12)	(0.12)	(0.12)
Age effects						
19 years old	-0.12	-0.13	-0.13	-0.19*	-0.20*	-0.20*
	(0.09)	(0.09)	(0.09)	(0.11)	(0.11)	(0.11)
Birth cohort effects						
Post cohort (1966-68)	0.40**	0.33**	0.33*	0.48**	0.37*	0.36*
	(0.16)	(0.17)	(0.17)	(0.21)	(0.21)	(0.21)
	[2.46]	[1.97]	[1.95]	[2.35]	[1.76]	[1.72]
	{1.50}	{1.39}	{1.39}	{1.62}	{1.45}	{1.43}
Time effects						
Linear		0.02**	0.02		0.03**	0.02
		(0.01)	(0.04)		(0.01)	(0.04)
Quadratic			-0.00			0.00
			(0.00)			(0.00)
Proportional odds test for Post cohort						
Chi-square	1.02	1.46	1.38	1.44	2.33	2.25
P-value	0.602	0.481	0.502	0.230	0.127	0.134
Observations	63,530	63,530	63,530	55,350	55,350	55,350
Pseudo R-squared	0.09	0.09	0.09	0.12	0.12	0.12

Note: See notes to Table 3.2. Baseline group is the birth cohorts born between 1961 and 1963, age of 18, and whose householders are unmarried (spouse being absent) and have 0 to 4 years of education. For Column (1) to (3), dependent variable has four categories: "high school dropout"; "still in school"; "high school graduates"; and "college enrollment". For column (4) to (6), "still in school" category is excluded. Estimated standard errors in parentheses are corrected for heteroskedasticity. Absolute values of t-ratios are in square brackets, and odds ratios are in curly brackets.

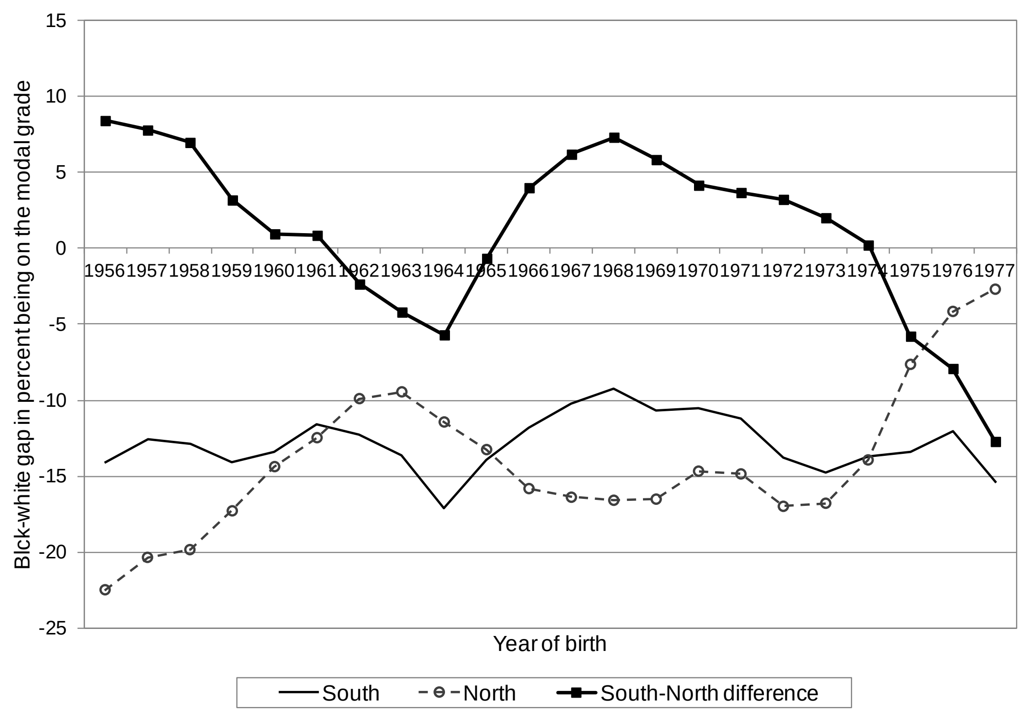
*** significant at 1-percent level, ** significant at 5-percent level, * significant at 10-percent level.

