Do responses to news matter? Evidence from interventional cardiology*

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Abstract

We examine physician responses to global information shocks and investigate how these impact on their patients. We exploit an international "firestorm" over the safety of an innovation in healthcare: drug-eluting stents. We use rich micro-data on interventional cardiologists' use of stents to define and measure responsiveness to news shocks. We find substantial heterogeneity in responsiveness to news and an association between speed of response and patient outcomes. Patients treated by cardiologists who respond slowly to news shocks have fewer adverse outcomes. These findings are not due to patient-physician sorting, but are driven by a lower rate of decision error among slow responders to news.

Keywords: Practice style, response to news, quality of care.

JEL Classifications: H51; I11; I18; J24; O33.

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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 provision of 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.

In this paper we examine heterogeneity in supplier responses to a frequent type of information shock and how this affects their consumers. Our context is innovation in healthcare, where information shocks are particularly pertinent. 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, known as "medical reversal" (see, e.g., Prasad and Cifu, 2015).[2] In this setting, acting upon or disregarding new 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 such common information shocks, the extent of heterogeneity across physicians, and the impact of this heterogeneity on patient outcomes.

To do this we exploit 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 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

[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 patients was 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).

released showing DES caused potentially life threatening side-effects. This information shock, widely reported internationally, drastically reversed the trend of increasing DES use worldwide. Within just one month, DES lost half its global market share to BMS. This led to an extensive re-evaluation of the safety of DES. These investigations largely confirmed its superiority and led many national regulatory bodies to issue guidance as to the appropriate use of DES and BMS.[3]

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 60 percent of the Swedish stent market. Only one year later this share had plummeted to less than 10 percent.[4] This led to a regulatory response with the introduction of new national guidelines in late 2007 providing guidance as to when DES should be used, which led to a renewed uptake, albeit at a lower rate.

[Figure 1 about here]

We use this context to examine physician heterogeneity in the speed of response to these common news shocks and the association between physician speed of response and patient outcomes. We use the universe of cardiologists in Sweden and data on all their patients from 2002 to 2011. Our setting 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. Second, the setting is one that affects a relatively large patient population for which the consequences of medical errors can be important.[5] Third, the issuance of national guidelines after the two news shocks allows us to use the "guideline period" to define appropriate treatment and to benchmark cardiologist responses and patient outcomes prior to these national guidelines to

[3]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).

[4]Trends were similar in many countries. For example, Figure F.1 in Appendix F plots US data from Bangalore *et al.* (2014), similar trends observed in other countries, including Canada and Scotland (see, e.g., Austin *et al.*, 2009; Epstein *et al.*, 2011).

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

responses and outcomes in this period.[6] 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 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 may drive decisions about treatment in many healthcare markets. These include patient selection (patients have virtually no choice of selecting physicians in the Swedish inpatient sector; we show absence of selection in Appendix C below), 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 response to information.

To define responsiveness to news, we exploit the three mutually exclusive information regimes of "good news", the period between regulatory approval of DES in 2002 and 2006; "bad news", the period between 2006 and 2007; and "guidelines", the period 2007–2011. We construct a cardiologist period-specific measure of responsiveness to the information shocks, defined as the rate with which each cardiologist adopted (or abandoned) DES relative to the period-specific national trend. We use this to group cardiologists into types according to their speed of response to the information shocks. We then examine whether cardiologist speed of response is associated with patient outcomes and explore whether this association is due to differences across

[6]We show below that cardiologists followed this guidance, reducing the probability of serious complications in the patient population.

[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 US (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 compared to more market-oriented systems.

cardiologists in patient suitability for a DES stent (i.e., selection) or decision error on the part of cardiologists in the choice of stent.

