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Keywords: Practice style, response to news, Quality of care

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Information shocks and provider responsiveness: evidence from interventional cardiology

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March 19, 2019

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1 Introduction

Information is frequently advocated as a tool to improve public services.[1] In this context, much research has drawn attention to the fact that greater information may induce gaming behavior by suppliers with negative consequences for consumers (see, e.g., Dranove *et al.*, 2003). However, gaming aside, some suppliers' responses to information shocks may be objectively better for consumers because it is costly to respond when there are many shocks and some suppliers may be better placed to evaluate these shocks.

In this paper we examine heterogeneity in supplier responses to common information shocks and how this affects their consumers. Our context is an innovation in healthcare. Information shocks and news reversals are particularly pertinent in this setting. Innovations are generally introduced through clinical trials and successful trials are often based on a relatively homogeneous set of patients. Rolling out the innovation to a wider group of patients commonly leads to less positive (or negative) effects on patient health than in the initial trial. This can even lead to abandonment of the innovation, a phenomenon known as "medical reversal" (see, e.g., Prasad and Cifu, 2015).[2] In this setting, acting upon or disregarding information can have a large impact on consumer welfare. Given that even specialist medical societies appear to be resistant to medical reversals, suggesting considerable inertia in changing (ineffective) clinical practice (see, e.g., Wang *et al.*, 2015), there is a need to investigate supplier responses to common information shocks, the extent of heterogeneity across suppliers, and the impact of this heterogeneity on patient outcomes.

To do this we examine an important innovation in the production technology that interventional cardiologists use in their work, the drug-eluting stent (DES). Starting in 2002 DES was widely heralded as the solution to a

[1] Initiatives such as government websites to aid consumer choice, the publication of "league tables", the provision of information to aid school choice, and policies such as "naming and shaming" of poor suppliers all involve the provision of information to help consumers and improve public services.

[2] A recent systematic overview of the clinical evidence supporting US Food and Drug Administration (FDA) "breakthrough approvals" between 2012 and 2017 found that such approvals were often made on the basis of weak evidence. Specifically, the median number of pivotal trials per indication was one, the median number of patient subjects enrolled among all pivotal trials were 222, and only about half of all trials were based on gold standard scientific methods, such as randomization of subjects to treatments (Puthumana *et al.*, 2018).

key problem in coronary catheterization. As a result, it captured over half the stent market from the older technology (bare-metal stents, henceforth BMS) in only a few years after regulatory approval. But in 2006 information was released showing DES caused potentially life threatening side-effects. This information shock, widely reported internationally, drastically reversed the trend of increasing DES use.[3] Within just one month DES lost half its market share to BMS.[4] This led to an extensive re-evaluation of the safety of DES. These investigations largely confirmed their superiority and led national regulatory bodies to issue guidance as to the appropriate use of DES and BMS.[5]

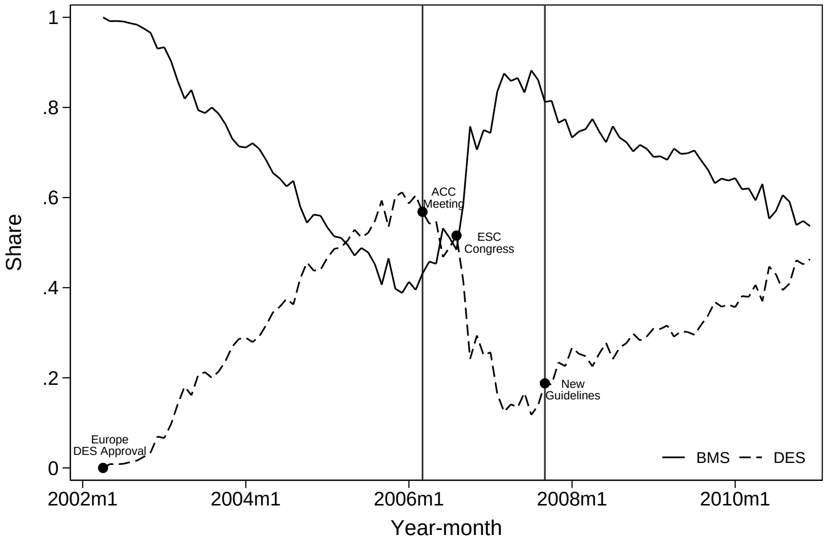
Figure 1 shows the effects of these information shocks on the use of DES in our "test-bed", Sweden. Between the date of approval in Europe of DES in early 2002 and the release of adverse information in 2006, DES had become the dominant choice of Swedish cardiologists, accounting for approximately 65 percent of the Swedish stent market. Only one year later this share had plummeted to less than 20 percent. This led to a regulatory response with the introduction of national guidelines in late 2007 that provided extensive guidance as to when DES should be used, which led to a renewed uptake, albeit at a lower rate.

[3]This event is also referred to as the DES "firestorm" of the annual congress of European cardiologists (ESC) where a meta-analysis was presented suggesting that DES was potentially unsafe. This sparked intense discussions among the cardiovascular community throughout the following years. See, e.g., https://www.escardio.org/Congresses-&-Events/ESC-Congress/Congress-resources/Congress-news/barcelona-firestorm-2006-killed-initial-enthusiasm-for-drug-eluting-stents.

[4]Trends were similar in many countries. For example, Figure E.1 in Appendix E plots US data from Bangalore *et al.* (2014), showing an initial rise in DES use after approval in early 2003, dominating the market only two years later, and a sharp drop in 2006. Similar trends are observed in other countries, including Canada and Scotland (see, e.g., Austin *et al.*, 2009; Epstein *et al.*, 2011).

[5]For example, the American College of Cardiologists/American Heart Association/Task Force on Practice Guidelines (ACC/AHA/SCAI) issued a focused update for PCI guidelines in the end of 2007 (King *et al.*, 2008).

Figure 1.
Trends in the use of BMS and DES in Swedish hospitals
2002–2011



Note.— The vertical lines indicate the different time periods we analyze as described in detail in the text. The shares sum to one.

Our aim is to examine physician heterogeneity in the responses to these common news shocks and, importantly, the association between the responses and patient outcomes. We exploit the three mutually exclusive information regimes of “good news”, the period between regulatory approval of DES in 2002 and 2006; of “bad news”, the period between 2006 and 2007 (more precise dates are provided below); and of guidelines, the period 2007–2011. We use the universe of cardiologists in Sweden and data on all their patients to construct a cardiologist period-specific measure of responsiveness to the information, defined as the rate with which each cardiologist adopted (or abandoned) DES relative to the period-specific national trend. This provides a measure of the heterogeneity in responsiveness for each of the three periods.

We use these distributions to characterize cardiologists into four mutually exclusive “types” based on their relative speed of responsiveness to information in the two periods before the guidelines. These are (1) “slow responders”, who are slow to respond to new information whether good or bad, (2) “fast responders”, who respond quickly to new information whether good or bad, (3) those who are slow to respond to good news but respond quickly to bad news, and (4) those who are fast to respond to good news but slow to respond to bad news. We use this characterization to examine whether cardiologist type is associated with patient outcomes, cardiologist characteristics and the hospitals they work in.

Our specific context has several advantages for the study of the impact of information on physician behavior and patient outcomes. First, the shocks were large, salient and exogenous, allowing us to identify the responses to the shocks. Second, the setting is one that affects a relatively large patient population for which the consequences of medical errors can be harrowing.[6] Third, the issuance of national guidelines after the two news shocks allows us to compare the impact of good and bad news to a period in which cardiologist behavior was informed by extensively disseminated guidance. We show that cardiologists followed this guidance, which reduced the probability of serious complications in the patient population. Fourth, the treatment alternatives we study (DES versus BMS) are in all relevant aspects equivalent in how they are clinically administered. Thus we can exclude potential explanations for heterogeneity in behavior and patient outcomes arising from differences in cardiologist skills (e.g., motor skills or visual acuity). Furthermore, the introduction of DES did not affect the appropriateness of other treatment options (for example, coronary artery bypass grafting) so the relevant patient population of interest can be considered as fixed over time.

Finally, by examining these issues in the context of the Swedish healthcare system we are able to rule out market mechanisms that drive many decisions about treatment in many healthcare markets. These include patient selection (patients have virtually no choice of selecting provider in the Swedish inpatient sector), competition (Swedish hospitals are publicly owned and managed and physicians are salaried) or costs of treatment (the expected price differential between the use of BMS and DES in PCI treatments was relatively small in Sweden).[7] Thus, we may interpret variation in responsiveness across cardiologists as arising from individual discretion in the response to information.

We find the following: First, there is substantial variation in the rate with

[6] Coronary artery disease (CAD) is the global leading cause of death and angioplasty, which is performed by interventional cardiologists, has become the gold standard of treating common and severe conditions such as acute myocardial infarction (AMI).

[7] See, e.g., Ekman *et al.* (2006) who estimates that the expected one-year cost of a PCI with a Taxus DES in 2004 amounted to SEK 72,000 (USD 7,900) versus SEK 67,000 (USD 7,400) for BMS. Both direct and indirect (i.e., repeat revascularization) treatment costs are included as Swedish hospitals are paid on a capitation basis. This contrasts, for example, with much larger cost differences in the USA (see, e.g., Karaca-Mandic *et al.*, 2017). In addition, we can rule out large incentives for adoption from lobbying by the medical devices industry as this is much more muted in the Swedish centralized healthcare system than in more market-driven systems.

which cardiologists respond to information in each of the "news periods". After the introduction of national guidelines, however, cardiologists changed their behavior in line with the guidelines, causing the variability in behavior to reduce significantly. Hence, the guidelines restricted (as they were intended to) individual discretion. Further, there is substantially more variation in the bad news period compared to the good news period. This variation in the bad news period is particularly striking given that the adverse information disseminated in 2006 suggested that DES resulted in potentially life-threatening side effects. Second, cardiologists' speed of response to news prior to the guidelines (i.e., in the first two periods) is associated with their patient outcomes. Patients treated by "slow" responders have a lower risk of adverse cardiac events compared to those treated by all other cardiologist types. These effects are not driven by patient-cardiologist sorting and are robust to a wide range of controls for patient and hospital type. Finally, we find that cardiologists who are slow to respond to both good and bad news are more likely to work in environments in which there is greater private information. This suggests that cardiologists with greater access to, or ability to use, private information make better decisions when faced with public news shocks.

Our work contributes to the literature exploring the causes and consequences of physician practice styles (see, e.g., Chandra and Staiger, 2007; Epstein and Nicholson, 2009). Chandra *et al.* (2012) provide an overview of potential causes for variations in provider treatment decisions across similar patients. These include (i) "defensive medicine", where providers perform unnecessary procedures to avoid complaints, bad reputation and possible lawsuits from patients; (ii) financial incentives associated with fee-for-service reimbursement models (McClellan, 2011); (iii) patient preferences and demand for specific procedures (Cutler *et al.*, 2013); and (iv) unobserved heterogeneity across providers (Doyle *et al.*, 2010). Our institutional setting allows us focus on the variation in the behavior of providers, abstracting from the first three sets of potential drivers of this variation.

In particular, we contribute to a small set of recent studies which analyze the relation between provider practice styles and costs and quality of care. Currie *et al.* (2016) study whether more aggressive (defined as the use of more invasive treatments) or responsive (the tailoring of treatment to patient characteristics) practice styles matter for costs and health outcomes using data on patients with acute myocardial infarction. Currie and MacLeod

(2018) explore whether physician experimentation with anti-depressant drugs is associated with better patient health outcomes. Molitor (2018) examines how cardiologists' practice styles are affected by their environment by assessing how their behavior changes when they move across healthcare regions. He finds that migrating physicians are highly malleable and largely change their treatment behavior in line with the prevailing environment, suggesting that hospital characteristics may play a substantial role in shaping practice styles. Cutler *et al.* (2019) examine physician behaviour using responses to vignettes (hypothetical medical cases) and identify types of behaviour from these responses. Although they do not study the association with patient outcomes, they find that these types of behaviour explain a relatively large share of variance in medical expenditures.

While information is likely to play a role in these decisions, none of these papers focus on responses to information. The closest paper to ours is Staats *et al.* (2017), who study the negative news shock for DES stents. They examine how physician experience (defined as volume of activity) affects the speed of response to this news in a US context. They find that the more experienced respond more rapidly. Our focus is broader. We focus explicitly on the heterogeneity in response to news across three information periods and link patterns of responses across both good and bad news to patient outcomes. In addition, our Swedish setting allows us to close down avenues of behavior that constitute responses to the many financial incentives present in the US context.[8]

We also contribute to the huge literature on responses to information and their impacts. This literature shows that individuals may over- or under-react to news (e.g., Daniel *et al.* 1998), and that individuals respond differently to good and bad news (e.g. in psychology (Baumeister *et al.*, 2001), empirical finance (De Bondt and Thaler, 1985, 1987; Veronesi, 1999; Hong *et al.*, 2000; Hong and Stein, 2007; Kacperczyk *et al.*, 2015), and politics (Soroka,

[8]There is also a large literature on the diffusion of innovation in medical technology and its impact on treatment costs and quality of care. Within this, some authors have argued that the marginal benefit of new treatment technology, such as surgical robots, is lower than the costs due to overenthusiastic practitioners, long learning curves, and industry lobby groups (see, e.g., Parsons *et al.*, 2014). Others provide evidence of synergy and spillover effects from the introduction of technology on established treatment procedures, due to economics of scale and increased competition among physicians (see, e.g., Sivarajan *et al.*, 2015). In contrast with much of this literature, we focus on diffusion where the treatment alternatives follow the same procedures.

2006)). There is a growing interest in ideas of differential responses to common information driven by salience and limited attention, whereby cognitively overloaded individuals (investors) rationally pay attention to only a subset of information (see, e.g., Mackowiak *et al.*, 2018). Our study shows that heterogeneity in responses to common information shocks also affect physician behavior and, importantly, the health of their patients.