Figure 3.1: Black-white gap in college enrollment rates by year of birth (individuals aged 18 to 19)



Notes: Each line is smoothed by three-year moving averages.
Sources: Current population Survey (CPS), October Supplement.

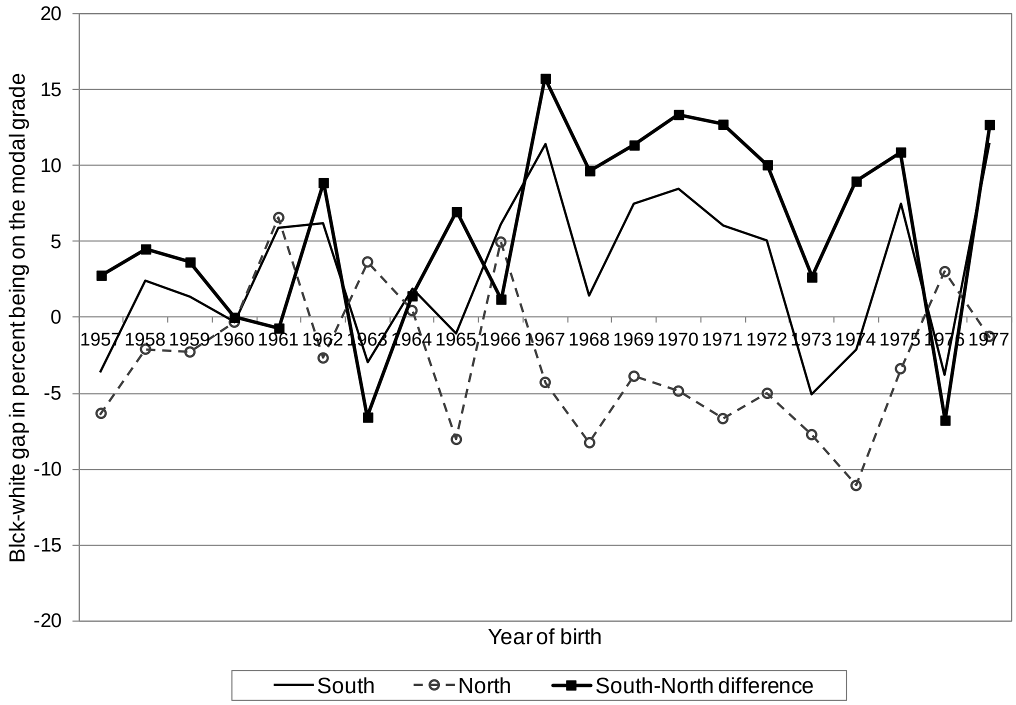
Figure 3.2: Black-white gap in percent being on the modal grade (individuals aged 15)