We find the following. First, there is little heterogeneity in the speed with which cardiologists take up DES after the guidelines were published. Hence they restricted (as they were intended to) individual discretion. Furthermore, we show that they improved patient outcomes. We use these findings to justify the use of the guideline period as a period of appropriate practice. Second, we find no correlation between speed of response in the guideline period and the other two periods, but a strong correlation between speed of response in the good and bad news periods, indicating that fast responders to good news are also fast responders to bad news. Utilizing this, we characterize cardiologists into two groups based on their relative speed of response to information in the two pre-guideline periods: those who are relatively slow to respond to new information (whether good or bad) and those who are fast.[8] Third, cardiologists' speed of response to news is associated with their patient outcomes, with patients treated by slow responders having a lower risk of adverse clinical events compared to those treated by fast responders. We find no evidence that the differences in patient outcomes are driven by patient-physician sorting. Instead, our analysis suggests the differences are due to decision error in the choice of stent type. Investigating the correlates of decision error, we find that cardiologists with more adverse events *prior to* the introduction of DES make larger decision errors. However, controlling for this does not affect the impact of being a slow responder *per se*, suggesting that fast responders are not simply "poor doctors". Exploring the correlates of cardiologist *type*, we find that cardiologists who are slow to respond to news are more likely to work in environments in which there is greater private information.

Our work contributes to several strands of literature. The first explores 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 pos-

[8]The number who are on the off-diagonal, i.e., slow to respond to good news but quick to respond to bad news or fast to respond to good news but slow to respond to bad news, is small. Appendix E shows that our results are robust to this four "type" characterization.

sible 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 potential drivers of 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 behavior using responses to vignettes (hypothetical medical cases) and identify types of behavior from these responses. Although they do not study the association with patient outcomes, they find that these types of behavior 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. An exception 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 less rapidly to the negative news shock. Our focus is broader. We focus explicitly on the heterogeneity in response to news across three information periods and, importantly, link the speed of response to patient outcomes.[9] In addition, our Swedish setting allows us to close down behavior in response to the (many)

[9] Other interesting angles that could be explored within this setting are response dynamics, learning and peer effects. However, to keep the paper focused we leave these topics for future research.

financial incentives present in the US context.[10]

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 (see, 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, 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, how we estimate cardiologist responsiveness to news shocks, the effect on patient outcomes and how we use guidelines to distinguish between patient selection and decision error in driving these outcomes. Section 4 presents the data, Section 5 the results and Section 6 concludes.

2 Institutional Setting

We start by providing a short summary of the relevant parts of the Swedish healthcare system for our subsequent analysis. This is followed by information on the medical context of interventional cardiology. Finally, we provide details on the DES controversy that we exploit as news shocks in our analysis.

[10] 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.

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 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 typically determines the specific hospital a patient will be admitted to. Patients and physicians are quasi-randomly matched based on which physician(s) are on duty on the day of admission.[11] These institutional features alleviate potential concerns of sorting between patients and doctors, though we also explore this empirically below. 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. Interventionist techniques have become the gold standard for treating heart diseases such as acute myocardial infarc-

[11] 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.

tion (AMI). The main procedure in interventional cardiology is 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 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 consisting of more biocompatible and anti-inflammatory materials, drug-eluting stents (DES), were developed. Procedurally, however, inserting a DES is equivalent to inserting a BMS.

Coronary stenting is also associated with stent thrombosis (ST), the formation of an arterial blood clot caused by the stent itself due to arterial damage from the stent implantation process or balloon inflation. This is a serious clinical outcome resulting in myocardial infarction (a heart attack, MI) or death in up to 80 percent of affected patients. This adverse outcome may occur some time 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 ST.

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

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 up to three years after receipt (Lagerqvist *et al.*, 2007). In December 2006, the Swedish Medical Products Agency, the 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. 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). 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.[12]

[12] Appendix A provides more detail about the 2006 DES controversy and the trends in DES use, and Appendix B shows that cardiologists changed their behavior in response to these guidelines.