The paper proceeds as follows. The next section provides an overview of the Swedish healthcare system and the clinical context. Section 3 explains our empirical approach and how we estimate cardiologist responsiveness to news shocks. Section 4 presents the data, Section 5 the results and Section 6 concludes.

2 Institutional Setting

Our empirical setting includes all coronary interventions performed in Swedish hospitals between 2002 and 2011. We start by providing a short summary of the Swedish healthcare system, followed by information on the medical context and details on the DES news shock we exploit in our empirical framework.

2.1 Healthcare in Sweden

Virtually all healthcare in Sweden is provided and financed by the public sector. The Swedish public sector comprises three tiers; the national, the regional, and the local level. The responsibility for delivery of healthcare, regulated by the Swedish Health Services Act (1982:763), takes place primarily at the regional level where there are 21 county councils. Each council is required by law to provide its residents with equal access to health services and medical care. The county councils are allowed to contract with private providers but most healthcare is provided by public organizations. This institutional setting means that political representatives of the county councils and local bureaucrats, rather than competition among healthcare providers, determine the number, size, location, and coverage of hospitals within each region. Patient fees are low and subject to national caps and all Swedish residents, employed and unemployed, are covered by a universal sickness and disability insurance that covers forgone earnings due to health-related work absence up to a cap of 80 percent of earnings. This means that individuals are generally well-insured against both the direct monetary cost of care and any time off work.

Patients do not choose their hospital or their physician in that hospital. Each hospital is responsible for all specialized care within their respective catchment area and therefore the place of residence determines the specific hospital a patient will be admitted to. Patients and physicians are typically quasi-randomly matched based on which physician(s) are on duty on the day of admission.[9] These institutional features alleviate potential concerns of sorting between patients and doctors.[10] Hospital physicians are paid on a salaried basis and have no financial links with referring primary care physicians.

2.2 Interventional cardiology, angioplasty and PCI

Interventional cardiology is a branch of cardiology that deals with catheter-based treatment of heart disease.[11] Interventionist techniques have become the gold standard for treating heart diseases such as acute myocardial infarction (AMI). The main procedure in interventional cardiology is angioplasty, or percutaneous transluminal angioplasty (PTA). This entails the insertion of a deflated surgical balloon attached to a catheter, which is passed over a guide-wire into a narrowed or fully obstructed artery. The balloon is then inflated, forcing expansion of the blood vessel and allowing for an improved blood flow. To ensure that the vessel remains open after the balloon dilation, the cardiologist may also insert a stent, a tube-shaped metal device, to reinforce the artery wall. This is known as percutaneous coronary intervention (PCI) and follows the same steps as other angioplasty procedures with the exception that the cardiologist first injects a contrast medium through the guide catheter to assess the location and estimate the size of the blockage. The cardiologist uses the information from this procedure to decide whether and which type of stent to use to treat the blockage.

The main disadvantage of using stents is that, because they are objects

[9] According to the Swedish Patient Act (2014:821) patients have no legal right to choose the treating physician within the inpatient care sector. This is different in the primary care sector where patients have extended rights in choosing both provider (clinic) and physician. These treatments do not apply in the context of this paper.

[10] In Section 5, we provide evidence that patient-provider selection does not play a major role in our study.

[11] Coronary catheterization involves the insertion of a sheath into a major artery (e.g., the femoral artery) and cannulating the heart under X-ray visualization.

foreign to the human body, they can result in an immune response that may re-occlude the blood vessel and necessitate a new intervention. This is known as restenosis. It is a very common adverse clinical event associated with use of first-generation bare-metal stents (BMS) in PCI treatments. To reduce the risk of restenosis, a second-generation of stents that consisted of more biocompatible and anti-inflammatory materials, drug-eluting stents (DES), were developed.[12] Procedurally, however, inserting a DES is equivalent to inserting a BMS.

Coronary stenting is also associated with stent thrombosis (ST).[13] This is a serious clinical outcome resulting in myocardial infarction (a heart attack, MI) or death in up to 80% of affected patients. This adverse outcome may occur sometime after treatment (late and very late ST occur 30+ days and 1+ year after implantation respectively). The drugs coated on the DES can inhibit the natural process in the body that prevents thrombus formation and thus DES are potentially associated with increased risk of stent thrombosis.[14]

2.3 The 2006 DES controversy

The market share of DES rose very rapidly following its approval in Europe and the US in 2002 and 2003, respectively. This increase in popularity was driven by results from clinical trials that showed a substantial reduction in the rate of restenosis, with no effects on other clinical outcomes, such as death and myocardial infarction (see, e.g., Morice *et al.*, 2002; Babapulle *et al.*, 2004). In less than two years, DES became the leading stent used in PCI treatment. But the widespread optimism about DES came to an abrupt end in 2006 after the European Society of Cardiologists (ESC) annual congress, at which an (unpublished) meta-analysis showed an increased rate of death and ST-elevated myocardial infarction (STEMI, or Q-wave MI) in those treated with DES compared to BMS. This result initiated a “firestorm” about the potentially unsafe use of DES, reinforced by the media, the public and other stake-

[12] DES were designed to prevent fibrosis (the body’s reparation process) by slowly releasing anti-proliferative drugs that inhibit cell growth, which thereby reduces the risk of restenosis.

[13] When a blood vessel is injured, the body uses platelets (thrombocytes) and fibrin to form a blood clot to prevent blood loss. ST is the formation of an arterial blood clot caused by the stent itself due to arterial damage caused by the stent implantation process or balloon inflation.

[14] Anti-platelet drug therapy that reduces thrombus formation is often used in combination with DES when performing coronary interventions (Kaliyadan *et al.*, 2014).

holders. The reaction among the cardiologist community, public regulatory institutions, and the industry was immediate, calling for further systematic review and re-evaluation of available data. Within one year, the use of DES in the United States fell by nearly 20 percentage points (see Figure E.1 in Appendix E).[15] Not until the American College of Cardiologists/American Heart Association/Task Force on Practice Guidelines (ACC/AHA/SCAI) issued a focused update for PCI guidelines at the end of 2007 was the downward trend in DES use reversed (King *et al.*, 2008).[16]

In Sweden, the DES controversy of 2006 was even more salient due to the relatively small physician community and the publication of a further (Swedish) study demonstrating a significantly higher risk of mortality among patients receiving DES after up to three years followup (Lagerqvist *et al.*, 2007). In December 2006 the Swedish Medical Products Agency, National Board for Health and Welfare and the National College of Cardiologists issued a joint statement to practitioners to be "restrictive" in their use of DES until further notice.[17] However, the results from an additional year of follow-up, presented at the subsequent ESC conference in September 2007, showed that the association between mortality and DES was no longer present in the data (James *et al.*, 2009).[18] At the same time, the Swedish National Board of Health and Welfare issued new national guidelines for cardiac care in line with the ACC/AHA/SCAI recommendations (Socialstyrelsen, 2008). As shown in Figure 1 above, the publication of these guidelines led to renewed use of DES.[19]

In Appendix B, we show that, first, cardiologists' treatment decisions changed in line with these guidelines and, second, that this led to a reduction

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[15] As a response, the US Food and Drug Administration (FDA) convened an open meeting of its Circulatory System Devices Panel in December 2006 where it was concluded that DES were safe to use within their approved indications, but that further evidence from large-scale randomized trials were necessary to understand the underlying factors of ST in DES implantations (Shuchman, 2007)

[16] The essential recommendation from these revised guidelines was to extend so-called dual anti-platelet therapy (a combination of aspirin and an ADP receptor inhibitor) for approved DES to at least one year.

[17] This recommendation was reiterated with greater force in February 2007, stating that "drug-eluting stents should be used with utmost restraint". See https://lakemedelsverket.se/english/All-news/NYHETER---2007/Drug-eluting-stents-should-be-used-with-utmost-restraint/ [Accessed 13/03/2019].

[18] The impact of this reversal has been sarcastically coined "the Swedish yo-yo" (Serruys and Daemen, 2007b).

[19] Appendix A provides more detail about the 2006 DES controversy and the trends in DES use.

in serious adverse events, albeit at the expense of an increase in minor complications. More specifically, we find a reduction in the probability of patients experiencing a myocardial infarction in the post-guidelines period, relative to what a similar patient would have experienced had they been treated in the earlier (good or bad news) periods. However, this reduction in serious complications coincided with an increase in the probability of experiencing restenosis, a more minor complication that is associated with use of BMS. Nevertheless, this shows that the guidelines affected cardiologists' behaviour and in turn, reduced serious adverse outcomes among their patients.

3 Empirical approach

Our empirical approach exploits the unexpected DES safety information to identify responses to public information in three time periods: the initial good news period, the bad news period and the period post-guidelines. These are indicated by the vertical lines in Figure 1. The good news period, when the use of DES was licensed in Europe, is defined from the beginning of 2002 until February 2006. The bad news period, when the reports on the risks of DES were first publicized and discussed, is defined from March 2006 until September 2007. The post-guidelines period is from October 2007 to the end of our study period in 2011.

3.1 Defining cardiologist responsiveness

We seek to characterize cardiologists as responding quickly or slowly to new (good and bad) information relative to their peers, and to relate this responsiveness to patient outcomes. To do this, we first estimate general trends in the use of DES for each of the three time periods specified above. Specifically, for patient i, treated by cardiologist c in hospital h in year-month t we estimate the following regression model:

$$DES_{icht} = \sum_{p=1}^{3} \alpha_p \mathbf{I}[P_t = p] + \sum_{p=1}^{3} \beta_p (\mathbf{I}[P_t = p] \times M^p) + \epsilon_{icht}, \tag{1}$$

where DES is a binary indicator for whether the patient received a DES; $\mathbf{I}[\cdot]$ is an indicator function; $P = \{1, 2, 3\}$ indicates the specific information period; and $M^p = \{0, 1, ..., m^p_{\max}\}$ are the average monthly linear trends in

DES take-up in each period, respectively.[20] The first term on the right-hand side picks up the period-specific intercept (i.e., the initial level of DES take-up in each period). The main coefficients of interest are β_1–β_3, which pick up the average monthly trend in the use of DES in each of the three periods.[21]

We next estimate *cardiologist-specific* versions of equation (1) to obtain a measure of the speed with which each cardiologist's take-up of DES changes in response to new information in each time period. We estimate:

$$DES_{iht} = \sum_{p=1}^{3} \alpha_p^c \mathbf{I}[P_t = p] + \sum_{p=1}^{3} \beta_p^c (\mathbf{I}[P_t = p] \times M^p) + \epsilon_{iht}, \quad \forall \quad c = 1, \ldots, C \tag{1'}$$

Subtracting β_1 in equation (1) from the cardiologist-specific β_1^c in equation (1') yields a continuous measure, centered around zero, for how much faster (or slower) a particular cardiologist's take-up of DES in the first period is compared to the national trend. Doing the same for β_2^c and β_3^c yields the corresponding cardiologist-specific speed of response for periods 2 and 3, respectively. We denote these centered responsiveness measures by $A_c^p = \beta_p^c - \beta_p$. This provides estimates of the period-specific distributions of cardiologists' responses.

To deal with potential concerns about patient and physician selection we re-estimate equation (1) including patient case-mix controls and hospital and cardiologist fixed effects. Finding little difference in the distributions of responsiveness when additional regressors and fixed effects are included suggests that provider and patient characteristics do not play a large role in explaining our measure of responsiveness. In other words, selection of patients by cardiologists can be ruled out as a driver of responsiveness to news.

3.2 Cardiologist types and patient outcomes

The period-specific distributions of cardiologists' responses provide a measure of the heterogeneity in responsiveness across the periods of good news, bad news and post-guidelines. In addition to changing cardiologist behavior more generally, we show below that the guidelines drastically limited cardiologist

[20] M^p is superscripted since periods are of different length.

[21] Visual inspection of Figure 1 suggests that trends are linear. Comparing the Akaike Information Criterion (AIC) statistic in models with different degrees of flexibility (linear, quadratic, cubic) confirms that a linear specification provides the best fit.

discretion and consequently strongly reduced practice variation. We therefore use only the distributions in the first two periods to characterize cardiologists into “types” depending on their relative speed of responsiveness to news.

We characterize four mutually exclusive types: (1) those who are slow to change their behavior in response to news shocks whether these be good or bad (these cardiologists are in the lower part of the distribution in period one and in the upper part of the distribution in period two); (2) those who are quick in changing their behavior with the release of new information whether good or bad (in the upper part of the distribution in period one and the lower part in period two); (3) those who are slow to respond to good news but react quickly to bad news (in the lower part of the distribution in period one and also the lower part in period two); and (4) those who are fast to respond to good news but do not change their behaviour when there is bad news (in the upper part of the distribution in period one and the upper part in period two).

We use this characterization to examine the association between cardiologist type and patient outcomes. We define outcomes m^j_{icht}, where $j = 1, \ldots, J$ is the j^{th} outcome for patient i, treated by cardiologist c in hospital h in year-month t. We estimate the following model for each information period:

$$m^j_{icht} = \sum_{k=1}^{3} \delta_k Type^k_c + \zeta_c Z_c + \zeta_x X_{it} + \zeta_h H_h + \mu_{icht}, \quad (2)$$

where $Type^k_c$ are indicators for the three latter (2–4) types of cardiologists listed above (with slow responders as the reference category), and Z_c, X_{it}, and H_h are the vectors of cardiologist, patient and hospital characteristics, respectively. Our main interest lies in the coefficients δ_1–δ_3, which reflect differences in patient outcomes associated with being treated by different types of cardiologists.