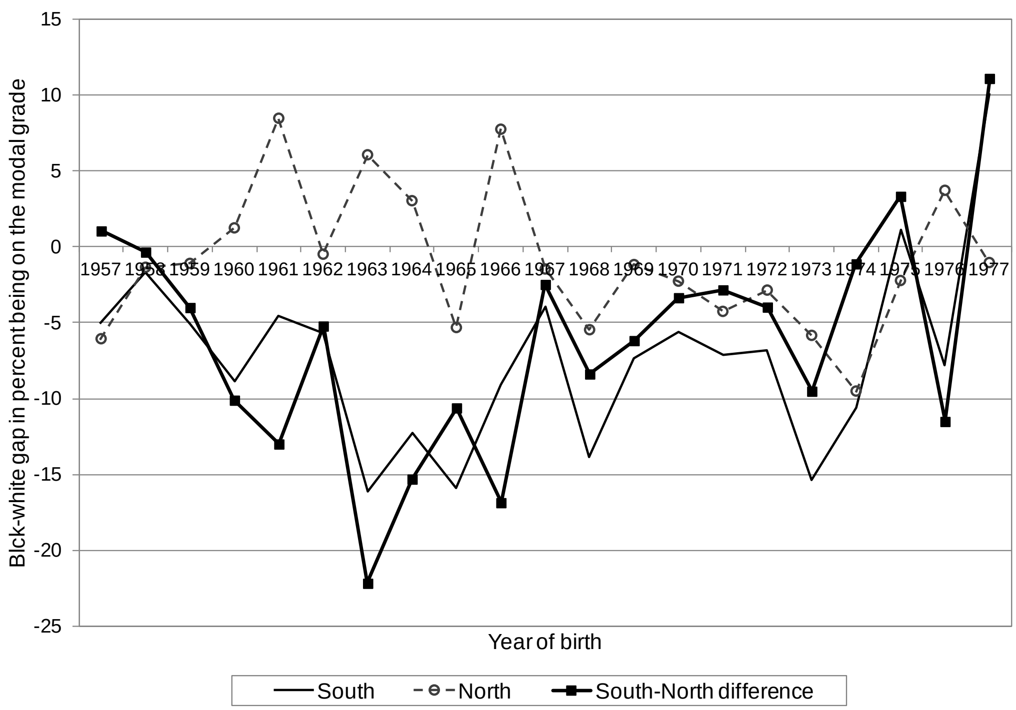
Notes: The modal grade is the year of school in which the largest proportion of students of a given age is enrolled. Each line was smoothed by three-year moving averages.
Sources: Current population Survey (CPS), October Supplement.