3 Empirical approach

Our empirical approach exploits the exogenous shocks in DES safety information to identify responses in three time periods: an initial good news period, a bad news period, and a guideline period. 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 guideline period is from October 2007, when the guidelines were first issued, to the end of our study window 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 intercepts and 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:

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

where DES is a binary indicator for whether the patient received a DES; $I[\cdot]$ is the indicator function; $P = \{1, 2, 3\}$ indicates the specific information period; and $m_{t_p} = \{0, 1, ..., M_{t_p}\}$ is defined as the total number of months from the start of period p, respectively.[13] The first term on the right-hand side picks up period-specific intercepts (i.e., the initial level of DES take-up in each period) through estimation of α_1–α_3. 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, respectively.[14]

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

[13] That is, $m_{t_p} = t_p - t_{p_{min}}$. M_{t_p} is sub-scripted since periods are of different length.

[14] Visual inspection of Figure 1 suggests that trends are approximately 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.

in response to new information in each time period. We estimate:

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

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. As some cardiologists may treat relatively few cases we use empirical Bayes shrinkage (EBS) to adjust for uncertainty in the estimated physician response.

To explore potential concerns about patient and physician selection we re-estimate Equation (1) including patient case-mix controls and hospital and cardiologist fixed effects. We find little difference in the distributions of responsiveness when additional regressors and fixed effects are included, indicating 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 guidelines. We show below that the guidelines drastically limited cardiologist discretion and strongly reduced practice variation. We therefore use only the distributions in the first two periods to characterize cardiologists into a "type", based on their relative speed of response to news. Based on the within cardiologist correlation of responses in the good and bad periods we define a combined slope, equal to the sum of the (absolute value of the) centered responsiveness measures in the good and bad news period. We then define cardiologists as either slow or fast responders, depending on whether their combined slope is significantly smaller or larger than the mean. Section 5 below provides details.

We use this 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 (parameter j and p scripts omitted for brevity):

$$m^j_{icht} = \delta Type_c + \zeta_c Z_c + \zeta_x X_{it} + \zeta_h H_h + \mu_{icht}, \tag{2}$$

where $Type_c$ is a binary indicator for whether the cardiologist is a slow or a fast responder to news (with fast being the reference category), and Z_c, X_{it}, and H_h are vectors of cardiologist, patient and hospital characteristics, respectively. Our main interest lies in the outcome- and period-specific δ coefficients, which reflect differences in patient outcomes associated with being treated by a slow (relative to a fast) responder to news.

3.3 Selection and decision errors

Finding differences in patient outcomes between fast and slow responders raises the question of what may be driving this. We therefore examine two mechanisms which may explain our findings. First, differences in patient outcomes between those treated by fast and slow responders could arise because of non-random allocation of patients to cardiologists. Even in the Swedish setting, patients who differ in their suitability for a DES stent could be non-randomly allocated across cardiologists. Second, differences in outcomes could arise because, conditional on patient suitability, the cardiologist uses the wrong stent. To investigate the importance of both potential mechanisms, we exploit the guideline period. More specifically, under the assumption that cardiologists' behavior in the guideline period reflects best practice (an assumption we explore, and confirm, empirically in Section 5.3 and Appendix B), we define patient suitability for DES as the predicted probability of receiving a DES conditional on a set of patient characteristics based on data from the guideline period only. We specify the following logistic model:

$$p(X_i) = \Pr(DES_i = 1 | X_i) = \frac{f(X_i)}{1 + f(X_i)} \tag{3}$$

where X is a vector of patient level characteristics and $f(X) = \exp(X'\beta)$ is the standard logistic CDF. We use the parameters from Equation (3), estimated using data from the guideline period only, to define a suitability score for each patient in the two *pre-guideline* periods: $s_i \equiv \hat{p}(X_i) \in [0, 1]$. Next, we define the DES decision error, DE_i as the absolute difference between the suitability score and the actual treatment received for patients in these periods, i.e., as $DE_i = |s_i - DES_i| \in [0, 1]$. Hence, the closer DE_i is to one, the larger the decision error. To examine differences between the two groups of cardiologists, we show the distribution of DE_i for slow and fast responders and examine the cardiologist correlates of decision errors. For the latter, we explore the importance of past decisions and patient outcomes (i.e., prior to the introduction of DES), cardiologist and hospital characteristics. Finally, we examine what is associated with each type, exploring whether there are any systematic differences between the two types.