4 Data

Our data are from the Swedish Coronary Angiography and Angioplasty Registry (SCAAR). This is the Swedish national database that registers all interventional coronary procedures from 2002 onwards.[22] SCAAR holds data on

[22]The registry dates back to 1991 but does not include the full population of PCI’s performed in Sweden until 2002. The registry is developed and administered by the Uppsala Clinical Research Center (UCR), sponsored by the Swedish Health Authorities and

patients from all 29 centers that perform coronary interventions in Sweden. All patients undergoing coronary interventions are included in the registry together with detailed information on the specific procedures performed.

4.1 Sample and variables

Our study population contains all patients in Sweden who received coronary stents between 2002 to 2011 and for whom complete follow-up data were available from other national registries. Since patients may have multiple stenting episodes, we base our investigation on the type of stent implanted at the first recorded procedure and discard all subsequent treatments to ensure the sample is homogeneous. For the same reason, we also exclude all treatment episodes where multiple-type stents were used. The data contain a large set of patient outcomes. We focus on five most common types of adverse cardiac events associated with a PCI. These are myocardial infarctions (MI), restenosis, stent thrombosis (ST), deaths, and requiring a new intervention, all coded as events occurring within three years from the first observed treatment. We also create a binary variable that equals one if at least one of these adverse events occurred, and zero otherwise.

Table 1 presents summary statistics of the variables in our sample. The upper panel of the table shows that of the 29 hospitals that perform catheterization around one-fifth are teaching hospitals. The large hospital measure is defined as a hospital that has a PCI case volume above the 75^{th} percentile of the volume distribution in 2002. The middle panel displays characteristics of the 157 unique cardiologists we observe in the data. About ten percent are female and one-fifth are experienced, measured as being above the 75^{th} percentile of the distribution of cumulatively treated cases at the start of the analysis period.[23] About one-fourth of cardiologists were not observed in the first period of our data but entered at a later stage, and ten percent left the sample before the last period of observation. Finally, the bottom panel of the table displays the different patient-level characteristics and outcomes that we include in the analysis. The average patient is 66 years old and more likely to be male. About eight percent of the sample of patients had a previous PCI or a coronary artery bypass grafting (CABG), and 17% and 47% of the

independent of commercial funding.

[23]Due to that some cardiologists enter later in the sample, there are relatively fewer experienced cardiologists than would be expected from the definition.

sample were diagnosed with diabetes and hypertension, respectively. The majority of patients are hospitalized due to acute conditions, such as an unstable CAD or a ST-elevated myocardial infarction (STEMI). Most cases concern interventions in the right coronary artery (RCA) or the left anterior descending artery (LAD). While most patients are treated with anti-platelet therapy (clopidogrel, aspirin) prior to the PCI, there is quite substantial variation in the length and width of the stent used. Finally, one-fourth of all patients experience some adverse clinical event after the procedure.

Table 1.
Summary statistics of variables in the analysis

	Mean	SD
	Hospital-level characteristics	
Large hospital	0.241	(0.435)
Teaching hospital	0.217	(0.412)
Hospital Region		
North	0.103	(0.310)
Stockholm	0.172	(0.384)
Southeast	0.103	(0.310)
South	0.207	(0.412)
Middle	0.241	(0.435)
West	0.172	(0.384)
No. of hospitals	29	
	Cardiologist-level characteristics	
Cardiologist female	0.096	(0.295)
Cardiologist experienced	0.191	(0.394)
Cardiologist not in period 1	0.236	(0.426)
Cardiologist not in period 2	0.242	(0.430)
Cardiologist not in period 3	0.108	(0.312)
No. of cardiologists	157	
	Patient-level characteristics	
Risk factors		
Patient age	66.21	(10.77)
Patient old (>75th pct)	0.222	(0.416)
Patient female	0.289	(0.453)
Previous PCI	0.081	(0.273)
Previous CABG	0.083	(0.276)
Patient has diabetes	0.168	(0.374)
Patient has hypertension	0.474	(0.499)
Smoking status		
Current Smoker	0.215	(0.411)
Former smoker	0.316	(0.465)
Never smoker	0.391	(0.488)
Unknown	0.079	(0.269)
Diagnosed condition		
Unstable CAD	0.465	(0.499)
Stable CAD	0.189	(0.391)
STEMI	0.325	(0.468)
Other	0.021	(0.144)

Continued on next page

Table 1.
— Continued from previous page

	Mean	SD
Angiography result		
Not significant	0.010	(0.101)
1-vessel disease	0.569	(0.495)
2-vessel disease	0.239	(0.426)
3-vessel disease	0.142	(0.349)
LCA disease	0.039	(0.193)
Treatment factors		
Treated segment		
RCA	0.292	(0.455)
LAD	0.452	(0.498)
LCx	0.197	(0.398)
LM	0.029	(0.168)
CABG graft	0.030	(0.172)
Clopidogrel before procedure	0.750	(0.433)
Aspirin before procedure	0.904	(0.295)
Number of inserted stents	1.000	(0.000)
Stent width		
<2.5 mm	0.043	(0.203)
2.5 to <3 mm	0.261	(0.439)
3 to <3.5 mm	0.353	(0.478)
3.5 to <4 mm	0.250	(0.433)
> 4 mm	0.093	(0.290)
Stent length		
<10 mm	0.043	(0.203)
10 to 14 mm	0.243	(0.429)
15 to 16 mm	0.259	(0.438)
17 to 19 mm	0.139	(0.346)
20 to 23 mm	0.145	(0.352)
24 to 25 mm	0.090	(0.286)
26 to 30 mm	0.050	(0.218)
> 31 mm	0.030	(0.172)
3 year outcomes		
Any Adverse event	0.251	(0.434)
Any Myocardial Infarction	0.071	(0.257)
Any Restenosis	0.050	(0.218)
Any Stent Thrombosis	0.011	(0.102)
Any TLR	0.147	(0.354)
Death	0.089	(0.285)
No. of patients	57,513	57,513

Note.— Means and standard deviations (in parentheses). Large hospitals and cardiologist experience are defined by the upper quartile of the respective distribution (hospital total case volume, number of performed surgeries) at the start of the analysis period in 2002. Cardiologists not observed in period one refers to cardiologists that performed their first PCI after 2006; cardiologists not observed in period three refers to those doing their last PCI after September 2007.

5 Results

5.1 Cardiologist responsiveness

Table 2 presents estimates of equation (1). Column (1) presents the monthly change in DES take-up in the good news period (period one (P1) trend), in the bad news period (P2 trend), and in the post-guidelines period (P3 trend). These show that the use of DES increased on average by 1.3 percentage points per month in the good news period, fell by 3.1 percentage points per month in the bad news period, and following the guidelines increased by 0.5 percentage points per month. The estimated trend parameters are all highly statistically significant and correspond closely to the descriptive pattern shown in Figure 1. The period intercept parameters provides information of the average use of DES at the beginning of each period. As expected, since the first period coincides with the approval of DES use in Europe, the first period intercept is estimated to be very close to zero. The second and third period intercepts suggests that DES was applied to over half and one-tenth of all patients at the beginning of the bad news and the post-guidelines period, respectively.

Columns (2)–(6) of Table 2 sequentially include a set of additional co-variates to explore the robustness of our estimates to inclusion of patient, cardiologist and hospital characteristics. Column (2) includes the variables for patient risk factors detailed in Table 1. Columns (3), (4), (5) and (6) include treatment-specific variables, hospital and/or cardiologist fixed effects. The trend estimates are very stable across the different specifications, suggesting that the overall responsiveness to news is not driven by patient selection and holds within hospital and cardiologist.[24]

[24]For brevity, we do not report the full list of regressors in Table 2. They show that it is generally less likely that patients with co-morbidities and more severe diagnoses (e.g., STEMI) are treated with DES. Exceptions are diabetes patients and patients with previous PCI treatments who have a higher probability of receiving DES.

Table 2.
Determinants of DES use

	(1)	(2)	(3)	(4)	(5)	(6)
P1 intercept	-0.043***	-0.005	0.203***	0.087	-0.201***	0.072
	(0.014)	(0.018)	(0.041)	(0.044)	(0.019)	(0.059)
P2 intercept	0.544***	0.624***	0.561***	0.635***	0.631***	0.580***
	(0.047)	(0.037)	(0.036)	(0.031)	(0.032)	(0.032)
P3 intercept	0.118***	0.202***	0.179***	0.216***	0.204***	0.197***
	(0.021)	(0.021)	(0.024)	(0.022)	(0.023)	(0.026)
P1 trend	0.013***	0.014***	0.013***	0.014***	0.014***	0.013***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
P2 trend	-0.031***	-0.031***	-0.028***	-0.032***	-0.032***	-0.029***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
P3 trend	0.005***	0.006***	0.005***	0.006***	0.006***	0.005***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Patient female		0.019***	0.012***	0.024***	0.024***	0.017***
		(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Patient old (>75th pct)		-0.005	-0.006	-0.010	-0.011	-0.013
		(0.009)	(0.008)	(0.008)	(0.008)	(0.008)
Patient age: 40-44						
Patient age: 45-49		-0.007	-0.013	-0.011	-0.010	-0.017
		(0.011)	(0.010)	(0.010)	(0.010)	(0.009)
Patient age: 50-54		-0.008	-0.021*	-0.018*	-0.018*	-0.032***
		(0.010)	(0.009)	(0.009)	(0.009)	(0.008)
Patient age: 55-59		-0.015	-0.029**	-0.033***	-0.032***	-0.048***
		(0.011)	(0.010)	(0.009)	(0.009)	(0.009)
Patient age: 60-64		-0.024*	-0.037***	-0.045***	-0.043***	-0.059***
		(0.010)	(0.009)	(0.009)	(0.009)	(0.008)
Patient age: 65-69		-0.032**	-0.046***	-0.054***	-0.052***	-0.069***
		(0.011)	(0.010)	(0.009)	(0.009)	(0.008)
Patient age: 70-74		-0.052***	-0.067***	-0.075***	-0.073***	-0.090***
		(0.012)	(0.011)	(0.010)	(0.010)	(0.010)
Patient age: 75-79		-0.068***	-0.080***	-0.090***	-0.088***	-0.102***
		(0.013)	(0.012)	(0.012)	(0.012)	(0.011)
Patient age: 80-84		-0.107***	-0.117***	-0.132***	-0.131***	-0.146***
		(0.015)	(0.014)	(0.013)	(0.013)	(0.012)
Patient age: 85-89		-0.158***	-0.157***	-0.173***	-0.173***	-0.179***
		(0.019)	(0.017)	(0.017)	(0.017)	(0.015)
Patient age: 90+		-0.203***	-0.185***	-0.199***	-0.204***	-0.198***
		(0.024)	(0.023)	(0.020)	(0.020)	(0.020)
Risk factors		✓				✓
Treatment factors			✓			✓
Hospital FE				✓		✓
Cardiologist FE					✓	✓
No of observations	57,513	57,513	57,513	57,513	57,513	57,513

Note.— OLS estimates where the dependent variable is a binary indicator whether the patient received a DES (vs. BMS). Patient risk and treatment factors correspond to variables reported under respective heading in Table 1. Robust standard errors clustered by cardiologist in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

To alleviate any remaining concerns that the trends in DES take-up are due to compositional changes over time in our sample, Table E.1 in Appendix E presents estimates from equation (1) with additional interactions between the DES take-up period trends and a number of hospital, cardiologist and patient characteristics. Each column reports the estimated coefficients from a regression of the probability of receiving a DES on the period-specific linear monthly trends and intercepts together with main effects and interactions between the trend and the specific characteristic described in the column header. The results suggest a significant negative interaction effect for the size and teaching status of the hospital, as well as for older patients (defined as being above the 75th percentile of the age distribution), indicating that each of these characteristics is associated with a more conservative treatment method. As a graphical example, Figure E.2 in Appendix E illustrates the average trend in DES uptake across the three periods separately for relatively older and younger patients. The trend in the use of DES for relatively younger patients is steeper in each of the three periods, consistent with the results from Table E.1. However, while there appears to exist heterogeneity in the *general* trends in DES take-up across patients, hospitals, and cardiologist types, none of these characteristics can explain the variation in DES take-up *across* periods.

Next, we show the variation in responsiveness across individual cardiologists. Figure 2 plots the centered period-specific responsiveness distributions based on the deviation between the estimated trends from the cardiologist-specific regressions of equation (1') and the sample average from equation (1).[25] Figure 2 firstly shows that the introduction of national guidelines in period three substantially reduced variation resulting in a highly concentrated responsiveness distribution. The figure secondly shows that the responsiveness dispersion varies depending on the type of information shock. There is substantially more heterogeneity in cardiologist responsiveness in the bad news period (period two) compared to the good news period (period one).[26] Hence, while most cardiologists reduce their use of DES in response to reports that they may do harm (see Figure E.3 in Appendix E, showing the uncentered distributions), there is considerably more heterogeneity in the pace at which they do this relative to their positive responses to good news.[27]

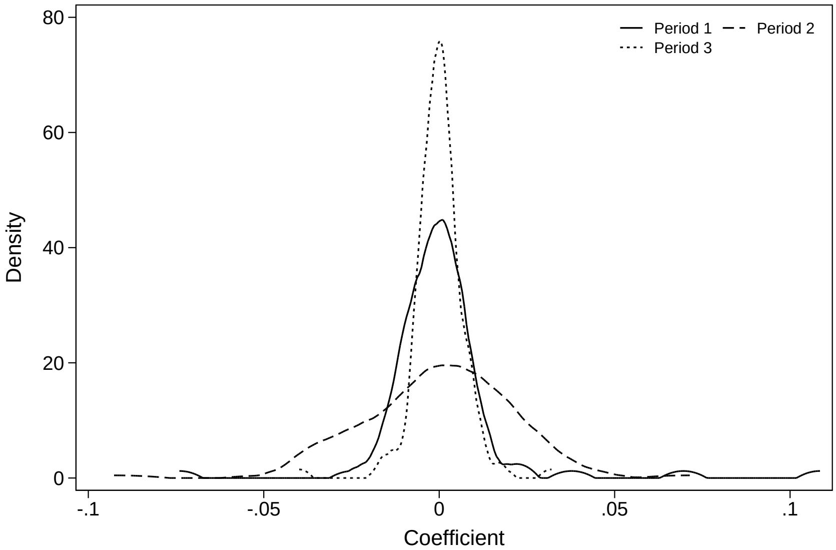
[25] Figure E.3 in Appendix E shows the corresponding uncentered responsiveness distributions. Figure E.4 compares the distributions of period-specific cardiologists' responsiveness that do and do not control for patient, cardiologist, and hospital characteristics. This shows identical distributions in all cases, again indicating that cardiologist responsiveness is not affected by observed patient, cardiologist or hospital characteristics.