Figure 3.3: Black-white gap in percent being on the modal grade (individuals aged 15 to 16)

A. Adjusted for linear time trend



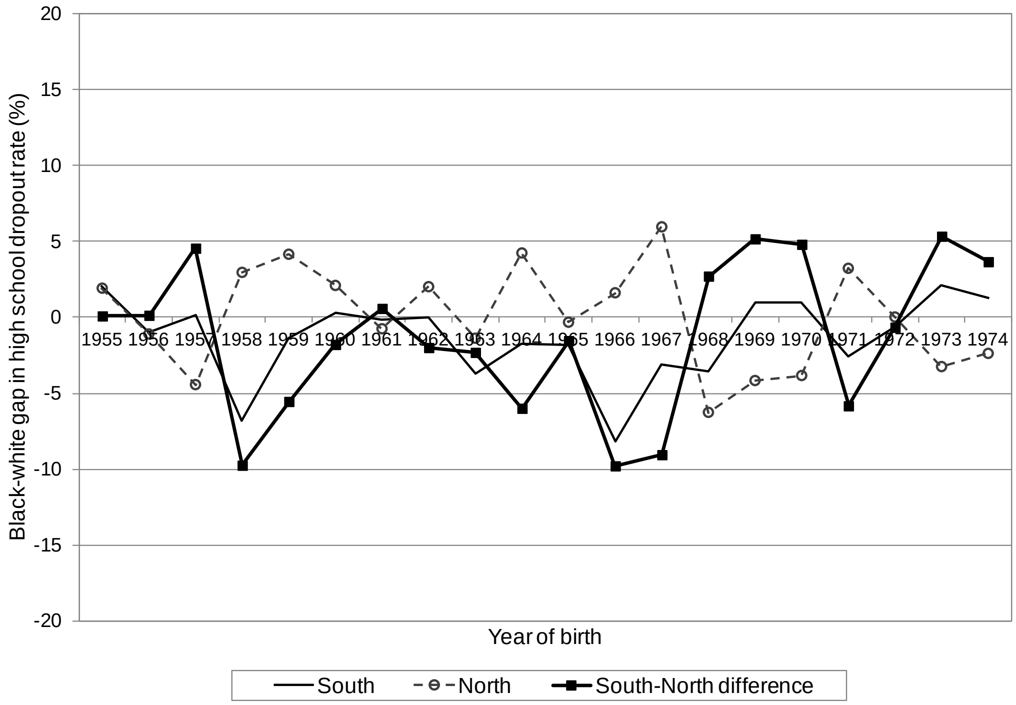
B. Adjusted for quadratic time trend



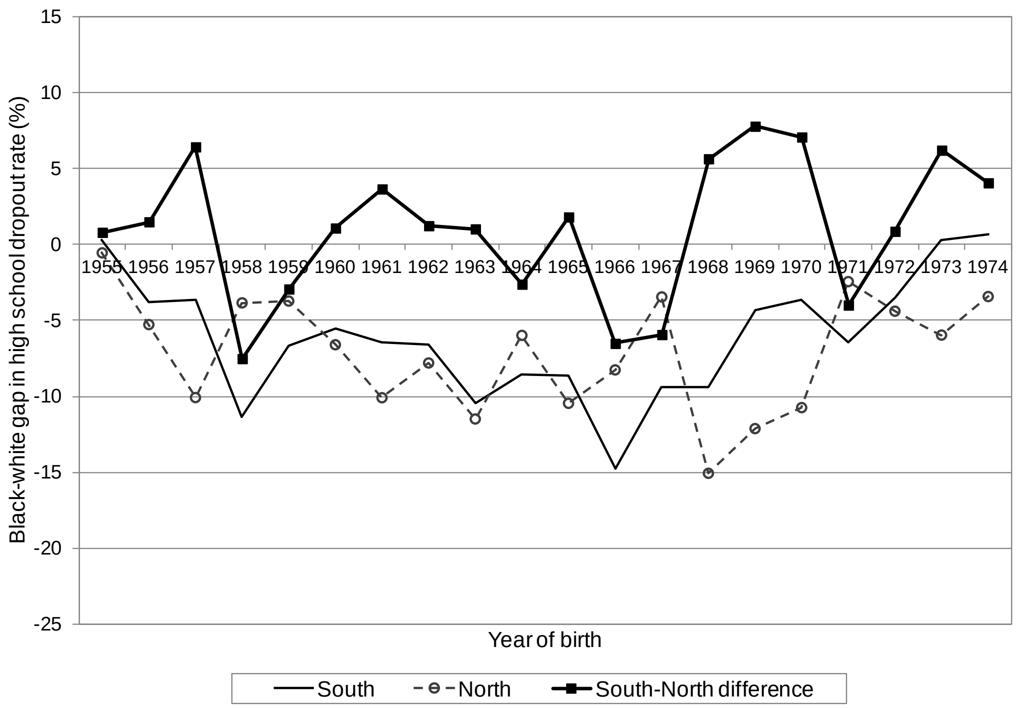
Notes: Figures are adjusted for householder's education, marital status, and individual age effects. The modal grade is the year of school in which the largest proportion of students of a given age is enrolled. Sources: Current population Survey (CPS), October Supplement.

Figure 3.4: Black-white gap in high school dropout rates (individuals aged 18 to 19)

