Moral Hazard and Less Invasive Medical Treatment for Coronary Artery Disease:
An Analysis of Smoking in the National Health Interview Survey*

Shin-Yi Chou       Jason Hockenberry       Michael Grossman       Jesse Margolis**

November 1, 2012

Abstract

We use Medicare claims data linked to the National Health Interview Survey (NHIS) to study how changes in patient smoking behavior are related to three common treatments for Coronary Artery Disease (CAD): medical management, Percutaneous Coronary Intervention (PCI), and Coronary Artery Bypass Graft (CABG). We find that those who have surgery, particularly more invasive surgery, are more likely to quit smoking. Compared to CAD patients who are medically managed, patients who have PCI or CABG are 74% and 197% more likely to quit smoking, respectively, in the one-year window surrounding their surgery. This and other behavioral responses may partially offset the inherent risks in more invasive surgery and help explain why the longer term outcomes for CABG patients rival or even exceed those of similar patients receiving PCI or medical management.

DRAFT – PLEASE DO NOT CITE

* We would like to thank Peter Cram for his medical insight and Sandra Decker for her advice on working with the linked NHIS/Medicare data. All errors are our own.

** Chou: Lehigh University and NBER (syc2@lehigh.edu). Grossman: City University of New York Graduate Center and NBER (mgrossman@gc.cuny.edu). Hockenberry: Emory University and NBER (jason.hockenberry@emory.edu). Margolis: City University of New York Graduate Center (jmargolis@gc.cuny.edu).
I. Introduction

Coronary Artery Disease (CAD) is a common and deadly disease. In 2010, over 350,000 people died of CAD in the United States, making the disease responsible for roughly one in seven deaths (Murphy, Xu, and Kochanek, 2012). CAD is caused by a build up of plaque on the arterial walls leading to the heart, resulting in reduced blood flow. If the build up is not checked, CAD can result in a myocardial infarction (MI) (aka “heart attack”) due to insufficient oxygen reaching the heart.

A number of medical treatments are available to patients with CAD. First, and least invasive, is “medical management.” Medical management involves non-surgical treatment including prescription medication, lifestyle modification, and frequent monitoring. The second treatment is a surgical procedure known as Percutaneous Coronary Intervention (PCI). A surgeon performing PCI makes a small incision and arthroscoically inserts and inflates a balloon at the site of the lesion to expand the vessel. PCI in the modern era usually involves the placement of a wire mesh stent at the blockage site, which assists in keeping the arterial walls expanded to maintain blood flow. The PCI procedure takes approximately 60 minutes and the patient usually spends one night in the hospital.1 The third and generally most invasive treatment is Coronary Artery Bypass Graft (CABG) surgery2, a major procedure that involves harvesting a section of vessel from a different area of the body (either vessels in the groin or chest wall) and opening the chest cavity via a sternectomy and connecting one healthy part of the diseased artery to another, surgically bypassing the lesion. CABG surgery takes approximately four hours and patients generally spend at least a week recovering in the hospital.3

Of the two surgical procedures, PCI is the more recent, having been initially used in the late 1970s, more than a decade after CABG was first performed, and its use expanding rapidly upon FDA approval of the coronary stent in 1994 (Cutler and Huckman, 2003). Since the development of PCI, there have been numerous studies comparing the effectiveness of the two procedures in various populations (see Rodriguez et al. 2001 and Serruys et al. 2009 for two recent articles with a summary of prior research). While the results vary, our general interpretation is that PCI involves lower perioperative mortality– due partly to fewer surgical

---

1 http://www.medicinenet.com/coronary_artery_bypass_graft/article.htm (accessed 5/31/12)
2 Less invasive CABG procedures have been in development and increasing use in recent years, though these were very infrequent during the period we examine.
3 http://www.medicinenet.com/coronary_angioplasty/article.htm (accessed 5/31/12)
complications from a less invasive procedure – but that the two procedures have similar long term outcomes. In other words, among those patients who don’t have surgical complications, CABG patients have better long term outcomes than PCI patients.

In this paper, we test one hypothesis that may explain why CABG patients have relatively good long-term outcomes, despite a higher surgical complication rate. Specifically, we expect that the more invasive nature of CABG surgery – a patient is in the hospital for a week, has a longer post-operative recovery period, and is left with a major scar and residual pain from the sternectomy long after the procedure – sends a stronger signal to the patient that he as a serious health problem. As a result, we hypothesize that a patient who undergoes CABG rather than PCI is more likely to change his behavior in a way that promotes good health and a longer life: he is more likely to quit smoking, begin exercising, improve his diet, and avoid excessive alcohol intake.

This hypothesis is consistent with a prior economic research on moral hazard, showing that individuals change their behavior when their perceived risks change. Peltzman’s (1975) study of the effects of automobile safety regulation is a classic and seminal example. He develops a model in which the introduction of the legally mandated installation of various safety devices on automobiles lowers the price of driving intensity (faster and more reckless driving) because it lowers the probability that the driver will die in an accident. Hence the demand for this activity rises. Empirically, he finds that the increase in this offsetting behavior (reckless driving) is so large that the regulations at issue had very little impact on highway deaths and actually increased pedestrian deaths. More recently, Kaestner and Dave (2009) investigate the impact of health insurance access on the health behaviors of the elderly, showing that access to Medicare at age 65 leads to a reduction in preventative behaviors and an increase in risky health behavior amongst the elderly. Peltzman (2008) demonstrates how medical technology breakthroughs can lead to offsetting behavior by showing that the age cohorts that benefited the most from the introduction of antibiotics experienced worse mortality rates from risky health behaviors.