[26] One potential concern is that the pattern in Figure 2 simply rises from sampling variation since the second period is substantially shorter than the other two periods. Figure E.5 of Appendix E shows the equivalent distributions when the first and third periods have been shortened to the length of the second period. These distributions look very similar to the distributions from using the full sample suggesting the differences are not driven by the different period-lengths.

[27] To explore potential determinants of cardiologist responsiveness more generally, Appendix C relates cardiologist responsiveness to physician as well as patient characteristics. In addition to estimating determinants of responsiveness, it allows us to investigate the

Figure 2.

Cardiologist responsiveness in the three periods (centered)



Note.— Responsiveness estimates are centered around zero (i.e. the cardiologist-level estimate minus the overall mean shown in column 1 of Table 2. Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively.

Our estimated responsiveness measure may give a misleading picture if the observed variation in DES were derived from a few cardiologists who deterministically switch back and forth between the old and new stents across periods. To explore this we estimate the distribution of the cardiologist-specific use of DES for each month over the sample period. Figure E.6 presents these distributions as monthly box plots for each of the three periods. The figure indicates a general increase in the share of DES used over time in periods one and three and a general decrease in period two. This suggests that the changes in DES use over time reflect a general trend among all cardiologists rather than being driven by just a small group.

Another potential issue with the interpretation of the responsiveness distributions is that it may capture cardiologists who stop using any type of stent in the bad news period. Although there are no obvious alternative treatments to PCI, it may be that some cardiologists chose to administer thrombolytic drug treatment, anti-clotting agents, or surgical treatment, such as coronary artery bypass grafting (CABG), if they lost faith in the efficacy of stents altogether. If this were the case, we would see a reduction in the overall use of stents in the treatment of patients with coronary artery disease, partic-

importance of patient or cardiologist selection. We find little evidence of either.

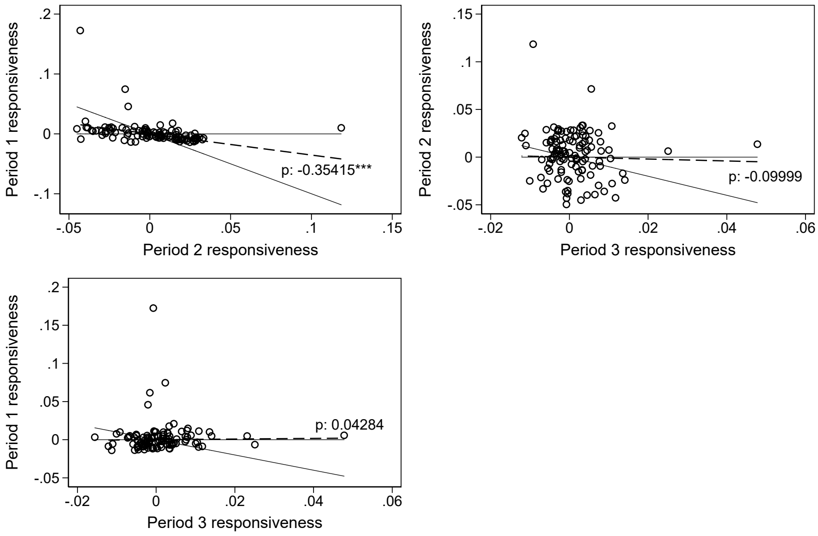
ularly in the bad news period. Figure E.7 presents the distributions of the total number of stents used each month by cardiologists for each of the three information periods. The figure clearly shows that the application of stents (DES or BMS) varied very little over the sample period, suggesting that the changes in use of DES was entirely due to switching between DES and BMS.

5.2 Cardiologist types and patient outcomes

To investigate whether there are cardiologist types defined with respect to their response to news, we examine the extent to which responsiveness correlates across periods *within* cardiologists. For example, a negative correlation between period one and period two would imply that cardiologists are predominantly either slow or fast responders (either react quickly or slowly to new information, irrespective of whether it is positive or negative news). On the other hand, a positive correlation between period one and period two responsiveness would suggest that cardiologists are predominantly either fast at responding to good news but reluctant to change behaviour despite adverse information, or the other way around: hesitant to adopt the new technology and quick to abandon it when adverse news arrives.

Figure 3 presents the within-cardiologist responsiveness across the three periods. The solid lines pertain to a correlation of zero and one between periods, respectively, while the dashed line shows the slope and correlation coefficient. As can be seen from the upper-left panel of the figure, the within-cardiologist correlation between period one and period two is strongly negative with a correlation coefficient of −0.35. In other words, the larger the estimate is in period one (i.e., the faster the response), the smaller (more negative) the estimate is in period two (i.e., the faster the response) and vice versa, suggesting that the cardiologists in our sample are predominantly either fast or slow responders to information, irrespective of whether the information is positive or negative. In contrast, within-cardiologist correlations in responsiveness between either period one or two and period three are much smaller in magnitude, −0.10 and 0.04, respectively, suggesting that all cardiologists react similarly to news in period three irrespective of their reaction in the two previous periods. This is consistent with the observation from Figure 2, that the introduction of national guidelines increased the signal to noise ratio in common information and/or reduced physician discretion in stent choice and with that, the variability in DES use.

FIGURE 3.
Correlation within cardiologist responsiveness across periods



NOTE.— Responsiveness estimates are centered around zero (i.e. the cardiologist-level estimate minus the overall mean shown in column 1 of Table 2. Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively. Each data point corresponds to the relationship of a cardiologist's responsiveness between two periods. The solid lines pertain to a correlation of zero and one between periods, respectively, while the dashed line shows the slope and correlation coefficient.

Based on these findings and the fact that period three is characterized by the introduction of guidelines that changed cardiologist behaviour and substantially reduced cardiologist discretion, we use the cardiologist-specific measure of responsiveness to news in the *first two periods only* to define four types of cardiologists. We group cardiologists in "fast" and "slow" responders according to whether they were above or below the period-specific median responsiveness. We only include cardiologists observed in all three periods, which reduces our sample to 50,014 patients treated by 105 cardiologists.[28] From these, we obtain four types, which are shown in Figure 4.

[28] To test whether our earlier results are robust to this selection we re-estimated the analyses of Table 2 on the reduced sample. The estimates are quantitatively and qualitatively similar and available from the authors upon request.

Figure 4.
Definition and sample size of cardiologist types

		Period Two	
		Slow	*Fast*
Period One	*Slow*	Slow responders ($n = 39$)	Overemphasize bad news ($n = 14$)
	Fast	Overemphasize good news ($n = 13$)	Fast responders ($n = 39$)

Note.— The figure displays the four categories of cardiologists used in the analysis according to the combination of normalized responsiveness estimates in the two initial periods (introduction and adverse news). A slow (fast) responder is defined as being below (above) the median of the distribution in each period. The number in parenthesis reports the number of cardiologists belonging to each group.

The top left corner of Figure 4 shows the number of "slow responders". These are cardiologists who responded slowly to information irrespective of whether it was positive or negative. They were slow to take up the new stents after their introduction in 2002 and were also slow to reduce their use of DES when the news of the negative side effects was published. In contrast those cardiologists in the bottom right hand corner are "fast responders" who quickly changed their treatment choice in both periods. They were quick to take up the new stents but also quick to revert back to the old stents in 2006. These two groups each account for around 37 percent of the sample of cardiologists.

In the bottom left hand corner are those who "overemphasize good news". These are fast in responding to the good news but slow to respond to the news of negative side effects in the second period. Hence, despite the information in period two that DES had strong adverse effects, they reduced their use more slowly than other cardiologists. Finally, the top right hand corner includes those who "overemphasize bad news". These cardiologists were slow to respond to the positive news in the first period, but quick to respond to the negative news in the second period. Hence, they took up the innovation slowly in the first period and dropped it fast in the second period.

To examine whether type is associated with patient outcomes we regress patient adverse events on the (mutually exclusive) indicator variables for each cardiologist type, as presented in equation (2). As cardiologist responsiveness is unrelated to (observable) patient-cardiologist sorting (see Section 5.1 and Appendix C), we attribute any impact of cardiologist type on the clinical outcome of interest as an effect on quality of care. Panel A of Table 3 reports the results using data from all three periods. These suggest that patient outcomes are best if treated by slow responders. Column (1) shows that patients treated by those who overemphasize bad news are 3.8 percentage points more likely to experience an adverse event, whilst patients treated by fast responders and those who overemphasize good news have an increased risk of 2.1 and 1.7 percentage points, respectively. With an average of 0.25 of patients experiencing any adverse event, these correspond to a 7–15% increase overall. Studying the separate clinical endpoints in columns (2)–(6), the results for those who overemphasize good and bad news respectively are driven by increases in the risk of myocardial infarction and revascularization, whilst fast responders have significantly worse results for three out of five adverse events.

Panels B–D of Table 3 report the rates of adverse events by period. These again show the relative superiority of slow responders in the first two periods. However, there is much less difference in patient outcomes by cardiologist type in the post-guideline period. Together with the evidence of reduced dispersion from Figure 2 and Figure 3, it is clear that the guidelines reduced variation in physician behavior and with that, also in clinical outcomes.[29]

[29] To investigate the robustness of these analyses, Appendix D examines whether *within-period* responsiveness is related to patient outcomes, exploring the difference in outcomes by the four quartiles of the responsiveness distribution for each period. Our findings support the analyses here, showing that cardiologists who did not strongly react to the new information had the best overall outcomes, with the differences becoming generally indistinguishable from zero in the post-guidelines period.

TABLE 3.
Effect of cardiologist type on patient outcomes

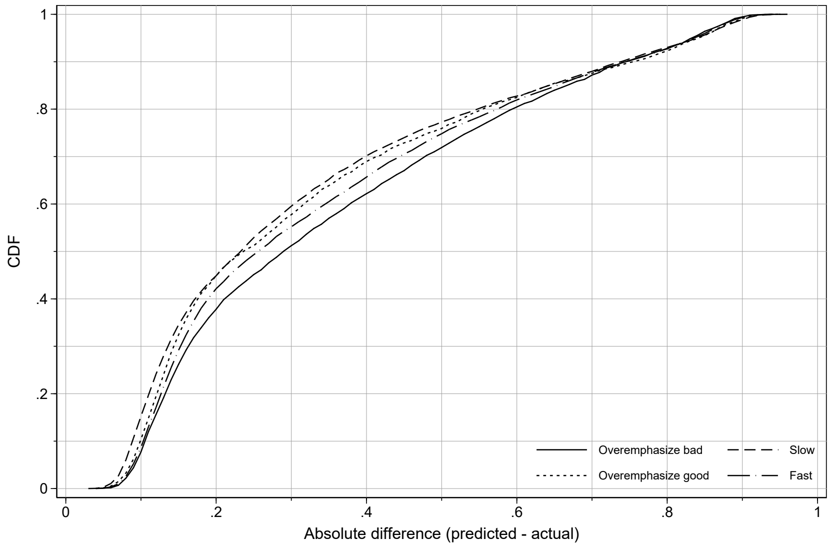
	(1) Any adverse event	(2) Myocardial Infarction	(3) Restenosis	(4) Stent Thrombosis	(5) Revascular-ization	(6) Death
A. All periods						
Slow [*ref.*]						
Overemph. bad	0.038***	0.000	0.002	0.002	0.044***	0.001
	(0.014)	(0.004)	(0.005)	(0.002)	(0.016)	(0.006)
Overemph. good	0.017*	0.013**	-0.005	0.001	0.017	0.001
	(0.009)	(0.005)	(0.005)	(0.001)	(0.010)	(0.004)
Fast	0.021*	0.006*	-0.002	0.003***	0.024**	0.001
	(0.011)	(0.003)	(0.003)	(0.001)	(0.011)	(0.004)
Controls	✓	✓	✓	✓	✓	✓
Observations	50,014	50,014	50,014	50,014	50,014	50,014
Mean of outcome	0.250	0.071	0.050	0.011	0.150	0.089
B. Only period 1						
Slow [*ref.*]						
Overemph. bad	0.038***	0.009	0.005	0.004**	0.040***	0.001
	(0.012)	(0.006)	(0.005)	(0.002)	(0.014)	(0.009)
Overemph. good	0.033***	0.022***	-0.001	0.005***	0.035***	0.001
	(0.011)	(0.008)	(0.008)	(0.001)	(0.011)	(0.005)
Fast	0.029**	0.013**	-0.008*	0.004***	0.036***	0.002
	(0.012)	(0.005)	(0.004)	(0.001)	(0.012)	(0.004)
Controls	✓	✓	✓	✓	✓	✓
Observations	19,330	19,330	19,330	19,330	19,330	19,330
Mean	0.250	0.073	0.043	0.007	0.150	0.082
C. Only period 2						
Slow [*ref.*]						
Overemph. bad	0.045***	0.001	0.001	-0.001	0.047***	0.009
	(0.012)	(0.006)	(0.005)	(0.002)	(0.016)	(0.010)
Overemph. good	0.006	0.007	-0.008	-0.002	0.018**	-0.003
	(0.011)	(0.007)	(0.009)	(0.003)	(0.008)	(0.006)
Fast	0.040***	0.024***	0.005	0.002	0.037***	0.011**
	(0.010)	(0.005)	(0.006)	(0.002)	(0.009)	(0.005)
Controls	✓	✓	✓	✓	✓	✓
Observations	10,763	10,763	10,763	10,763	10,763	10,763
Mean	0.250	0.069	0.056	0.013	0.140	0.091
D. Only period 3						
Slow [*ref.*]						
Overemph. bad	0.037*	-0.006	0.001	0.001	0.047**	0.000
	(0.019)	(0.004)	(0.007)	(0.002)	(0.021)	(0.006)
Overemph. good	-0.015	-0.003	-0.016**	-0.001	-0.017	-0.001
	(0.016)	(0.004)	(0.006)	(0.002)	(0.014)	(0.006)
Fast	0.011	-0.001	0.000	0.004**	0.013	-0.000
	(0.014)	(0.004)	(0.005)	(0.001)	(0.013)	(0.005)
Controls	✓	✓	✓	✓	✓	✓
Observations	19,921	19,921	19,921	19,921	19,921	19,921
Mean	0.260	0.070	0.054	0.013	0.150	0.095