A. Adjusted for linear time trend



B. Adjusted for quadratic time trend

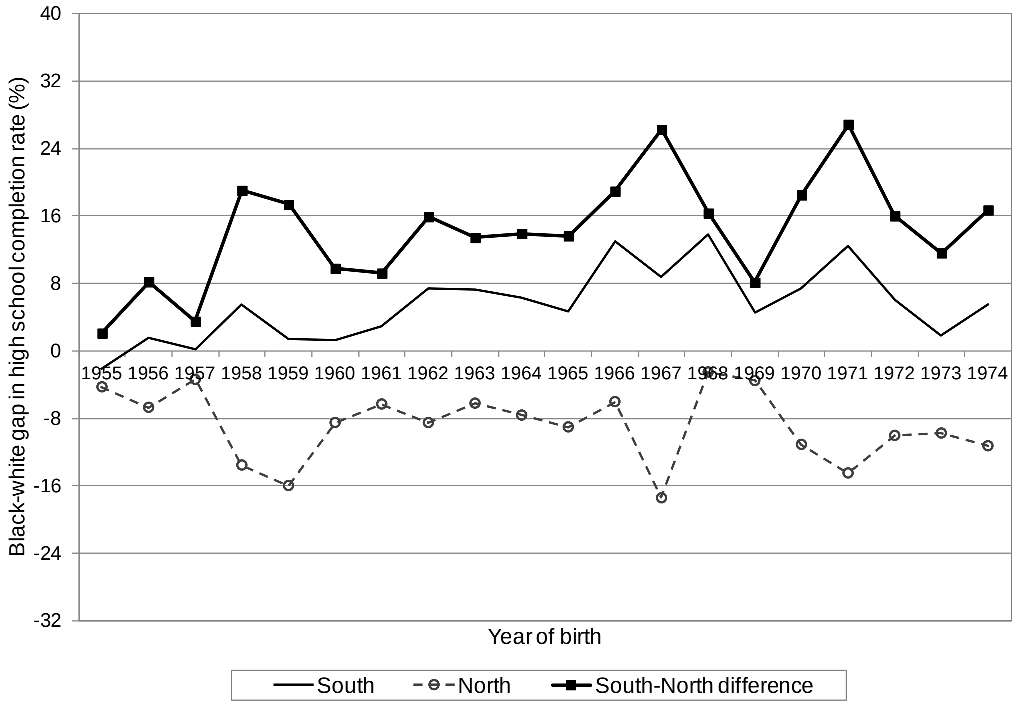


Notes: See notes to Figure 3.3.

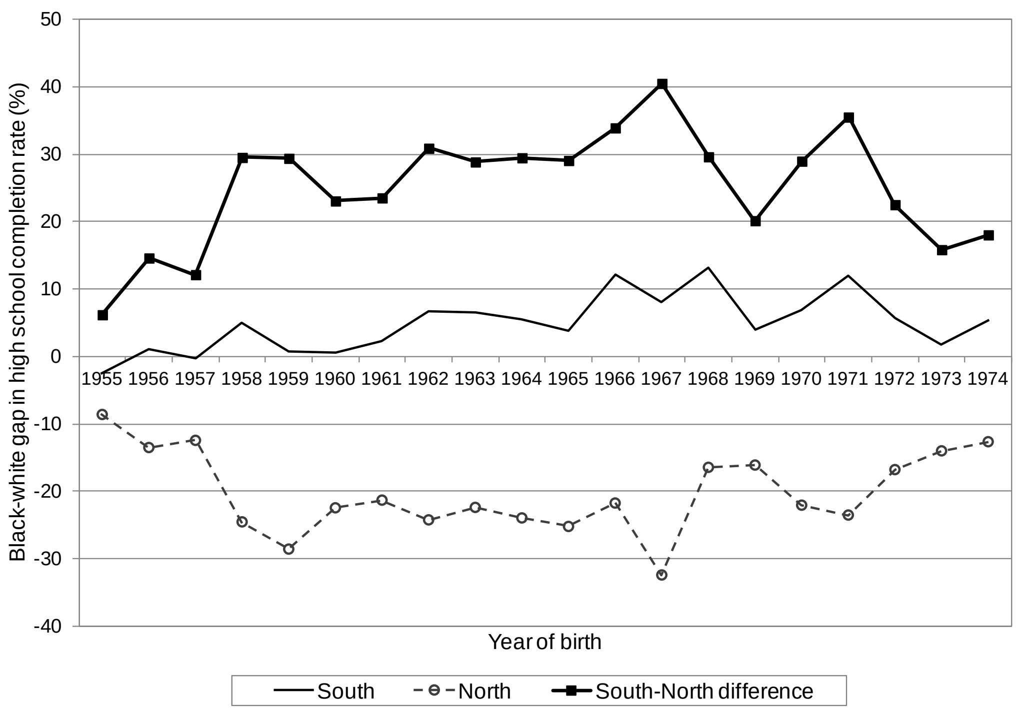
Sources: Current population Survey (CPS), October Supplement.

Figure 3.5: Black-white gap in high school completion rates (individuals aged 18 to 19)