In this study, we test one potential behavioral response to surgery – smoking – and find behavior consistent with patient offsetting behavior. Patients who undergo a more invasive treatment for CAD are more likely to quit smoking. Compared to CAD patients who are medically managed, patients who have PCI or CABG are 74% and 197% more likely to quit
smoking, respectively, in the one-year window surrounding their surgery. Our results are robust to a number of different specifications, including a simple grouped-by-year regression using 11 observations, done in the spirit of Donald & Lang (2007).

II. Data

In this study, we look at individual Medicare data merged with responses from the National Health Interview Survey (NHIS). The Medicare records identify those patients who have been diagnosed with CAD and show which of them have undergone PCI or CABG, along with the exact date of each diagnoses and procedure. The NHIS provides information on smoking and quitting behavior, as well as individual characteristics.

The Medicare data are provided by the Center for Medicare & Medicaid Services (CMS). To identify CAD patients and the type of treatment they underwent, we use the Medicare Standard Analytical Files, including the Inpatient, Outpatient, Skilled Nursing Facility, Carrier, Durable Medical Equipment, Home Health Agency, and Hospice claims files. These files contain one or more records for each individual. Each record contains the ICD-9-CM codes for all diagnoses made and procedures performed during that stay or claim. We identify CAD patients as those who have at least one diagnosis code beginning with 410, 411, 412, 413, or 414. We identify PCI patients as those CAD patients with at least one procedure code beginning with 0066, 3601, 3605, 3606, 3608, or 3609. We identify CABG patients as those CAD patients with procedure codes beginning with 361. Finally, we identify medically managed patients as those patients who have been diagnosed with CAD, but do not have a concurrent or subsequent PCI or CABG procedure.

The NHIS is an annual survey of approximately 85,000 individuals in over 30,000 U.S. households run by the National Center for Health Statistics (NCHS), part of the Centers for Disease Control and Prevention (CDC). All participants are asked questions about their general

---

4 A single record in the Inpatient file corresponds to a stay in a hospital. A single record in the Skilled Nursing Facility file corresponds to a stay in a Skilled Nursing Facility. A single record in the Outpatient file corresponds to a claim by an institutional outpatient provider (Hospital outpatient clinic, rural health clinics, etc.). A single record in the Carrier claim file corresponds to a claim by a non-institutional outpatient provider (physicians, physician assistants, etc.)

5 For both PCI and CABG, we exclude the small number of patients that do not have a concurrent or prior CAD diagnosis.

6 A patient who is diagnosed with CAD before her NHIS interview date and has PCI or CABG after her NHIS interview date is counted as medically managed at the time of the NHIS survey.
state of health and disability. Each year, a subset of approximately 30,000 individuals is asked about their smoking habits. These respondents are asked if they have ever smoked 100 cigarettes in their life. For those who say yes, they are asked if they currently smoke every day, some days, or not at all. If they do not currently smoke, they are asked when they quit, a question they can answer in days, weeks, months, or years. We use the responses to these questions to create a synthetic panel, identifying whether a person smoked on each date prior to their NHIS interview. Each person is categorized as either an always smoker, a never smoker, or a quitter who smoked up to the day he or she reports quitting.  

The individual NHIS responses have been linked to Medicare data by the CDC and CMS, and been made available as a restricted-use dataset to researchers. To date, the CDC and CMS have linked the 1994-1998 NHIS surveys to Medicare data from 1991-2007 and the 1999-2005 NHIS surveys to Medicare data from 1999-2007. The linkage is illustrated in Figure 1.

The individual NHIS responses have been linked to Medicare data by the CDC and CMS, and been made available as a restricted-use dataset to researchers. To date, the CDC and CMS have linked the 1994-1998 NHIS surveys to Medicare data from 1991-2007 and the 1999-2005 NHIS surveys to Medicare data from 1999-2007. The linkage is illustrated in Figure 1.

Figure 1 – NHIS/Medicare Data Link

|---------------|------------------------------------------------------------------------------------------------|

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NHIS</td>
<td>1999 2000 2001 2002 2003 2004 2005</td>
</tr>
<tr>
<td>Medicare</td>
<td>1999 2000 2001 2002 2003 2004 2005</td>
</tr>
</tbody>
</table>

Note: the Medicare years labeled on the chart are potentially useful for our study because they represent a Medicare record that is linked to a later NHIS interviews. Medicare records linked to earlier NHIS interviews provide no information on quitting behavior after CAD treatment.

For those respondents who were diagnosed with CAD prior to their NHIS interview date, we have the ability to look at their smoking behavior before and after their diagnosis. For the subset of CAD patients who underwent PCI or CABG surgery, we can also look at their smoking behavior before and after their procedure. For example, for individuals interviewed in 1994 who had PCI, we can look at their smoking behavior before and after surgery only if they had surgery.

---

7 This categorization vastly over-simplifies the complexity of smoking and quitting behavior, but still allows us to investigate our key question: what is the difference in quitting behavior between CAD patients undergoing medical management, PCI, or CABG.
between 1991 and 1994 (and within 1994, only if they had surgery before the date of the NHIS interview). If a person had PCI before 1991, then we have no record of their surgery. If a person had PCI after 1994, then we have no record of their smoking behavior after their surgery.

Each person in the linked dataset, therefore, has a “diagnosis window” within which they must be diagnosed with CAD to be included in our study. The longest window is for a person who was interviewed in 1998 – he will be included in our study if he was enrolled in Medicare and diagnosed with CAD at any point between 1991 and 1998. The shortest window is for a person who was interviewed in early 1999 – he will be included only if he was enrolled in Medicare and diagnosed with CAD on an earlier date in 1999 than the date of his interview.