NOTE.— The table presents the OLS estimates from a regression of patient outcomes on hospital, cardiologist, treatment, and patient characteristics. Robust standard errors, clustered by cardiologist, presented in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The above estimates indicate that slow responders have better patient outcomes. Our analysis shows that this is not due to patient-physician sorting, suggesting it is driven by slow responders treating their patients more appropriately. We explore this in more detail by exploiting the fact that the guidelines were designed to help cardiologists choose the correct treatment for patients with different characteristics and co-morbidities. Our analysis above shows that cardiologists closely followed these guidelines. We therefore use patients' characteristics (shown in the bottom panel of Table 1) to predict the probability of experiencing an adverse event in period three. We interpret the parameter estimates from this regression as the "true" contribution of each characteristic to the probability of experiencing an adverse event, if treated by best practice (i.e., following the guidelines). We then use these parameter estimates to predict the risk of experiencing an adverse event for patients treated in the first two periods. We calculate the absolute difference between the *predicted* risk and the *actual* experience of an adverse event, and interpret this as the deviation from appropriate treatment.

Figure 5 presents the cumulative density function of this absolute difference by cardiologist type. The distribution of absolute differences in skewed to the left for all cardiologist types, showing that, on average, differences between appropriate and actual treatment are small. However, the figure also clearly shows the dominance of slow responders over the other three types across the distribution, followed by those who overemphasize good news, fast responders, and those who overemphasize bad news, respectively. This dominance of the slow responders echoes the results in Table 3, which shows that the slow responders have better outcomes than the other cardiologist types. This suggests that slow responders are more likely to treat their patients according to best practice even before the guidelines were introduced.

FIGURE 5.
Cumulative absolute difference between predicted and actual rates of adverse events by cardiologist type



NOTE.— The figure presents the cumulative density distribution of the absolute difference in predicted versus actual adverse events in periods one and two for the four types of cardiologists specified in Figure 4. Adverse events are defined as the composite event of a myocardial infarction, restenosis, stent thrombosis, revascularization or death within one year after catheterization. Predictions use the parameter estimates of a logistic regression of an adverse event as a function of patient characteristics in period three.

5.3 What is associated with cardiologist type?

Table 4 examines whether any patient, hospital, and cardiologist characteristics are associated with the cardiologist types. It presents the estimates from a multinomial logistic regression of type on characteristics, with slow responders as the reference group. In this analysis, we include cardiologist outcomes for their patients treated prior to the introduction of DES. This allows us to examine if adverse events pre-DES, as well as characteristics of the patient, the cardiologist, and the type of hospital they are employed in, affects behaviour with respect to news about DES. This restricts the sample to those observed *before* 2002, which reduces the sample to 76 cardiologists.

The results suggest that neither average patient characteristics or past adverse outcomes (Panel I of Table 4), nor cardiologist characteristics (Panel III) are associated with how cardiologists respond to news. Although those who overemphasize bad news have a significantly lower share of patients with hypertension, this is not the case for fast responders or those who overemphasize good news. A test of the joint significance of the cardiologist's patients' pre-DES outcomes and characteristics (Panel I) suggests they are not significantly different from zero ($p = 0.868$). In contrast, hospital characteristics (Panel II) are associated with type. Relative to slow responders, the other types are more likely to work in large hospitals and less likely to work in teaching hospitals. These differences are significantly different from zero for fast responders and those who overemphasize bad news. A test of joint significance confirms the importance of these characteristics ($p = 0.031$).[30]

Hence, the only observable differences across types are in terms of where they are employed. But if all slow responders are employed in teaching hospitals, it is impossible to ascertain whether the improved patient outcomes are driven by slow responders or the benefits of being treated in a teaching hospital. It is therefore helpful to examine whether hospital type and cardiologist type are coterminous. Table 5 presents the proportion of each cardiologist type by hospital and cardiologist characteristics. This shows that, while it is true that the majority of slow responders (61.5%) are employed in teaching hospitals, a substantial proportion of other cardiologist types are also employed in these settings: 29% of those who overemphasize bad news, 31% of those who overemphasize good news, and 13% of fast responders. Similarly, 44% of slow responders work in a large hospital, which is only slightly higher than the 43% of those who overemphasize bad news, though higher than the 23% of those who overemphasize bad news, and the 33% of fast responders.

This suggests that our results in terms of patient outcomes are driven by the cardiologist *type*, as opposed to the characteristics of the hospital they are employed in. Having said that, there is likely to be selection into teaching hospitals that we cannot account for. For example, perhaps slow responders are more likely to select into an academic environment and these are the types of cardiologists that have better patient outcomes. We cannot, with the data we have, distinguish between these explanations.

[30]Restricting the sample to cardiologists observed across all three periods and dropping any information prior to period one gives very similar results. Table E.2 of Appendix E shows that fast responders and those who overemphasize bad news are less likely to be in teaching hospitals and more likely to be in large hospitals, with patient and cardiologist characteristics not significantly different from zero.

TABLE 4.
Multinomial logistic estimates of cardiologist type on cardiologist characteristics

	(1) Overemph. bad	(2) Overemph. good	(3) Fast
I			
Pre-DES deaths	2.68	5.62	0.24
	(5.50)	(6.30)	(2.94)
Pre-DES adverse events	-1.80	-4.28	-1.61
	(4.75)	(6.10)	(2.81)
Share diabetes patients	26.4	19.9	18.1
	(18.7)	(17.5)	(14.6)
Share hypertension patients	-24.6***	-5.91	-5.31
	(9.20)	(5.39)	(4.78)
Share old (>75th pct) patients	14.7	-1.78	7.74
	(12.8)	(11.5)	(9.06)
Share smoking patients	8.38	-1.22	-4.02
	(9.59)	(8.67)	(6.91)
II			
Large hospital	2.69**	0.89	1.85*
	(1.28)	(1.20)	(1.02)
Teaching hospital	-2.97**	-1.52	-3.32***
	(1.29)	(1.09)	(0.96)
III			
Cardiologist female	1.51	-14.8	1.09
	(1.91)	(2,189)	(1.40)
Cardiologist experienced	-0.29	-0.40	0.72
	(1.18)	(1.00)	(0.79)
Pr **I** $> \chi^2(18)$: 0.868			
Pr **II** $> \chi^2(6)$: 0.031			
Pr **III** $> \chi^2(6)$: 0.853			
Observations	76	76	76

NOTE.— The table presents maximum likelihood estimates from a multinomial logistic regression of the relationship between cardiologist type and cardiologist-level characteristics. Slow adapters are reference category. p-values from tests of joint significance of categories of variables defined by roman numbers are reported at the bottom of the table. Standard errors presented in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5.
Average values by cardiologist type

	(1) Overemph. bad	(2) Slow	(3) Overemph. good	(4) Fast	(5) Total
Large hospital	0.429	0.436	0.231	0.333	0.371
Teaching hospital	0.286	0.615	0.308	0.128	0.352
Cardiologist Experienced	0.357	0.231	0.154	0.333	0.276
Cardiologist female	0.143	0.103	0.000	0.103	0.095
Observations	14	39	13	39	105

NOTE.— The table presents shares of the four different cardiologist types defined in Figure 4 for selected characteristics.

6 Conclusions

We exploit the rapid introduction of an innovation in cardiology that was followed by the publication of unexpected bad information to study the extent of heterogeneity in responses to these exogenous news shocks and the impact on patient outcomes. Our results suggest substantial heterogeneity in the response to information shocks. The variation in medical practice was largest during the time of negative information and smallest during the period in which detailed information was provided by means of clinical guidelines. We show that cardiologists' responsiveness to news shocks pre-guidelines has an impact on patient outcomes. Cardiologists who were slow to respond to common news shocks had better outcomes than either those who responded fast to news, or those whose speed of response differed by whether the news was good or bad.

Reacting fast to news in this context was not optimal for patients. Instead, we find that those cardiologists who paid less attention to common shocks have better patient outcomes. Given the frequency with which "medical reversal" occurs (i.e., the abandonment of innovations due to its negative health effects following the roll out to a wider group of patients) in common and varying medical contexts such as internal mammary artery ligation, vertebroplasty for back pain and drug treatment of osteoarthritis, this finding and its implications are unlikely to be specific to the case studied here (see, e.g., Prasad and Cifu, 2015).

We find no evidence that the dominance of slow responders is the result of patient selection. Nor is it because of any adverse outcomes cardiologists may have had in the pre-innovation period. But it is associated with cardiologist location in a teaching hospital. There are, at least two, competing explanations for this. The first may be that physicians in teaching hospitals are better at weighing up information shocks because they are in an academic environment where this is facilitated, whereas those outside this environment rationally ignore the information because it is more difficult (costly) to process outside an academic environment. This would fit with ideas of rational inattention by individuals exposed to frequent information shocks that are difficult to evaluate. Or, it could be that those in teaching hospitals have private information which is internal to them and their networks (e.g., knowledge about on-going clinical studies) that they can use alongside the publicly available news to make decisions. In other words, they simply have better information than others. The two explanations have rather different policy implications. The first one would suggest a need to better educate physicians who are not affiliated with an academic institution, whilst the second suggests making information more available to all. Guidelines essentially do the latter, though a proliferation of them may result in them being rationally ignored.

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Appendix A The 2006 DES controversy

The market share of DES rose rapidly since its approval in Europe and the US in 2002 and 2003, respectively. Initially, only two versions of the DES (the CYPHER and the TAXUS) were available, differentiated by the active drug coated on the stent (Sirolimus and Paclitaxel, respectively). The main reason for their popularity was that clinical trials showed that the rate of restenosis was dramatically lowered with as much as 70% compared to implantation of BMS. At the same time, other clinical outcomes, such as incidence of death and myocardial infarction, were comparable to the old stents (see, e.g., Morice *et al.*, 2002; Babapulle *et al.*, 2004). In less than two years, DES had become the leading stent used in PCI treatments.

However, the widespread optimism for DES came to an abrupt end in 2006 when an unpublished meta-analysis based on four clinical trials, assessing the safety and efficacy of DES, was presented in a "hot-line" session at the annual congress for European Society of Cardiologists (ESC) (Camenzind, 2006). The, by now, notorious session disclosed a rate of total death and ST-elevated myocardial infarction (STEMI, or Q-wave MI) of 6.3% in the CYPHER DES group versus 3.9% in the BMS group, a statistically significant difference. This result initiated a "firestorm" about the potentially unsafe use of DES, reinforced by media, the public and interest groups, questioning their continued application. The reaction among the cardiologist community, public regulatory institutions, and the industry was immediate, calling for further systematic review and reevaluation of available data.[31] Reassuringly, based on the findings in around 18,000 patients, new research concluded that on key safety measures, such as overall and cardiac mortality, and stent thrombosis, DES and BMS produced comparable event rates. More importantly, patients who received DES experienced an impressive reduction in target lesion revascularization (TLR) rates (see, e.g., Stettler *et al.*, 2007). A special meeting of the US Food and Drug Administration (FDA) in the end of 2006 concluded that DES are safe to use within their approved indications (Daemen and Serruys, 2007). By that time, however, the use of DES had dropped dramatically, in favour of the older Bare Metal Stents (BMS).

In retrospect, the response to the adverse information on the safety of

[31] At the 2006 World Cardiologist Congress (WCC), a moratorium on DES implantation was called until all existing evidence had been reevaluated. Within one year, the use of DES in the United States fell by nearly 20 percentage points (see Figure E.1).

DES in 2006 can be considered to be an overreaction for a number of reasons (see, e.g., Serruys and Daemen, 2007a). First, the discouraging results presented at the ESC hot-line session in 2006 were based on aggregate pooled data from the four published trials in different points in time with different follow-up times. Second, only a selection of clinical endpoints were analyzed, STEMI and death. If non-STEMI's would also have been included, the significant difference in outcomes between BMS and the CYPHER stent would have vanished. Third, only the CYPHER results were significantly different from zero, while the difference between the TAXUS stent and its comparison group was not. Finally, when reevaluated using patient-level data from the four CYPHER clinical trials with a uniform follow-up period and a consensus regarding definitions, Spaulding *et al.* (2007) were unable to find a significant difference between the DES and BMS groups. While there were still some concerns about the incidence of very late ST among patients treated with DES, Serruys and Daemen (2007a) conclude that the DES firestorm of 2006 could have been avoided by only base changes in clinical practice on data published in peer reviewed manuscripts and a more careful evaluation of new techniques.