A. Adjusted for linear time trend



B. Adjusted for quadratic time trend

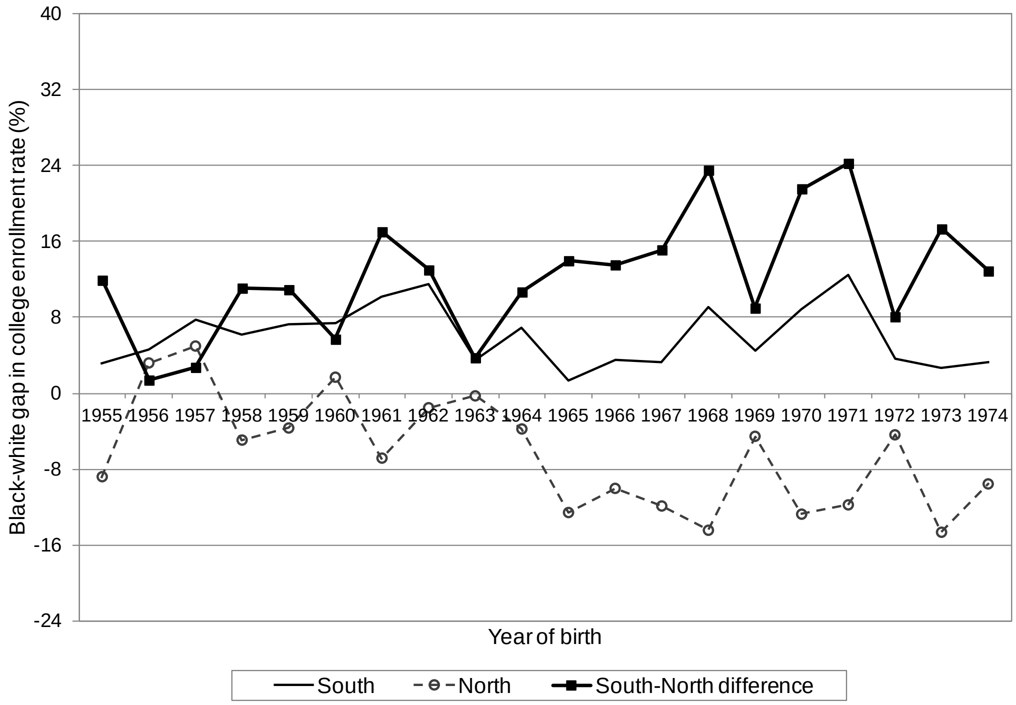


Notes: See notes to Figure 3.3.

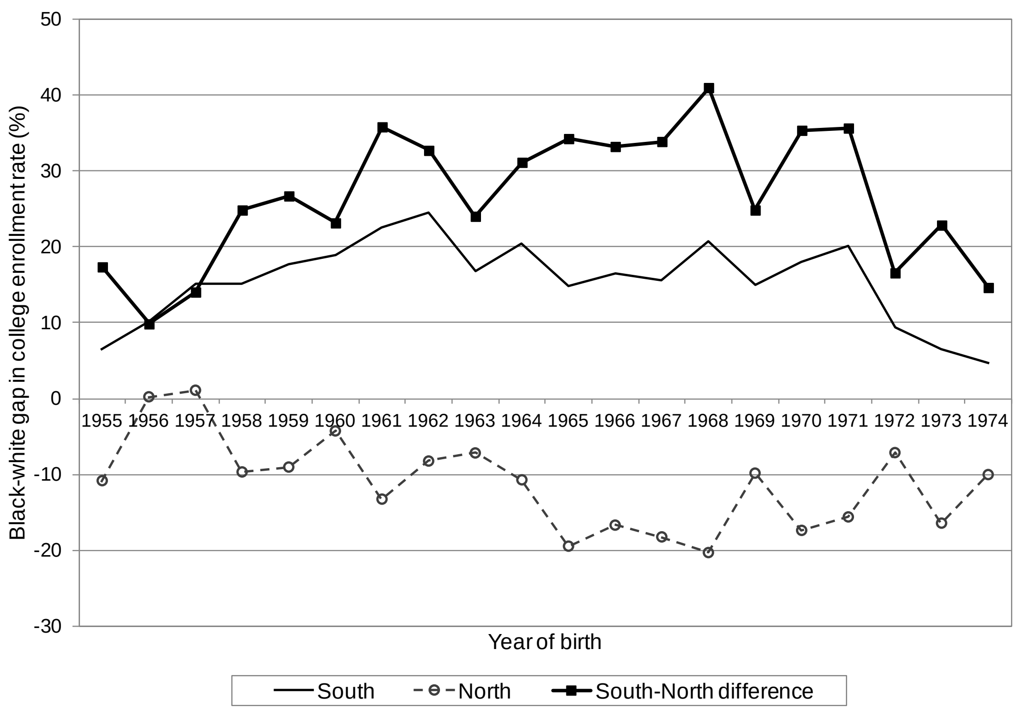
Sources: Current population Survey (CPS), October Supplement.

Figure 3.6: Black-white gap in college enrollment rates (individuals aged 18 to 19)

A. Adjusted for linear time trend



B. Adjusted for quadratic time trend



Notes: See notes to Figure 3.3.