III. Initial Analysis

In total, 12,265 NHIS respondents were linked to Medicare data and diagnosed with CAD during their diagnosis window. Of these individuals, between the date of their diagnosis and the date of their NHIS interview, 10,774 patients were treated only with medical management, 721 patients underwent PCI but not CABG surgery, and 766 patients underwent CABG surgery. Ninety-nine (99) patients underwent both PCI and CABG surgery. These patients are included in the CABG category, because that is the more invasive treatment. Our results are robust to including them in the PCI category or excluding them altogether.

Basic characteristics of these patients are shown in Table 1. Overall, when compared to medical management, patients who receive surgery (PCI or CABG) are more likely to be younger, male, and white. When comparing PCI to CABG, the patients appear to have largely similar characteristics, though CABG patients are somewhat more likely to be male and have a lower average Body Mass Index (BMI).

Table 2 shows the current smoking status of each group of respondents – medical management, PCI, and CABG – as of the date of the NHIS interview. In looking at this table, at least two items merit notice. First, CABG patients are more likely to have ever smoked than PCI patients, who were in turn more likely to have smoked than medically managed patients (i.e. the percentage of respondents who never smoked gets lower as one moves from left to right in the table). Second, most people who have ever smoked have quit smoking by the time of the NHIS interview, a trend that is most pronounced for CABG patients. While 61.2% of CABG patients
in our study smoked at some point in their life, only 9.1% smoke as of the NHIS interview date. PCI patients have a lower proportion of quitters, followed by medically managed patients.

Table 1 – Characteristics by Treatment

<table>
<thead>
<tr>
<th></th>
<th>Medical Management</th>
<th>PCI</th>
<th>CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>*<em>Age</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 55</td>
<td>5%</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>55-64</td>
<td>8%</td>
<td>10%</td>
<td>8%</td>
</tr>
<tr>
<td>65-69</td>
<td>25%</td>
<td>27%</td>
<td>32%</td>
</tr>
<tr>
<td>70-74</td>
<td>22%</td>
<td>26%</td>
<td>27%</td>
</tr>
<tr>
<td>75-79</td>
<td>20%</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>80-84</td>
<td>13%</td>
<td>11%</td>
<td>9%</td>
</tr>
<tr>
<td>85+</td>
<td>8%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>42%</td>
<td>52%</td>
<td>59%</td>
</tr>
<tr>
<td>Female</td>
<td>58%</td>
<td>48%</td>
<td>41%</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Black</td>
<td>11%</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>8%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>White</td>
<td>78%</td>
<td>84%</td>
<td>86%</td>
</tr>
<tr>
<td>Mult./Oth/Unknown</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elem (K-8)</td>
<td>23%</td>
<td>18%</td>
<td>22%</td>
</tr>
<tr>
<td>HS (non-grad); GED</td>
<td>19%</td>
<td>23%</td>
<td>18%</td>
</tr>
<tr>
<td>HS grad</td>
<td>28%</td>
<td>29%</td>
<td>28%</td>
</tr>
<tr>
<td>Some col; AA deg.</td>
<td>17%</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>BA degree</td>
<td>7%</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Grad. Degree</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Unknown</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Family Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0 to $9,999</td>
<td>21%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>$10,000 to $19,999</td>
<td>25%</td>
<td>23%</td>
<td>25%</td>
</tr>
<tr>
<td>$20,000 to $35,000</td>
<td>19%</td>
<td>23%</td>
<td>23%</td>
</tr>
<tr>
<td>$35,000 or over</td>
<td>17%</td>
<td>21%</td>
<td>20%</td>
</tr>
<tr>
<td>Unknown</td>
<td>18%</td>
<td>17%</td>
<td>16%</td>
</tr>
<tr>
<td><strong>Health Insurance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Health Ins.</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Has Health Ins.</td>
<td>100%</td>
<td>99%</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Body Mass Index (BMI)</strong></td>
<td>26.7</td>
<td>27.4</td>
<td>26.6</td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>10,774</td>
<td>721</td>
<td>770</td>
</tr>
</tbody>
</table>

* Age as of diagnosis (CAD) or procedure (PCI / CABG)
Table 2 – Smoking Status as of NHIS Interview Date

<table>
<thead>
<tr>
<th>Smoking Status as of Survey</th>
<th>Medical Management</th>
<th>PCI</th>
<th>CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>1,326</td>
<td>87</td>
<td>70</td>
</tr>
<tr>
<td>Quit</td>
<td>4,478</td>
<td>341</td>
<td>401</td>
</tr>
<tr>
<td>Never Smoked</td>
<td>4,970</td>
<td>293</td>
<td>299</td>
</tr>
<tr>
<td>Total</td>
<td>10,774</td>
<td>721</td>
<td>770</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Smoking Status as of Survey</th>
<th>Medical Management</th>
<th>PCI</th>
<th>CABG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>12.3%</td>
<td>12.1%</td>
<td>9.1%</td>
</tr>
<tr>
<td>Quit</td>
<td>41.6%</td>
<td>47.3%</td>
<td>52.1%</td>
</tr>
<tr>
<td>Never Smoked</td>
<td>46.1%</td>
<td>40.6%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The data in Table 2 are consistent with the broad hypothesis in our study – patients who undergo a more invasive treatment for CAD are more likely quit smoking. However, they could also be consistent with a story in which people who undergo CABG surgery are also more likely to quit smoking for reasons unrelated to surgery. If our hypothesis is true, we should see that the differential quitting behavior between CABG, PCI, and medical management is driven by quits that occur close to the date of the surgery.