In the context of this article, the DES controversy of 2006 had an additional impact on medical practice in Sweden due to the presentation and publication of one-to-three-year follow-up results from the Swedish administrative SCAAR registry for about 20,000 patients treated with DES and BMS between 2003–2004. This "landmark" study demonstrated a significantly higher risk of mortality among patients receiving DES (Lagerqvist *et al.*, 2007). However, subsequent extended analyses which also included data from 2005 (James *et al.*, 2009) instead showed improved outcomes for DES-treated patients. The impact of these articles on Swedish medical practice, shown in Figure 1, has been sarcastically coined "the Swedish yo-yo" (Serruys and Daemen, 2007b). Around the same time when the updated results were publicized in September 2007, the Swedish health authorities enacted national guidelines which stated that DES are safe when used within their licensed indications (Socialstyrelsen, 2008). As shown in Figure 1, this led to a renewed increase in their popularity, albeit at a slower pace then previously.

Since we are interested in the results underlying this "landmark study" (Lagerqvist *et al.*, 2007) that dramatically changed medical practice regarding the use of stents in Sweden, we compare and validate our sample to this study by initially attempting to replicate their main results. Figure E.8 shows the results from this exercise where we have restricted our sample to only include cases between 2003 and 2004 with a follow-up censored at June 30th, 2006. The outcome plotted in the figure is the cumulative hazard of the composite event of patient death or myocardial infarction. Panel (a) shows the overall cumulative hazard for the outcome by stent type until a maximum of three years follow-up, while panel (b) and (c) separately plot the cumulative hazards for the first six months and after six months, respectively. We find the same results as Lagerqvist *et al.* (2007), with an initial higher hazard from the old BMS and a later reversal with DES underperforming for the longer term outcomes. Hence, we are confident that our sample is comparable to Lagerqvist *et al.* (2007).

Appendix B Behavior change in response to guidelines

We present two main findings related to the guideline period. First, we show that cardiologists changed their behaviour in response to the introduction of guidelines. And second, we show that this led to a reduction in the probability of experiencing serious complications, albeit at the expense of an increase in minor complications.

The top left hand graph of Figure B.1 provides evidence for the first of our findings. More specifically, the September 2007 Swedish national cardiac care guidelines state that DES implantations must be followed by dual anti platelet therapy (DAPT; Socialstyrelsen, 2008). We therefore explore how the use of DAPT changes from the pre to the post-guideline period for patients with identical characteristics. We start by estimating the probability of receiving DAPT as a function of patient characteristics in the two *pre*-guideline periods and use the parameter estimates from this (logit) model to predict the use of DAPT for patients with the same characteristics in the *post*-guideline period.

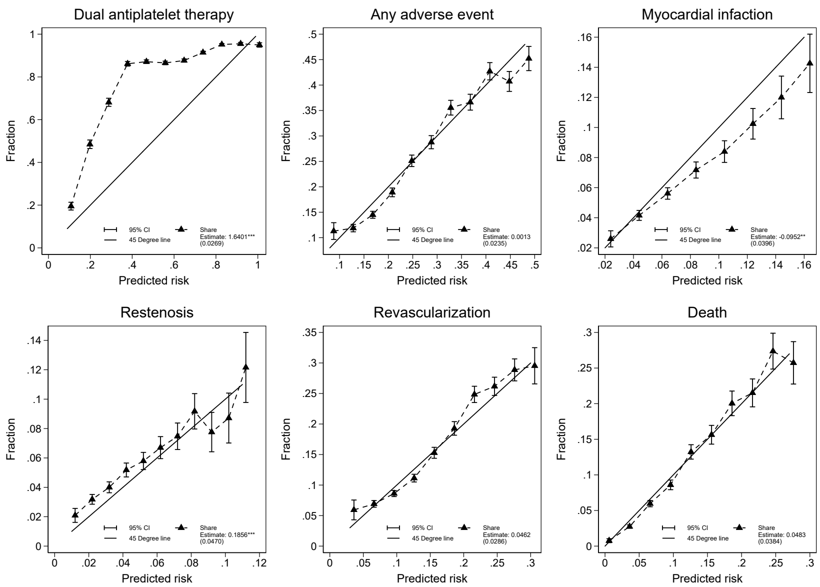
The horizontal axis in Figure B.1 presents this predicted probability, averaged over bins of 0.1, whilst the vertical axis shows the actual fraction of patients receiving DAPT in the post-guideline period in the respective bins. The 45 degree line indicates the expected share of DAPT from the pre-guidelines period. Hence, estimates above the 45 degree line imply that DAPT was used more frequently than predicted based on the pre-guideline model parameters.[32] This shows strong evidence that cardiologists dramatically increased their use of DAPT with the introduction of the guidelines.

We next show how the change in cardiologists' behavior affected the probability of experiencing complications. The remaining graphs in Figure B.1 explore the probability of experiencing different adverse events. In contrast to DAPT, these are negative outcomes, and hence being above the 45 degree line indicates a *worse* outcome in the post-guideline period compared to the pre-guideline period. The figures show that the propensity of experiencing a myocardial infarction reduced significantly in the post-guidelines period, although this is not reflected in a reduction in deaths. The reduction

[32] A regression of the binary indicator of the use of DAPT on the predicted DAPT from the pre-guidelines period and a dummy for the post-guideline period shows the estimate of the latter is 1.64 and highly significant (shown in the bottom right hand corner of each figure). This suggests that the use of DAPT is on average 164 percentage points more likely in the post-guidelines period, holding constant the predicted use of DAPT.

in MI is expected given the increased use of DAPT, since the latter reduces the risk of blood clots and with that, MI. However, we find an increase in the probability of restenosis in the post-guideline period, and hence the net effect on any adverse event (combining all outcomes; i.e., this equals one if any of the adverse outcomes occurred) is zero. The increase in restenosis may be driven by the fact that patients who are no longer deemed appropriate to receive DES post-guidelines instead receive BMS, which in turn is associated with an increased risk of restenosis. Nevertheless, these analyses show that cardiologists changed their behaviour post-guidelines, reducing the risk of serious adverse events, albeit at the expense of an increase in more minor complications related to BMS.

FIGURE B.1.
Association between post-guidelines outcomes and
pre-guidelines predicted outcome risks



NOTE.— The figure displays the relationship between the share of the outcome of interest occurring in the post-guideline period (period three) as a function of the predicted risk of the same event in the pre-guideline periods (periods one and two). Predictions are based on a logistic regression using only period one and two data including a set of patient risk factors and averaged over bins with a width of 0.1. Each panel retains to a different outcome. The 45 degree line indicates the expected share of the outcome of interest in a given risk group in the pre-guidelines periods. The bottom left estimate refers to the corresponding parameter estimate of a binary indicator for the post-guidelines period from a logistic regression of the outcome controlling for the predicted risk.

Appendix C Determinants of cardiologist responsiveness

In this appendix, we explore the determinants of cardiologist responsiveness based from the estimates obtained from equation (1) and (1'). This allow us to examine in more detail whether differences in responsiveness are associated with any provider or patient characteristics and, thus, whether we can rule out selection on observables in our analysis. Thus, we run the following regression separately for each of the three time periods:

$$A_c^p = \gamma_0 + \gamma_1 Z_c + \gamma_2 \bar{X}_{c(i)}^p + \nu_c \text{ for } p = 1, 2, 3, \tag{3}$$

where A_c^p is the cardiologist- and period-specific responsiveness estimate defined in Section 3.1; Z_c are cardiologist characteristics; $\bar{X}_{c(i)}^p$ is a vector of average patient characteristics, where subscript $c(i)$ refers to patient i treated by cardiologist c; and ν_c is the error term. Hence, γ_1 captures whether, for example, female cardiologists respond faster or slower than male cardiologists, whilst γ_2 picks up whether cardiologists treating, for example, older or unhealthier patients respond faster or slower than cardiologists treating younger or healthier patients. The latter will allow us to explore whether certain patient categories are more or less likely to be treated by cardiologists with different responsiveness, shedding light on potential patient and cardiologist selection.

Table C.1 reports the results separately for each of the three information periods. In general, cardiologist and average patient characteristics do not perform well in explaining responsiveness as can be seen by the mostly small and insignificant parameter estimates. Although some estimates are significantly different from zero, there is no clear pattern across the three periods, suggesting that these results are artifacts of multiple testing. The estimates reported in Table C.1 also shed light on the importance of patient and cardiologist selection. For example, if fast-responding cardiologists prefer to treat patients with certain characteristics (e.g., without co-morbidities), or if patients with certain characteristics (e.g., older patients) prefer to be treated by certain cardiologists (e.g., fast responders), the estimates would show a correlation between responsiveness and such characteristics. We do not find this. Rather, the included regressors explain very little of the variation in responsiveness as can be seen from the adjusted R^2 and a F-test of the joint significance of the coefficients of the included variables reported at the bottom of the table.

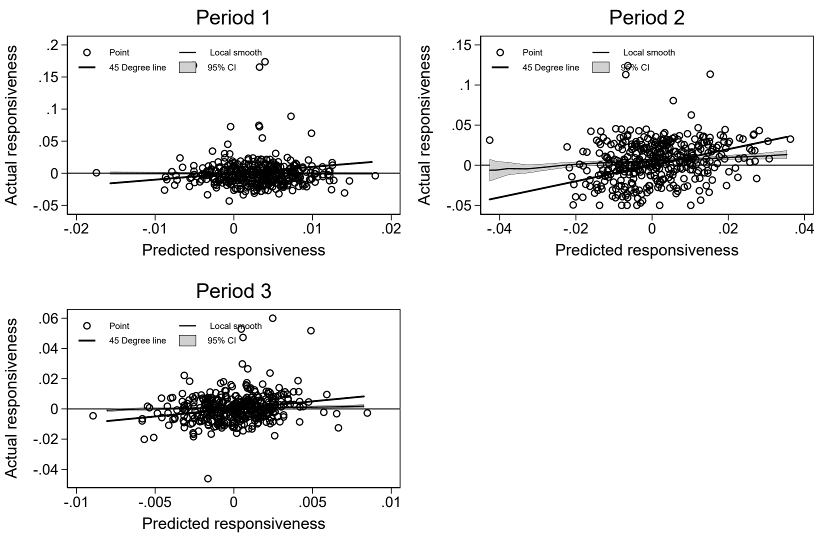
TABLE C.1.
Determinants of cardiologist responsiveness

	(1) Period 1	(2) Period 2	(3) Period 3
Cardiologist female	0.000	-0.004	-0.003*
	(0.004)	(0.008)	(0.001)
Cardiologist experienced	-0.002	-0.005	-0.000
	(0.002)	(0.005)	(0.001)
Cardiologist not in period 1		-0.001	0.000
		(0.009)	(0.001)
Cardiologist not in period 2	0.005		-0.002
	(0.003)		(0.002)
Cardiologist not in period 3	-0.004	-0.007	
	(0.002)	(0.009)	
Mean patient female	-0.018	-0.021	-0.001
	(0.022)	(0.040)	(0.014)
Mean patient previous PCI	0.006	-0.118	-0.006
	(0.020)	(0.065)	(0.022)
Mean patient previous CABG	-0.013	0.016	-0.016
	(0.033)	(0.060)	(0.020)
Mean patient diabetes	0.020	-0.069	0.019
	(0.030)	(0.063)	(0.020)
Mean patient hypertension	-0.010	0.053	-0.002
	(0.010)	(0.028)	(0.009)
Mean patient age	0.002	-0.004	0.000
	(0.001)	(0.003)	(0.001)
Mean patient old (>75th pct)	0.000	0.103	0.018
	(0.037)	(0.068)	(0.035)
Mean patient never smoked	-0.006	0.080**	0.016
	(0.018)	(0.030)	(0.017)
Mean patient quit smoking	-0.030	0.061	0.003
	(0.023)	(0.054)	(0.020)
Mean patient smoker	-0.034*	0.054	0.009
	(0.016)	(0.029)	(0.014)
Constant	-0.101	0.225	-0.015
	(0.078)	(0.172)	(0.066)
No. of observations	120	119	140
Adjusted R^2	0.147	0.038	0.065
F-stat	1.418	1.536	0.969
p-value	0.156	0.106	0.492

NOTE.— The table presents the estimates from a regression of responsiveness on cardiologist and average treated patient characteristics as described by equation (3).

Table C.1 uses a continuous measure of responsiveness and, by virtue of the OLS estimator, only explores determinants at the (conditional) mean of this distribution. However, it may be that associations between cardiologist responsiveness and observable patient characteristics only show up in certain parts of the responsiveness distribution, which will be important for our analysis on patient outcomes below. Figure C.1 evaluates this concern by relating the prediction from estimation of equation (3) to actual cardiologist responsiveness using the variables reported in Table C.1 for each period. Specifically, the figure plots the dependent variable in equation (3) on the vertical axis as a function of the prediction from equation (3) on the horizontal axis. It assesses the relationship between the measures by fitting a local linear regression line with corresponding confidence intervals. If the prediction is able to capture (parts of) cardiologist responsiveness, we would expect the smoothed line to be closer to the 45 degree line (corresponding to a perfect fit) and further away from the horizontal line at zero (corresponding to pure randomness). The estimated slope is close to and statistically indistinguishable from the horizontal line, hence providing additional evidence that non-trivial patient-cardiologist sorting is unlikely to occur in our sample. Note that this is not unexpected, given that the hospital market in Sweden is heavily regulated with essentially no room for competition and choice of provider.

FIGURE C.1.
Relationship between actual and predicted cardiologist responsiveness



NOTE.— The figure illustrates the relation between actual cardiologist responsiveness and predicted responsiveness using the same set of regressors as in Table C.1. The solid 45 degree line corresponds to a perfect fit and the zero line to pure randomness. The local linear regression and its corresponding confidence interval is estimated using a rectangular kernel with a bandwidth of 0.01.