4 Data

Our data are from the Swedish Coronary Angiography and Angioplasty Registry (SCAAR), the Swedish national database that registers all interventional coronary procedures from 2002 onwards.[15] SCAAR holds data on 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

[15] The registry dates back to 1991 but does not include the full population of PCI's performed in Sweden until 2002. The registry is independent of commercial funding.

common types of adverse cardiac events associated with a PCI. These are myocardial infarction (MI), restenosis, stent thrombosis (ST), deaths, and requiring a new intervention (revascularization), 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.[16] Finally, the bottom panel of the table displays the different patient-level outcomes that we include in the analysis. This shows that 25 percent of patients experience some adverse clinical event after the procedure.[17]

[Table 1 about here]

5 Results

5.1 Cardiologist responsiveness

Table 2 presents the 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 guideline 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

[16] Because some cardiologists enter the data later, there are fewer experienced cardiologists than 25%.

[17] Table F.1 presents the means and standard deviations of additional patient characteristics used in our analysis.

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 guideline period, respectively.

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

[Table 2 about here]

To explore potential concerns that the trends in DES take-up are due to compositional changes over time in our sample, Table F.2 in Appendix F presents estimates from Equation (1) with additional interactions between the 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 75^{th} percentile of the age distribution), indicating that each of these characteristics is associated with a more conservative treatment method. As a graphical example, Figure F.2 in Appendix F illustrates the average trend in DES take-up 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 F.2. 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 distributions of cardiologists' speed of response to news.[18] This firstly shows that the introduction of national guidelines in period three substantially reduced practice variation, resulting in a highly concentrated responsiveness distribution. Secondly, it shows that the responsiveness dispersion varies depending on the period: there is substantially more heterogeneity in cardiologist responsiveness in period two (the bad news period) compared to period one (the good news period).[19] Hence, while most cardiologists reduce their use of DES in response to reports that they may do harm (see Figure F.3 in Appendix F, showing the uncentered distributions), there is considerably more heterogeneity in the pace at which they do this relative to their positive responses in period one.[20]

[Figure 2 about here]

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 F.4 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.

[18]Figure F.3, Appendix F, shows the corresponding uncentered responsiveness distributions. Controlling for patient, cardiologist and hospital characteristics does not affect the shape of these distributions (not shown here, but available from the authors upon request), indicating that cardiologist responsiveness is not affected by observed patient, cardiologist or hospital characteristics.

[19]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. Shortening the first and third periods to the length of the second period, however, shows very similar distributions (results not shown here, but available upon request), suggesting the differences are not due to different period-lengths.

[20]To explore potential determinants of cardiologist responsiveness, 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 importance of patient or cardiologist selection. We find little evidence of either.

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 instead to administer thrombolytic drug treatment, anti-clotting agents, or surgical treatment, such as 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 CAD, particularly in the bad news period. Figure F.5 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 type

To investigate whether cardiologists can be characterized into "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 the speed of response in 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 the speed of response in period one and period two would suggest that cardiologists are predominantly either fast at responding to good news but reluctant to change behavior 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 indicate a correlation of zero and *minus* one between periods, 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 -0.71. 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, -0.21 and 0.27, respectively, and insignificant, 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, reduced physician discretion in stent choice and with that, the variability in DES use.

[Figure 3 about here]

Given these patterns, we define types based on the sum of each cardiologist's absolute value of the slopes in the first two periods only. The left panel of Figure 4 shows the combined slopes for all cardiologists in our data with their standard errors. The vertical line shows the mean response (centered at zero). Cardiologists to the left are slower than average, those to the right faster than average. We then drop all those with a combined slope that is not significantly different from zero. This restricted sample is shown in the right hand panel of Figure 4. Inspection of this graph shows that it is mainly cardiologists on the off-diagonals who are most frequently dropped. The resulting distribution of the responses to news is shown in Figure 5.[21]

[Figure 4 and Figure 5 about here]

Figure 6 shows the average DES uptake amongst the slow and fast cardiologists. This confirms that the fast are quicker to take up the innovation in the good news period and faster to drop it in the bad news period. As DES was first introduced in 2002 in Sweden, both groups on average have the same take up rates (of zero) at the beginning of the good news period. By 2006 the take up rate of the fast group was around twice that of the slow. Both groups end the bad news period with very similar take up rates. Thus our characterization of slow and fast is not driven by differences in the average rate of uptake in the two groups at either the beginning of the first period or at the end of the second period.