Figures 2 and 3 provide graphical evidence supporting our hypothesis. In Figure 2, we calculate the percentage of the population smoking each year at twelve points in time, measured in years relative to the date of diagnosis (in the case of medically managed patients) or surgery (in the case of PCI and CABG patients). In the CABG series, for example, the year -3.5 shows the percentage of CABG patients who were smoking exactly three years and six months prior to their date of surgery. In the 10 years prior to diagnosis/surgery, the three series track each other reasonably closely. At the first point on the graph, 9.5 years before diagnosis/surgery, roughly the same share of eventual CABG and PCI patients are smoking, and this share is approximately 1.5 percentage points higher than the share of eventual medical management patients smoking. The CABG and PCI series track each other very closely until 3.5 years prior to surgery, at which point the CABG series declines at a slightly faster rate. The differences between the three series emerge most starkly in the period immediately after diagnosis/surgery, when the PCI series drops below the medical management series for the first time, and the percentage of CABG recipients

---

8 Because we have data on only the most recent quit date for each individual, we assume that each smoker was smoking in all years before their quit date. Because we are using Medicare data for our analysis, most people are over 65 when they received their diagnosis or surgery. It is unlikely that these individuals started smoking for the first time in the ten years prior to their diagnosis or surgery. It is possible that individuals quit and restarted during this time period, and we do not distinguish them from continuous smokers.
smoking falls at a substantially faster rate. Six months after surgery, the percentage of CABG recipients smoking is more than three percentage points lower than the corresponding percentage for either medically managed or PCI patients.

Figure 2 – Smoking Rate by Year Relative to Diagnosis (MM) or Surgery (PCI & CABG)

Figure 3 displays the same data in a different format, showing the annual quit rate for patients in each of the three treatment groups relative to the date of diagnosis/surgery. For the group who receives only medical management, roughly 5% of smokers quit each year in the nine years prior to being diagnosed, a rate that doubled to 10% during the year of their diagnosis with coronary artery disease. The PCI and CABG series show a similar trend, though they represent fewer individuals and are somewhat nosier. In the years prior to surgery, roughly 5% of smokers quit each year, though this percentage began to rise between one and three years before surgery. During the year of surgery – defined to be the six month window on either side of the procedure date – the quit rate jumped to 18% for patients receiving PCI and 30% for patients receiving
CABG. In the year following diagnosis/surgery, the quit rate for all three groups dropped back to approximately 5%. Figures 2 and 3 provide reasonably compelling evidence that at least a portion of the increased quit rate for more invasive treatments observed in Table 2 is related to treatment received, and not simply a spurious correlation.

Figure 3 – Quit Rate by Year Relative to Diagnosis (MM) or Surgery (PCI & CABG)

IV. Results Using Individual Data

To further explore the relationship between treatment for coronary artery disease and smoking behavior, we fit two different, but related models of smoking behavior. The first is a quit model, which most closely parallels Figure 3 presented above. Conditional on a person smoking at the time of treatment, we predict her likelihood of quitting based on the treatment received – medical management, PCI, or CABG – and other control variables. The second is a participation model, which allows us to incorporate data from all 12,265 NHIS respondents for
whom we have CAD treatment data, whether they smoked or not at the time of treatment. For these respondents, we use their historical smoking answers to create a synthetic two-period panel, with the first period being before treatment and the second period being after treatment.

To fit either of these models, we have to decide what constitutes “before” and what constitutes “after.” The most straightforward definition, with the day prior to diagnosis/surgery counting as the before snapshot, and the day after diagnosis/surgery counting as the after snapshot, presents two problems. First, it seems unlikely that a large number of people quit exactly on the day of their diagnosis or surgery, so we would miss treatment-induced quits that occurred a short time before or after diagnosis/surgery. Second, our smoking data, which are based on individuals’ recollections, are insufficiently precise to pinpoint the exact day of quitting. An alternative definition, which follows the presentation in Figures 2 and 3, is to make the before snapshot exactly six months prior to diagnosis/surgery, and the after snapshot exactly six months after. This creates a “quit window” of one year – with six months on either side of the diagnosis/surgery – that will be captured by the model. We take this approach below, though our results change little with other reasonable quit window definitions (see Appendix).

Table 3 – Counts of Smokers Before and After Treatment

<table>
<thead>
<tr>
<th></th>
<th>Count</th>
<th></th>
<th></th>
<th>Count</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medical Management</td>
<td>PCI</td>
<td>CABG</td>
<td>Medical Management</td>
<td>PCI</td>
<td>CABG</td>
</tr>
<tr>
<td>Smoke before</td>
<td>1,714</td>
<td>120</td>
<td>115</td>
<td>15.9%</td>
<td>16.6%</td>
<td>14.9%</td>
</tr>
<tr>
<td>Don’t smoke before</td>
<td>9,060</td>
<td>601</td>
<td>655</td>
<td>84.1%</td>
<td>83.4%</td>
<td>85.1%</td>
</tr>
<tr>
<td>Total</td>
<td>10,774</td>
<td>721</td>
<td>770</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Smoke after</td>
<td>1,540</td>
<td>99</td>
<td>81</td>
<td>14.3%</td>
<td>13.7%</td>
<td>10.5%</td>
</tr>
<tr>
<td>Don’t smoke after</td>
<td>9,234</td>
<td>629</td>
<td>695</td>
<td>85.7%</td>
<td>87.2%</td>
<td>90.3%</td>
</tr>
<tr>
<td>Total</td>
<td>10,774</td>
<td>721</td>
<td>770</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Change in smokers</td>
<td>-174</td>
<td>-21</td>
<td>-34</td>
<td>-1.6%</td>
<td>-2.9%</td>
<td>-4.4%</td>
</tr>
<tr>
<td>% Quit (Change / Smoke before)</td>
<td>10.2%</td>
<td>17.5%</td>
<td>29.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows the raw numbers that correspond to a quit window that extends six months in either direction from diagnosis (medical management) or surgery (PCI & CABG). Among the 10,774 patients diagnosed with CAD who receive only medical management, 1,714 smoked
exactly six months before their diagnosis and 1,540 smoked exactly six months after their diagnosis. The 174 who quit smoking represent a 1.6 percentage point reduction in the number of smokers and a 10.2 percent reduction. The corresponding numbers for PCI are a 2.9 percentage point reduction and a 17.5 percent reduction. For CABG, they are a 4.4 percentage point reduction and a 29.6 percent reduction.