Appendix D Robustness of 'cardiologist type'-effects

To investigate the robustness of the analysis that explores the impact of cardiologist type on patient outcomes, we examine whether *within-period* responsiveness is related to patient outcomes. For each period, we define four dummy variables, indicating the four quarters of the responsiveness distribution, which is shown in Figure 2. For each period separately, we then examine how the outcomes of patients treated by cardiologists in the upper three quartiles of the responsiveness distribution differs from the outcomes of patients treated by cardiologists in the lowest quartile, after adjustment for hospital, cardiologist, treatment, and patient characteristics. In other words, we estimate the following:

$$m^j_{icht} = \sum_{k=1}^{4} \delta_k Q^p_k + \zeta_c Z^p_c + \zeta_x X_{it} + \zeta_h H_h + \mu_{icht} \text{ for } P = p, \tag{4}$$

where m^j_{icht} is the j^{th} outcome for patient i, treated by cardiologist c in hospital h at year-month t, $Q^p_k = \mathbf{I}[q^p_{k-1} < A^p_c \leq q^p_k]$ is an indicator for the kth quartile $q^p_k \equiv \Pr[A^p < a] \leq k/q$ of the estimated period-specific responsiveness distribution cardiologist c belongs to; and H_h, X_{it}, and Z^p_c are vectors of hospital, patient and cardiologist characteristics, respectively.[33] Our main interest lies in the coefficients δ_1–δ_4, which reflect differences in patient outcomes associated with being treated by cardiologists at different quartiles of the responsiveness distribution.[34]

Figure D.1 presents the results for the first (introduction) period, whilst Figure D.2 and Figure D.3 present the results for the subsequent two periods

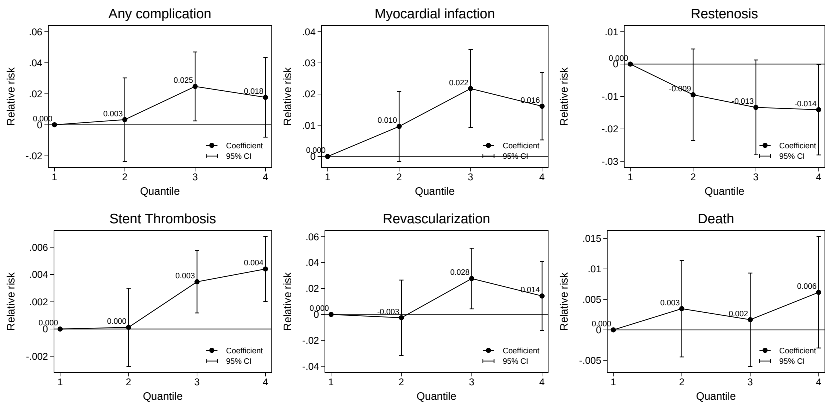
[33]This equation is similar to equation (2), replacing the mutually exclusive cardiologist types by the quartiles of the responsiveness distribution. In addition, Z^p_c also includes the estimated intercept parameters α^c_p from (1) in order to control for the initial level of DES take-up in each period. Since the responsiveness intercepts and slopes are estimated, we perform bootstrap replications to estimate the standard errors of the model parameters.

[34]Our measure of responsiveness is a function of DES and any direct effect of DES on patient outcomes would also be captured by this measure. Based on the background information in Section 2 we have no obvious reason to believe that patient outcomes should be affected by the type of stent used, except for the risk of restenosis. We therefore do not control for the type of stent used in our main analyses, though we also estimate equation (4) with an additional control for the type of stent used (i.e., DES versus BMS). Our findings are unchanged, except for the risk of restenosis and ST, in which the results including the stent type dummy are slightly attenuated. This is exactly what we would expect, given the prior information regarding the superiority of DES. For all other outcomes, however, including the type of stent used does not change the finding that patient outcomes are best if treated by slow responders.

(i.e., adverse news and the introduction of guidelines). The figures are plotted by outcome and present the ordered quartile-specific coefficients together with corresponding 95% confidence intervals.

The upper left panel of Figure D.1 shows that the risk of any type of adverse event within three years from the date of the procedure was substantially higher among cardiologists who were fast in responding to the new stents (i.e., with the steepest slopes). Relative to the baseline adverse event risk of about 0.25 (see Table 1), the figure suggests an increase of about ten percent (or 0.025 percentage points) from being treated by a cardiologist above compared to below median responsiveness. Separately examining each specific clinical endpoints, the higher risk of experiencing an adverse cardiac event stems from, in particular, an increase in the risk of MI and ST among patients treated by fast responding cardiologists in the first period while the risk of restenosis is lower.[35]

Figure D.1.
Effect of cardiologist responsiveness on patient outcomes in period one



Note.— The figure presents OLS estimates from a regression of patient outcomes on a set of dummy variables for being treated by a cardiologist at different quartiles of the period-specific responsiveness distribution adjusted for hospital, cardiologist, and patient characteristics as described in equation (4). Robust 95% confidence intervals, clustered by cardiologist, presented as vertical lines around each point estimate.

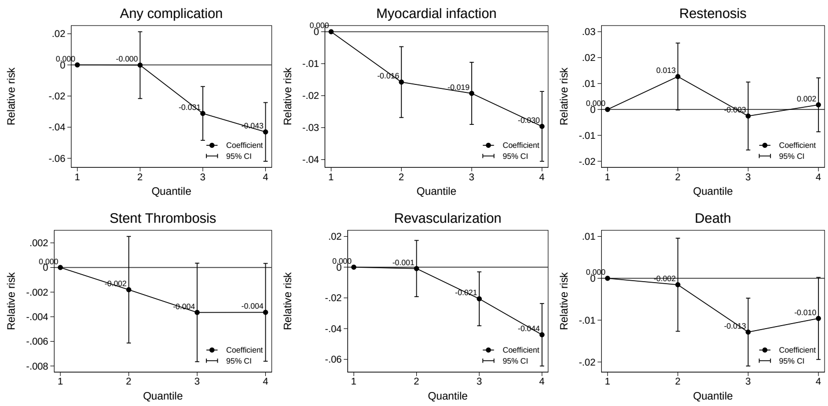
The results from the bad news period in Figure D.2 show that cardiologists who revert back to the old technology quickly have worse patient outcomes (note that they have the most negative responsiveness estimates, i.e. quartile 1 and 2). The magnitude of these effects is substantial: there is an estimated

[35]These results correspond with an early medical study (Lagerqvist *et al.* (2007)) which showed that cardiologists that were fast to adopt DES generally had poorer patient outcomes.

20% relative difference in the risk of any adverse event between the lowest (those quickest to revert to BMS use) and the highest quartile of the distribution. This effect is mainly driven by a relative reduction in the risk of MI and revascularization among cardiologists that did not immediately revert back to BMS, but also is seen in the risk of patient death.

Figure D.2.

Effect of cardiologist responsiveness on patient outcomes in period two

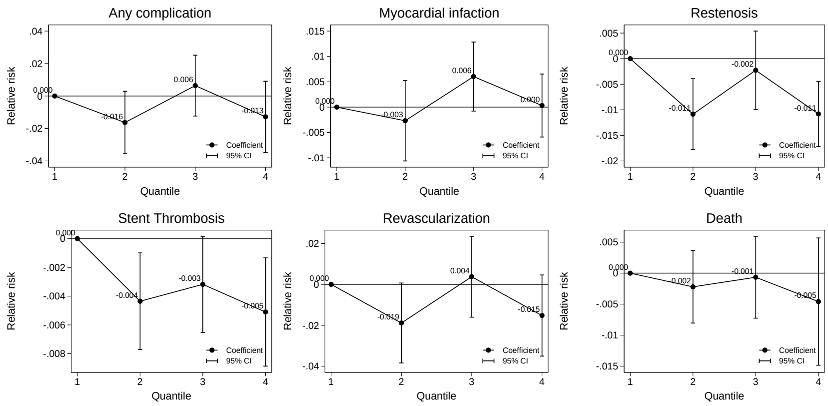


Note.— The figure presents OLS estimates from a regression of patient outcomes on a set of dummy variables for being treated by a cardiologist at different quartiles of the period-specific responsiveness distribution adjusted for hospital, cardiologist, and patient characteristics as described in equation (4). Robust 95% confidence intervals, clustered by cardiologist, presented as vertical lines around each point estimate.

Figure D.3 shows the estimated association between patient outcome and cardiologist responsiveness in the national guideline period. This shows that the relative risk of any type of adverse cardiac event is indistinguishable from zero across all four quartiles of the responsiveness distribution. Except for a slight reduction in the relative risk of restenosis and ST for faster responders (i.e., cardiologists that were quick in returning back to DES), no clear pattern in patient outcomes can be discerned. This is expected. In combination with the evidence that cardiologists closely follow the new guidelines, this suggest that the greater conformity of behavior post-guidelines also reduced variation in quality of patient care. Hence, these results confirm our earlier findings. Indeed, they suggest that cardiologists who did not strongly react to the new information (irrespective of whether it was positive or negative) had the best overall outcomes, with the heterogeneity in response greatly reduced in the period of national guidelines, and with that, also the heterogeneity in clinical outcomes.

FIGURE D.3.

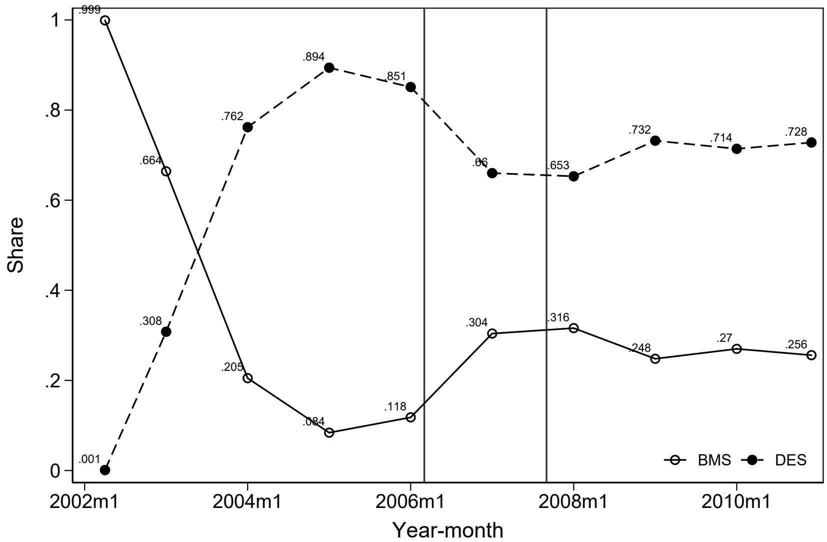
Effect of cardiologist responsiveness on patient outcomes in period three



NOTE.— The figure presents OLS estimates from a regression of patient outcomes on a set of dummy variables for being treated by a cardiologist at different quartiles of the period-specific responsiveness distribution adjusted for hospital, cardiologist, and patient characteristics as described in equation (4). Robust 95% confidence intervals, clustered by cardiologist, presented as vertical lines around each point estimate.

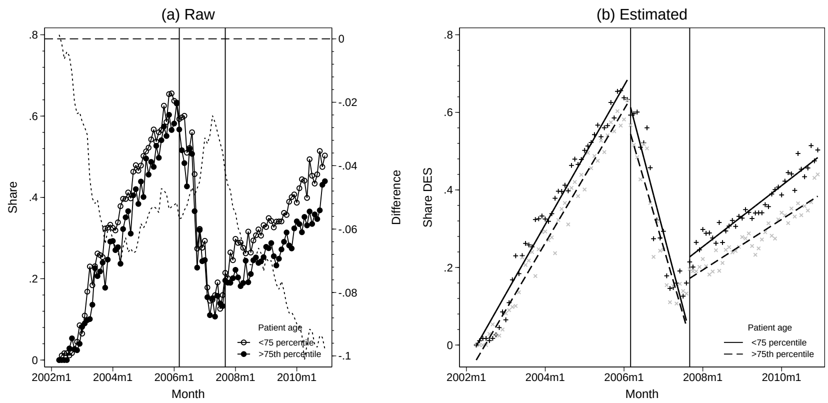
Appendix E Additional Tables and Figures

Figure E.1.
US trends in BMS and DES take-up



Note.— The vertical lines indicate the different time periods we analyze as described in detail in the text. The shares sum to one.

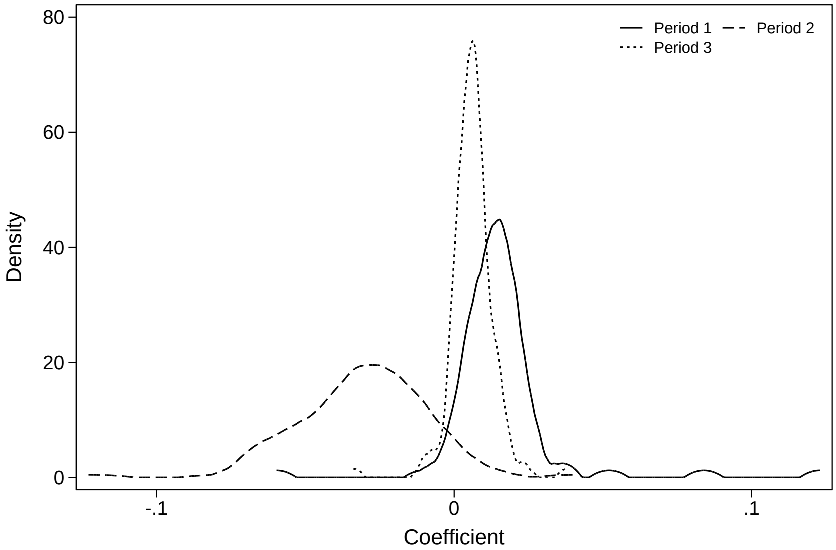
Figure E.2.
Trends in DES take-up by patient age



Note.— The figure shows the raw (panel a) and estimated (panel b) trends in DES take-up by time period and patient age. The dotted line measured on the right y-axis in panel (a) indicates the average group difference over time. The trends in panel (b) are estimated with a piece-wise linear spline defined by the three time periods separately for old and young patients.