[21] Appendix E presents the results that use four mutually exclusive types, defined by their responses in each of the periods.

[**Figure 6** **about here**]

5.3 Patient outcomes

Table 3 presents the OLS estimates from a regression of patient outcomes on whether a cardiologist is a slow responder controlling for treatment, hospital and patient characteristics, as in Equation (2).[22] Panel A presents the results for all periods and the following panels for the three periods separately. We examine six adverse clinical endpoints. Panel A shows that slow responders have better outcomes and these are statistically different from those from those of fast responders for any adverse event, myocardial infarction, stent thrombosis and revascularization. Panels B and C show that these better outcomes arise in both the good and the bad news period. Furthermore, slow responders have a lower risk of patient death in period two. In contrast, Panel D shows that, with the (expected) exception of slightly lower rates of stent thrombosis, there are no differences in outcomes in the guideline period. This again supports our use of the guideline period as the benchmark for appropriate practice.

[**Table 3** **about here**]

To explore whether the better performance of slow responders holds across the full distribution of outcomes, Figure 7 shows the cumulative distribution of adverse events, adjusted for case-mix, for all periods. The horizontal axis shows the predicted probability of an adverse event, obtained from estimation of Equation (2) on period three only. This clearly shows that, across the whole distribution, cardiologists who react more slowly to news have better outcomes than those who are faster.

[**Figure 7** **about here**]

5.4 Mechanisms

In Figure 8 we examine whether the better outcomes for slow responders are due to patient sorting or errors in choice of stent. We have already shown above the lack of importance of patient characteristics in determining speed of

[22] We do not control for stent type in this analysis. However, Appendix D shows that including stent type does not affect our findings.

response, suggesting that patient selection is not a reason for the difference in outcomes. We examine this further by using our rich data to define predicted suitability for a DES. As discussed in Section 3.2, under the assumption that cardiologists' behavior in the guideline period reflects best practice, we define suitability based on cardiologists' observed behavior in the guideline period.

The left hand side of Figure 8 shows the cumulative densities of patients' predicted *suitability* in period one and two for fast and slow responding cardiologists. The figure suggests that there is no difference between fast and slow responders across the entire distribution of patients' suitability. In other words, as expected in the Swedish institutional context, there is no evidence of any patient-physician sorting. In contrast, the right hand side of Figure 8 shows the distribution of the *decision error*, DE_i, for fast and slow responders: the difference between the predicted suitability and actual treatment. This shows that fast responders are substantially more prone to committing errors in the choice of stent across the entire distribution of decision errors. This can also be seen in Figure 9, plotting the decision error for each cardiologist against their speed of response to news. This again shows that fast responders make larger errors than slow responders.

[Figure 8 and Figure 9 about here]

To explore how much of the correlation between decision error and cardiologist type can be explained by other factors, Table 4 reports the estimates from linear regressions of decision error on cardiologist type, controlling for a set of cardiologist and hospital characteristics. In addition to the cardiologist and hospital characteristics listed in Table 1, we account for cardiologists' rate of adverse events (heart attacks and mortality) *prior to* the introduction of DES (*Pre-DES adverse events*), picking up whether decision error is driven by cardiologists who were performing poorly even prior to DES introduction. Furthermore, we include a dummy indicating whether the cardiologist has a specialization in interventional cardiology (*specialized*). The estimates show that cardiologists with more adverse events prior to the introduction of DES indeed make larger decision errors. However, even after controlling for this and other factors, being a slow responder remains associated with a lower decision error.