**Quit Model**

We first fit a quit model using only those respondents who smoked before their diagnosis or surgery. Specifically, we estimate

\[ q_i = \alpha_1 + \alpha_2 PCI_i + \alpha_3 CABG_i + \alpha_4 X_i + \epsilon_i \]  

(1)

where \( q_i \) is an indicator equal to 1 if person \( i \) quit smoking during the quit window and 0 otherwise, \( PCI_i \) is a dummy variable indicating whether person \( i \) underwent PCI surgery, \( CABG_i \) is a dummy variable indicating whether person \( i \) underwent CABG surgery, \( X_i \) is a vector of control variables, and \( \epsilon_i \) is a disturbance term. To count each person once in this regression, we assign individuals who had both PCI and CABG surgery to the CABG category, as that is the more invasive treatment.\(^9\)

The results appear in Table 4. The first column shows the simplest specification, with quitting predicted only based on the treatment dummies. According to this specification, a patient undergoing PCI is 7.5 percentage points more likely to quit than a patient diagnosed with CAD who is medically managed, a result that is significant at the 0.10 level. Moreover, a patient undergoing CABG is 20.0 percentage points more likely to quit smoking than a medically managed patient, a result that is significant at the 0.01 level. Given that 10.2% of medically managed patients quit smoking within a year in either direction of their diagnoses, these effects represent a 74% and 197% increase in the probability of quitting if one undergoes PCI or CABG, respectively.

---

\(^9\) For people who had both PCI and CABG, we cannot simply give them a 1 for both the PCI and CABG indicators, since they may have had the surgeries on different dates, requiring a different quit indicator \( q_i \) for each surgery. As shown in the appendix, our conclusions are not sensitive to assigning these patients to the PCI group or excluding them entirely.
Table 4 – Quit Model

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>0.075 *</td>
<td>0.077 *</td>
<td>0.072 *</td>
<td>0.085 **</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.040)</td>
<td>(0.040)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>CABG</td>
<td>0.200 ***</td>
<td>0.193 ***</td>
<td>0.193 ***</td>
<td>0.181 ***</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td>(0.046)</td>
<td>(0.046)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>P-Value: PCI = CABG</td>
<td>0.036 **</td>
<td>0.049 **</td>
<td>0.042 **</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Controls
Gender: X X X X
Age: X X X X
Race: X X X X
Education: X X
Health Insurance: X X
Income: X X

Observations: 1,949 1,949 1,932 1,646

Note: Robust standard errors in parentheses, clustered by PSU. Observations are weighted by the NHIS probability weights. "P-Value: PCI = CABG" is the p-value on a test of equality of the PCI and CABG coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG coefficient.

In columns 2 through 4, we see that these results are robust to adding a number of covariates, including gender, age, race, education, income, and a dummy for having health insurance coverage. In each regression, we also test the significance of the difference between the PCI and CABG coefficients. In the first three specifications, this coefficient is significant at the 0.05 level, indicating that CABG patients – who receive a substantially more invasive surgery – are more likely to quit smoking. The fourth specification includes a measure of family income, which is missing for roughly 15% of the sample. In this specification, while the magnitude of the difference between PCI and CABG patients is still large (nearly 10 percentage points), the p-value of 0.13 is not significant at traditional levels. Overall, these results provide further evidence that surgery increases the propensity for CAD patients to quit smoking, with strongest effect being for the most invasive surgery.

*Smoking Participation Model*
We also fit a model to predict smoking participation. Specifically, we estimate:

\[ s_{it} = \beta_0 + \beta_1 PCI_i + \beta_2 CABG_i + \beta_3 After_t + \beta_4 PCI_i * After_t + \beta_5 CABG_i * After_t + \epsilon_i \]  

(2)

This model is estimated for each of 12,265 individuals \( i \) and each of two time periods \( t \). The first time period is before diagnosis/surgery and corresponds to exactly six months prior to diagnosis, in the case of medical management patients, or surgery, in the case of PCI or CABG patients. The second time period is after diagnosis/surgery and corresponds to exactly six months after diagnosis or surgery. As before, \( PCI_i \) and \( CABG_i \) are indicators equal to 1 if a person had PCI or CABG surgery, respectively, and 0 otherwise. \( After_t \) is an indicator equal to 1 in the period after diagnosis/surgery and 0 before. The coefficients of interest are \( \beta_4 \) and \( \beta_5 \), which reflect the differential effect on smoking in the after period for PCI and CABG patients, respectively.