Sources: Current population Survey (CPS), October Supplement.

3.A Proof of Proposition

This appendix provides the proof of equation (3.9). From Equation (3.6) and (3.7), the Lagrangian function become

$$\mathcal{L} = \sum_{t=1}^{\infty}(1-\rho)^t \log(X_t) \cdot \frac{H_t}{\overline{H}} - \lambda \left[\sum_{t=1}^{\infty} \left(\frac{1}{1+r} \right)^t \left(p_m \left[\frac{H_t - (1-\delta)H_{t-1}}{q} \right]^{\frac{1}{\phi}} + X_t \right) - Y \right] \tag{3.14}$$

Then, the first order condition gives

$$\frac{\partial \mathcal{L}}{\partial X_\tau} = \frac{(1-\rho)^\tau}{X_\tau} \frac{H_\tau}{\overline{H}} - \lambda \left(\frac{1}{1+r} \right)^\tau = 0 \tag{3.15}$$

$$\frac{\partial \mathcal{L}}{\partial H_\tau} = (1-\rho)^\tau \frac{\log(X_\tau)}{\overline{H}} - \lambda \left(p_m \frac{1}{\phi} \left[\frac{H_t - (1-\delta)H_{t-1}}{q} \right]^{\frac{1}{\phi}-1} \left\{ \frac{1}{q} \left(\frac{1}{1+r} \right)^\tau - \frac{(1-\delta)}{q} \left(\frac{1}{1+r} \right)^{\tau+1} \right\} \right) = 0 \tag{3.16}$$

Substituting Equation (3.15) into Equation (3.16),

$$(1-\rho)^\tau \frac{\log(X_\tau)}{\overline{H}} - \frac{(1-\rho)^\tau (1+r)^\tau}{X_\tau} \frac{H_\tau}{\overline{H}} \left(\frac{p_m}{q} \frac{1}{\phi} \frac{1}{(1+r)^\tau} \left[\left(m_\tau^\phi\right)^{\frac{1}{\phi}-1} - \frac{1-\delta}{1+r} \left(m_{\tau+1}^\phi\right)^{\frac{1}{\phi}-1} \right] \right) = 0 \tag{3.17}$$

Equivalently,

$$F \equiv \log(X_\tau) X_\tau \cdot \phi - H_\tau \frac{p_m}{q} \left[\left(m_\tau^\phi\right)^{\frac{1}{\phi}-1} - \frac{1-\delta}{1+r} \left(m_{\tau+1}^\phi\right)^{\frac{1}{\phi}-1} \right] = 0 \tag{3.18}$$

Then, by the implicit function theorem,

$$\frac{\partial m_\tau}{\partial q} = -\frac{\frac{\partial F}{\partial q}}{\frac{\partial F}{\partial m_\tau}} \tag{3.19}$$

First, since $H_\tau = q m_\tau^\phi - (1-\delta) \cdot H_{\tau-1}$

$$\frac{\partial F}{\partial q} = \frac{(1-\delta)H_{\tau-1}}{q^2} > 0 \tag{3.20}$$

Second,

$$\frac{\partial F}{\partial m_\tau} = -\phi q m_\tau^{\phi-1} \cdot p_m \left(m_\tau^{1-\phi} - \frac{1-\delta}{1+r} m_{\tau+1}^{1-\phi} \right) - H_\tau \cdot p_m \left((1-\phi) m_\tau^{-\phi} \right) < 0 \tag{3.21}$$

Hence,

$$\frac{\partial m_\tau}{\partial q} = -\frac{\frac{\partial F}{\partial q}}{\frac{\partial F}{\partial m_\tau}} > 0 \tag{3.22}$$

For the proof of second inequality of Equation (3.9),

$$\frac{\partial F}{\partial X_\tau} = \phi + \phi \log X_\tau > 0 \tag{3.23}$$

From Equation (3.20), $\frac{\partial F}{\partial q} > 0$. Therefore, by the implicit function theorem again,

$$\frac{\partial X_\tau}{\partial q} = -\frac{\frac{\partial F}{\partial q}}{\frac{\partial F}{\partial X_\tau}} < 0 \tag{3.24}$$

■

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