Figure E.3.

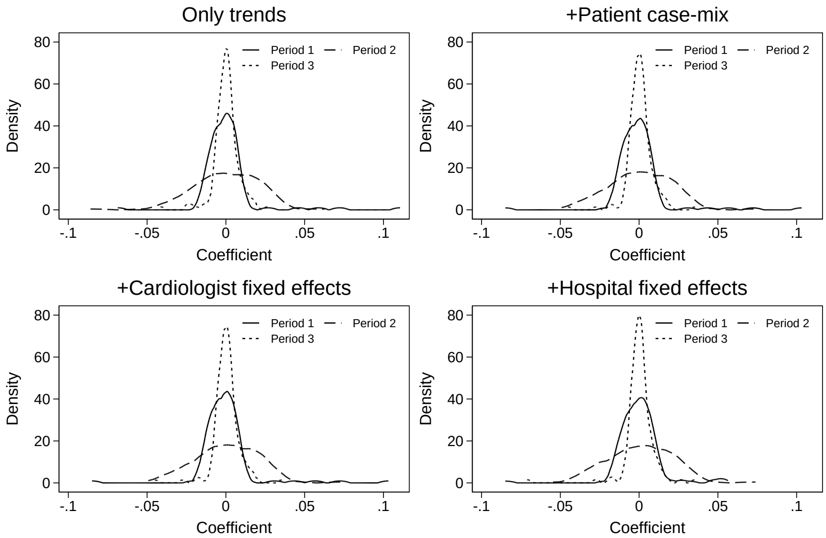
Cardiologist responsiveness in the three periods (uncentered)



Note.— Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively.

Figure E.4.

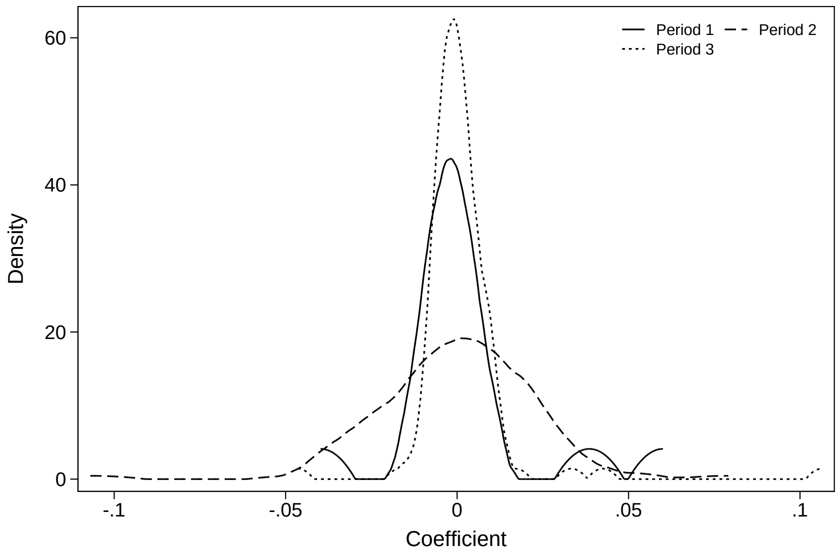
Adjusted cardiologist responsiveness in the three periods



Note.— Responsiveness estimates are centered around zero (i.e. the cardiologist-level estimate minus the overall mean shown in column 1 of Table 2. Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively. The top-left figure is identical to Figure 2; the top-right figure additionally controls for patient case-mix; the bottom left figure accounts for cardiologist fixed effects; the bottom-right figure accounts for hospital fixed effects.

FIGURE E.5.

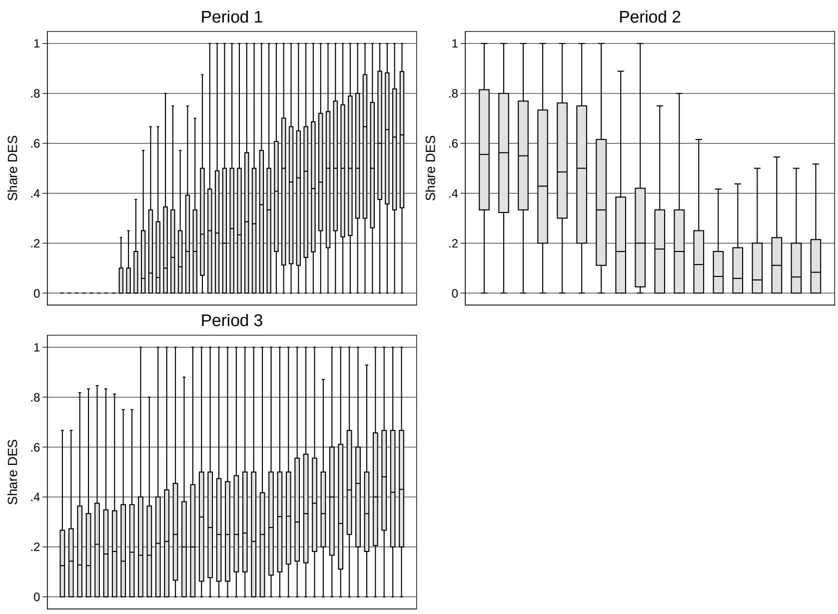
Cardiologist responsiveness by periods of equal length



NOTE.— Responsiveness estimates are centered around zero (i.e. the cardiologist-level estimate minus the overall mean shown in column 1 of Table 2. Each density is based on periods of 18 months (the original length of period two).

FIGURE E.6.

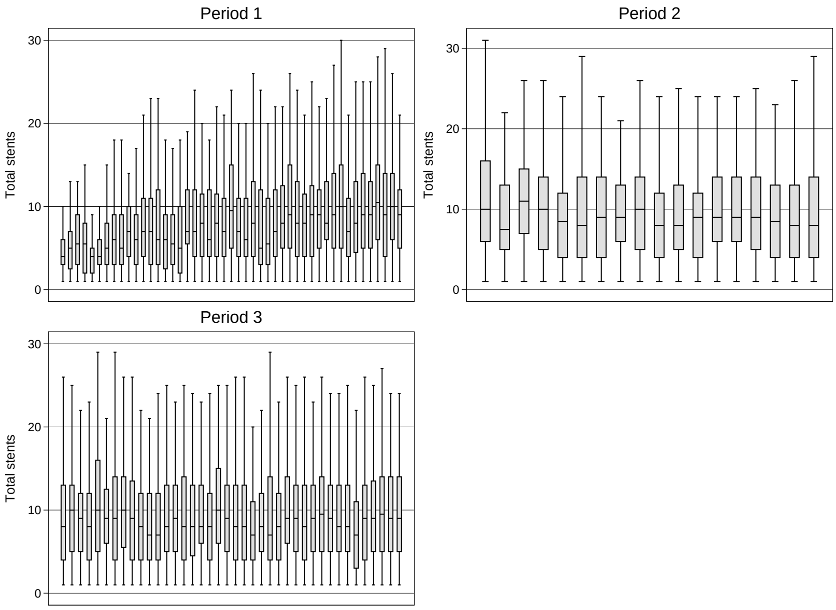
Monthly cardiologist distributions of share DES used



NOTE.— The box and whiskers indicates the inter-quartile range and the maximum and minimum of the monthly cardiologist responsiveness distributions, respectively.

Figure E.7.

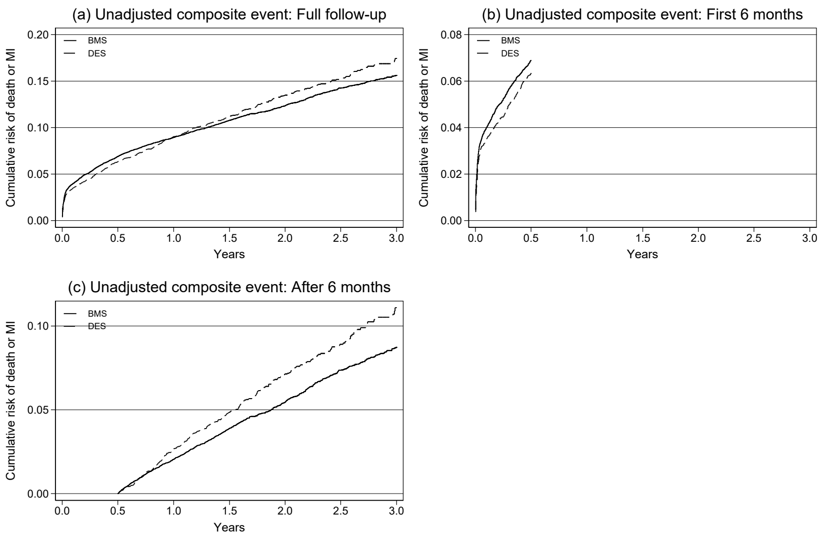
Cardiologist distribution of total stents applied by month



Note.— The box and whiskers indicates the inter-quartile range and the maximum and minimum of the monthly cardiologist responsiveness distributions, respectively.

Figure E.8.

Estimated hazards to death and myocardial infarction by stent type using 2003-2004 SCAAR data



Note.— Own calculations based on replications of Figures 1 (a) and 2 (a) in Lagerqvist *et al.* (2007). Data is based on sampled cases between 2003 and 2004 with a follow-up censored at June 30th, 2006. Outcome is measure as the composite event of death or myocardial infarction. All definitions are otherwise the same as in the main analysis sample.

TABLE E.1.

Trends in DES take-up for selected characteristics

	(1) Trends only	(2) Large hospital	(3) Teaching hospital	(4) Cardiologist female	(5) Cardiologist experienced	(6) Cardiologist not in period 1	(7) Patient old	(8) Patient female	(9) Patient diabetes
P1 intercept	-0.043***	-0.041**	-0.004	-0.041***	-0.059***	-0.043***	-0.038***	-0.045***	-0.055***
	(0.014)	(0.018)	(0.018)	(0.014)	(0.021)	(0.014)	(0.014)	(0.013)	(0.013)
P2 intercept	0.544***	0.544***	0.566***	0.547***	0.534***	0.545***	0.552***	0.542***	0.530***
	(0.047)	(0.045)	(0.046)	(0.047)	(0.044)	(0.047)	(0.048)	(0.047)	(0.046)
P3 intercept	0.118***	0.118***	0.138***	0.121***	0.110***	0.120***	0.127***	0.116***	0.104***
	(0.020)	(0.021)	(0.022)	(0.020)	(0.020)	(0.022)	(0.021)	(0.019)	(0.018)
P1 trend	0.013***	0.015***	0.015***	0.013***	0.013***	0.013***	0.014***	0.013***	0.013***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
P2 trend	-0.031***	-0.030***	-0.031***	-0.031***	-0.030***	-0.031***	-0.032***	-0.032***	-0.031***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
P3 trend	0.005***	0.006***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
P1 trend interaction		-0.003**	-0.007***	-0.000	0.000		-0.001**	0.000	0.001
		(0.001)	(0.001)	(0.002)	(0.001)		(0.000)	(0.000)	(0.001)
P2 trend interaction		-0.003*	-0.001	0.002	-0.004**	0.002	0.001	0.000	-0.000
		(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.001)	(0.001)	(0.001)
P3 trend interaction		-0.001	-0.001	-0.003***	0.001	-0.000	-0.001**	0.000	0.002*
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
Large hospital		0.001							
		(0.030)							
Teaching hospital			-0.073***						
			(0.025)						
Cardiologist female				-0.042					
				(0.057)					
Cardiologist experienced					0.023				
					(0.033)				
Cardiologist not in P1						-0.016			
						(0.045)			
Patient old (>75th pct)							-0.036***		
							(0.011)		
Patient female								0.008	
								(0.009)	
Patient diabetes									0.082***
									(0.019)
p-value		0.841	0.003	0.531	0.039	0.577	0.004	0.955	0.409
Observations	57,513	57,513	57,513	57,513	57,513	57,513	57,513	57,513	57,513

NOTE.— The table presents OLS estimates where the dependent variable is a binary indicator whether the patient received a DES (vs. BMS). Column 1 models only trends; column 2-11 interact the trend with the variable indicated in the column heading (e.g. large hospital, teaching hospital, female cardiologist, etc.). Robust standard errors clustered by cardiologist in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table E.2.
Multinomial logistic estimates of cardiologist type on cardiologist characteristics

	(1) Overemph. bad	(2) Overemph. good	(3) Fast
I			
Share diabetes patients	10.3	9.01	9.57
	(13.0)	(11.9)	(10.1)
Share hypertension patients	-12.8**	-2.68	-3.29
	(5.56)	(4.03)	(3.77)
Share old (>75th pct) patients	8.86	0.42	4.85
	(8.51)	(8.94)	(6.96)
Share smoking patients	6.23	-2.97	-2.08
	(6.86)	(7.02)	(5.63)
II			
Large hospital	1.26	0.02	1.43*
	(0.92)	(0.95)	(0.80)
Teaching hospital	-2.54***	-1.16	-3.34***
	(0.93)	(0.90)	(0.81)
III			
Cardiologist female	1.04	-13.7	0.27
	(1.25)	(844)	(1.07)
Cardiologist experienced	0.43	-0.42	0.50
	(0.82)	(0.82)	(0.64)
Pr **I** $>$ $\chi^2(12)$: 0.321			
Pr **II** $>$ $\chi^2(6)$: 0.003			
Pr **III** $>$ $\chi^2(6)$: 0.914			
Observations	105	105	105

Note.— The table presents maximum likelihood estimates from a multinomial logistic regression of the relationship between cardiologist type and cardiologist-level characteristics. Slow adapters are reference category. p-values from tests of joint significance of categories of variables defined by roman numbers are reported at the bottom of the table. Standard errors presented in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.