Table 5 – Smoking Participation Model

<table>
<thead>
<tr>
<th></th>
<th>( PCI )</th>
<th>( CABG )</th>
<th>( After )</th>
<th>( PCI * After )</th>
<th>( CABG * After )</th>
<th>Constant</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.003</td>
<td>-0.007</td>
<td>-0.016 ***</td>
<td>-0.011 *</td>
<td>-0.029 ***</td>
<td>0.158 **</td>
<td>24,530</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.001)</td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.004)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Robust standard errors, clustered by PSU in parentheses. Observations are weighted by the NHIS probability weights. "P-Value: PCI*After = CABG*After" is the p-value on a test of equality of the PCI*After and CABG*After coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG*After coefficient.
The results are shown in Table 5. In the *after* period, the percentage of PCI patients who smoke decreased by 1.1 percentage points more than for medically managed patients, a result that is statistically significant at the 0.10 level. The percentage of CABG patients who smoke decreased by 2.9 percentage points more than for medically managed patients, a result that is statistically significant at the 0.01 level. A test of equality between the two coefficients has a p-value of 0.08, indicating that we would be unlikely to see this substantial a difference between the PCI and CABG patients due solely to chance. Like the quit model, the participation model provides evidence that more invasive treatments for CAD are associated with larger decreases in smoking.

V. Results Using Grouped Data

In the section above, we have presented reasonably compelling evidence that smoking behavior changed differentially in each of the three treatment groups for coronary artery disease. Our quit model showed that a CABG patients quit smoking at a higher rate than PCI patients, who in turn quit at a higher rate than medically managed patients. In essence, we showed that the sample size is large enough to conclude that the three points at Year 0 in Figure 3 are different from one another, a result that largely held up after including a number of control variables. Our participation model showed that a smaller share of CABG patients smoked after surgery, when controlling for prior smoking, than did PCI or medical management patients. In essence, we showed that the sample size is large enough to conclude that the three points at Year 0.5 in Figure 2 are different from one another when controlling for the “before” period at Year -0.5.

With both of these specifications, we are testing uncertainty related to sample size. Are the differences we are seeing big enough that it is improbable they would go away if we gathered more data? However, there is another type of uncertainty that is important to consider: is the smoking behavior of the patients with less invasive treatment a valid counterfactual for the smoking behavior of patients with more invasive treatment? While we may demonstrate that smoking behavior almost certainly changed differentially for patients receiving CABG, PCI and medical management, why should we expect that their smoking behavior would otherwise have been the same absent treatment?
Figures 2 and 3 provide additional data that can provide one avenue for addressing this uncertainty. In addition to the period right around diagnosis/surgery, we have also constructed historical data on smoking participation and quitting rates.\(^{10}\) This data is shown in Table 6.

### Table 6 – Smoking Participation Grouped Data

<table>
<thead>
<tr>
<th>Year</th>
<th>CABG</th>
<th>PCI</th>
<th>MM</th>
<th>CABG</th>
<th>PCI</th>
<th>MM</th>
<th>CABG - PCI</th>
<th>PCI - MM</th>
<th>CABG - MM</th>
<th>Treat</th>
</tr>
</thead>
<tbody>
<tr>
<td>-9.5</td>
<td>26.8%</td>
<td>26.2%</td>
<td>24.8%</td>
<td>-1.7%</td>
<td>-1.1%</td>
<td>-1.3%</td>
<td>-0.6%</td>
<td>-0.4%</td>
<td>0.2%</td>
<td>0</td>
</tr>
<tr>
<td>-8.5</td>
<td>25.1%</td>
<td>25.1%</td>
<td>23.5%</td>
<td>-1.4%</td>
<td>-1.5%</td>
<td>-0.9%</td>
<td>0.1%</td>
<td>-0.5%</td>
<td>-0.6%</td>
<td>0</td>
</tr>
<tr>
<td>-7.5</td>
<td>23.6%</td>
<td>23.6%</td>
<td>22.6%</td>
<td>-1.0%</td>
<td>-1.4%</td>
<td>-1.0%</td>
<td>0.3%</td>
<td>-0.1%</td>
<td>-0.4%</td>
<td>0</td>
</tr>
<tr>
<td>-6.5</td>
<td>22.6%</td>
<td>22.2%</td>
<td>21.6%</td>
<td>-0.8%</td>
<td>-0.8%</td>
<td>-1.0%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0</td>
</tr>
<tr>
<td>-5.5</td>
<td>21.8%</td>
<td>21.4%</td>
<td>20.6%</td>
<td>-0.9%</td>
<td>-1.2%</td>
<td>-0.9%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>-0.3%</td>
<td>0</td>
</tr>
<tr>
<td>-4.5</td>
<td>20.9%</td>
<td>20.1%</td>
<td>19.7%</td>
<td>-0.9%</td>
<td>-0.3%</td>
<td>-0.9%</td>
<td>-0.6%</td>
<td>0.0%</td>
<td>0.7%</td>
<td>0</td>
</tr>
<tr>
<td>-3.5</td>
<td>20.0%</td>
<td>19.8%</td>
<td>18.7%</td>
<td>-0.9%</td>
<td>-0.3%</td>
<td>-0.9%</td>
<td>-0.6%</td>
<td>0.0%</td>
<td>0.7%</td>
<td>0</td>
</tr>
<tr>
<td>-2.5</td>
<td>18.2%</td>
<td>18.9%</td>
<td>17.9%</td>
<td>-1.8%</td>
<td>-1.0%</td>
<td>-0.9%</td>
<td>-0.8%</td>
<td>-0.9%</td>
<td>-0.1%</td>
<td>0</td>
</tr>
<tr>
<td>-1.5</td>
<td>16.8%</td>
<td>18.2%</td>
<td>16.9%</td>
<td>-1.4%</td>
<td>-0.7%</td>
<td>-1.0%</td>
<td>-0.7%</td>
<td>-0.4%</td>
<td>0.3%</td>
<td>0</td>
</tr>
<tr>
<td>-0.5</td>
<td>14.9%</td>
<td>16.6%</td>
<td>15.9%</td>
<td>-1.8%</td>
<td>-1.5%</td>
<td>-1.0%</td>
<td>-0.3%</td>
<td>-0.8%</td>
<td>-0.5%</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>10.5%</td>
<td>13.7%</td>
<td>14.3%</td>
<td>-4.4%</td>
<td>-2.9%</td>
<td>-1.6%</td>
<td>-1.5%</td>
<td>-2.8%</td>
<td>-1.3%</td>
<td>1</td>
</tr>
<tr>
<td>1.5</td>
<td>9.7%</td>
<td>12.8%</td>
<td>13.5%</td>
<td>-0.8%</td>
<td>-1.0%</td>
<td>-0.8%</td>
<td>0.2%</td>
<td>0.0%</td>
<td>-0.2%</td>
<td>0</td>
</tr>
</tbody>
</table>

Columns 1-3 show the smoking participation rate for each of the three treatment groups: CABG, PCI, and medical management. Columns 4-6 show the annual change in the participation rate for each of the three treatments. Columns 7-9 show the difference-in-difference, subtracting the change in the participation rate for one treatment from another treatment. Column 7, for example, subtracts the change in the PCI participation rate from the change in the CABG participation rate. Finally, column 10 is a treatment dummy that is equal to one in the period corresponding to diagnosis/surgery and zero otherwise.

In the spirit of Donald and Lang (2007), we can use this data to perform a simple difference-in-difference regression with 11 observations. The dependent variable is the diff-in-diff value in column 7, column 8, or column 9 and the independent variable is the treatment dummy. In doing this, we are asking whether the difference in the change in the smoking

---

\(^{10}\) All of our information on quitting behavior is based on survey respondents’ recollections. While an imperfect measure, we have no reason to suspect it is any worse for periods far from diagnosis/surgery than the period immediately prior to or immediately after diagnosis/surgery. If one did assume that in periods far from diagnosis/surgery – especially those periods that are farther in the past – individuals had a worse recollection of when they quit smoking, there we see no reason to expect it would be differentially worse based on treatment.
participation rate during the treatment year is sufficiently unusual compared to past and future values that it is unlikely to have arisen by chance. If the change in the two series normally track one another but don’t during the treatment year, we would expect that there is something unusual about the treatment year. On the other hand, if the change in the two series often diverges wildly, then a substantial divergence in the treatment year might simply be due to chance. We find the former to be true.

Table 7 – Smoking Participation Regression (Grouped Data)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CABG - PCI</td>
<td>-1.30 **</td>
<td>-2.50 ***</td>
<td>-1.21 **</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.41)</td>
<td>(0.42)</td>
</tr>
<tr>
<td>CABG - MM</td>
<td>-0.21</td>
<td>-0.30 **</td>
<td>-0.09</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.12)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>PCI - MM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Note: OLS standard errors in parentheses

In all three regressions, the coefficient on the treatment is negative and statistically significant. This implies that the more invasive treatments lead to a greater than typical decline in smoking participation rates during the period right around surgery. This magnitude of this effect is largest when comparing the most invasive treatment (CABG) to the least invasive treatment (medical management).

VI. Conclusion

Coronary artery disease is a frequently occurring and deadly disease. There are several common treatments – including medical management, PCI, and CABG – and each has benefits and costs associated with it. In this paper, we have examined one previously unexplored benefit of more invasive treatment: those who have surgery, particularly more invasive surgery, are more likely to quit smoking. In our simplest model, we estimate that CAD patients who have PCI rather than medical management are 74% more likely to quit smoking in the one-year
window surrounding their surgery. Patients who have CABG are 197% more likely to quit smoking during this timeframe. These results are robust to a number of alternative specifications.

While we don’t have data on behaviors other than smoking, we suspect that patients undergoing more invasive surgery are also more likely to improve their diet, limit the excessive consumption of alcohol, and (when recommended) exercise more. Taken together, these behavioral responses may offset the inherent risks in more invasive surgery and help explain why the longer term outcomes for CABG patients rival or even exceed those of similar patients receiving PCI or medical management. Our findings also highlight the importance of emphasizing healthier behavior to those patients who have less invasive medical treatment.
VII. References


### VIII. Appendix

Table A1 – Quit Model with Dual PCI/CABG Assigned to PCI Group

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>0.064 *</td>
<td>0.066 *</td>
<td>0.062 *</td>
<td>0.066 *</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.037)</td>
</tr>
<tr>
<td>CABG</td>
<td>0.207 ***</td>
<td>0.198 ***</td>
<td>0.199 ***</td>
<td>0.185 ***</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
<td>(0.053)</td>
<td>(0.053)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>P-Value: PCI = CABG</td>
<td>0.02 **</td>
<td>0.032 **</td>
<td>0.029 **</td>
<td>0.073 *</td>
</tr>
</tbody>
</table>

#### Controls

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Insurance</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Observations: 1,951 1,951 1,934 1,647

Note: Robust standard errors in parentheses, clustered by PSU. Observations are weighted by the NHIS probability weights. "P-Value: PCI = CABG" is the p-value on a test of equality of the PCI and CABG coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG coefficient.
Table A2 – Quit Model with Dual PCI/CABG Dropped

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>0.075 *</td>
<td>0.077 *</td>
<td>0.073 *</td>
<td>0.087 **</td>
</tr>
<tr>
<td></td>
<td>(0.041)</td>
<td>(0.040)</td>
<td>(0.040)</td>
<td>(0.043)</td>
</tr>
<tr>
<td>CABG</td>
<td>0.207 ***</td>
<td>0.198 ***</td>
<td>0.199 ***</td>
<td>0.185 ***</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
<td>(0.053)</td>
<td>(0.053)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>P-Value: PCI = CABG</td>
<td>0.041 **</td>
<td>0.06 *</td>
<td>0.053 *</td>
<td>0.159</td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Insurance</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Observations</td>
<td>1,927</td>
<td>1,927</td>
<td>1,910</td>
<td>1,624</td>
</tr>
</tbody>
</table>

Note: Robust standard errors in parentheses, clustered by PSU. Observations are weighted by the NHIS probability weights. "P-Value: PCI = CABG" is the p-value on a test of equality of the PCI and CABG coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG coefficient.
Table A3 – Quit Model with a Quit Window Extending 1 Year Prior to 1 Year After Diagnosis/Surgery

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>0.123</td>
<td>0.127</td>
<td>0.120</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td>(0.046)</td>
<td>(0.046)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>CABG</td>
<td>0.223</td>
<td>0.218</td>
<td>0.218</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.046)</td>
<td>(0.047)</td>
<td>(0.050)</td>
</tr>
<tr>
<td>P-Value: PCI = CABG</td>
<td>0.114</td>
<td>0.145</td>
<td>0.119</td>
<td>0.253</td>
</tr>
</tbody>
</table>

Controls
- Gender: X, X, X
- Age: X, X, X
- Race: X, X, X
- Education: X, X
- Health Insurance: X, X
- Income: X

Observations: 2,028, 2,028, 2,011, 1,707

Note: Robust standard errors in parentheses, clustered by PSU. Observations are weighted by the NHIS probability weights. "P-Value: PCI = CABG" is the p-value on a test of equality of the PCI and CABG coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG coefficient.
Table A4 – Quit Model with a Quit Window Extending Zero Years Prior to One Year After Diagnosis/Surgery

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>0.039</td>
<td>0.043</td>
<td>0.042</td>
<td>0.046</td>
</tr>
<tr>
<td></td>
<td>(0.036)</td>
<td>(0.037)</td>
<td>(0.037)</td>
<td>(0.039)</td>
</tr>
<tr>
<td>CABG</td>
<td>0.127 ***</td>
<td>0.126 ***</td>
<td>0.127 ***</td>
<td>0.125 ***</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.043)</td>
<td>(0.043)</td>
<td>(0.045)</td>
</tr>
<tr>
<td>P-Value: PCI = CABG</td>
<td>0.102</td>
<td>0.123</td>
<td>0.119</td>
<td>0.166</td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Race</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Education</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Health Insurance</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Observations</td>
<td>1,834</td>
<td>1,834</td>
<td>1,819</td>
<td>1,551</td>
</tr>
</tbody>
</table>

Note: Robust standard errors in parentheses, clustered by PSU. Observations are weighted by the NHIS probability weights. "P-Value: PCI = CABG" is the p-value on a test of equality of the PCI and CABG coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG coefficient.
Table A5 – Participation Model Robustness Checks

<table>
<thead>
<tr>
<th></th>
<th>(3)</th>
<th>(1)</th>
<th>(2)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCI</td>
<td>-0.003</td>
<td>0.005</td>
<td>-0.012</td>
<td>0.009</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>CABG</td>
<td>-0.007</td>
<td>0.003</td>
<td>-0.019</td>
<td>-0.020</td>
<td>-0.020</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.015)</td>
<td>(0.013)</td>
<td>(0.015)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>After</td>
<td>-0.016***</td>
<td>-0.026***</td>
<td>-0.013***</td>
<td>-0.016***</td>
<td>-0.016***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>PCI * After</td>
<td>-0.011*</td>
<td>-0.022**</td>
<td>-0.004</td>
<td>-0.012*</td>
<td>-0.011*</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>CABG * After</td>
<td>-0.029***</td>
<td>-0.038***</td>
<td>-0.015**</td>
<td>-0.026***</td>
<td>-0.026***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.009)</td>
<td>(0.006)</td>
<td>(0.008)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.158***</td>
<td>0.163***</td>
<td>0.150***</td>
<td>0.158***</td>
<td>0.158***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>P-Value: PCI<em>After = CABG</em>After</td>
<td>0.08*</td>
<td>0.200</td>
<td>0.17</td>
<td>0.156</td>
<td>0.158</td>
</tr>
<tr>
<td>Dual PCI/CABG Assigned to:</td>
<td>CABG</td>
<td>CABG</td>
<td>CABG</td>
<td>PCI</td>
<td>Dropped</td>
</tr>
<tr>
<td>Quit Window:</td>
<td>-0.5 / 0.5</td>
<td>-1 / 1</td>
<td>0 / 1</td>
<td>-0.5 / 0.5</td>
<td>-0.5 / 0.5</td>
</tr>
<tr>
<td>Observations</td>
<td>24,530</td>
<td>24,530</td>
<td>24,530</td>
<td>24,530</td>
<td>24,332</td>
</tr>
</tbody>
</table>

Note: Robust standard errors, clustered on PSU in parentheses. Observations are weighted by the NHIS probability weights. "P-Value: PCI*After = CABG*After" is the p-value on a test of equality of the PCI*After and CABG*After coefficients, implemented by running a regression where PCI is the excluded treatment and looking at the p-value on the CABG*After coefficient.