[Table 4 about here]

Finally, we explore whether fast and slow responders differ systematically in a way that could explain our findings. Columns (1) and (2) of Table 5 compare mean characteristics across fast and slow responding cardiologists and column (3) shows whether the corresponding difference is significantly different from zero.

Only two characteristics are significantly different from zero between the cardiologist types: whether the physician has a specialization in interventional cardiology (with fast-responding physicians are more likely to have a specialization) and whether the physician is located in a teaching hospital (with slow-responding physicians more likely to work in a teaching hospital). The former result may suggest that specialized physicians are keen to innovate within their field of specialization, but at the same time quick in reverting back to standard practice when confronted with potential negative consequences. The latter results could indicate that academic hospitals have additional private information in the form of quicker access to research findings compared to other clinical workplaces. Importantly, there exist little evidence for a difference in the rate of adverse events prior to DES introduction across slow- and fast-responding cardiologists. This suggests that fast responders are not simply "bad doctors", but instead that their speed of response to news leads to them making the wrong decision about which types of stent to use on a given patient.

[Table 5 about here]

6 Conclusions

This paper examines physician heterogeneity in the response to new medical information and its impact on patient outcomes. Our setting includes all interventional cardiologists in Sweden between 2002 and 2011, when news about the safety of drug-eluting stents (DES) caused global information shocks. We find substantial variation in the speed of cardiologists' responses to news. In particular, the heterogeneity in response was lowest after the implementation of new clinical guidelines on the appropriate use of DES. Using the empirical response variation, we classify cardiologists into two types: those that respond relatively slowly to news and those that respond relatively fast. We show that patients treated by slow responders in the period preceding clinical guidelines had a significantly lower risk of post-treatment adverse cardiac events compared to those treated by fast responders.

We find no evidence that the superiority of slow responding cardiologists is the result of patient-physician sorting. Instead, we find that differences in patient outcomes are driven by slow responding cardiologists being better at matching treatments to patients in terms of having a significantly smaller decision error between the optimal treatment and their chosen treatment. Furthermore, we show that cardiologists who are fast to respond to news are more likely to have a specialization, whereas those who are slow to respond to news are more likely to work in teaching hospitals. The former may suggest that specialized physicians show more interest to push boundaries within their field, exploring new technologies as they get rolled out, though not always with desirable effects. We show, however, that it is the speed of response, rather than a potential desire to innovate, that is driving the adverse effects on patient outcomes, since these physicians are also quick in dropping the innovation when news of negative consequences is published.

There are at least two competing explanations for the latter result. 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 others 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.

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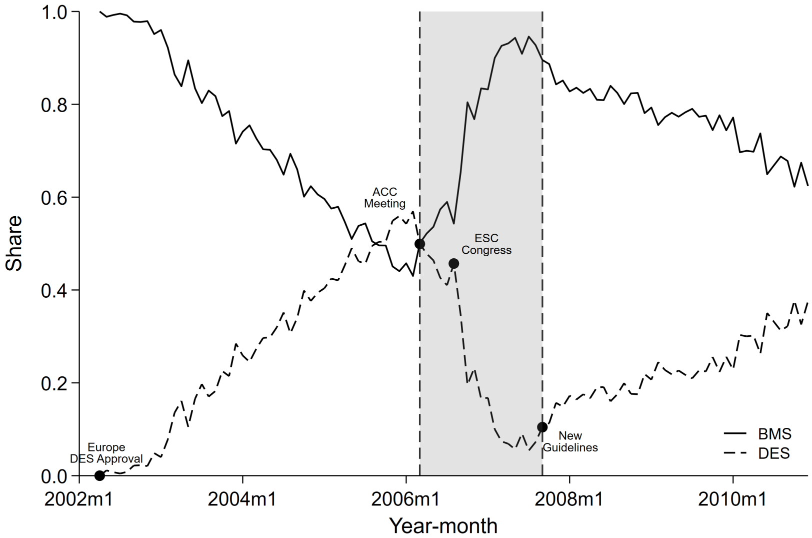
Tables and Figures

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.

Table 1.
Sample summary statistics

	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)
No. of cardiologists	157	
	Patient-level characteristics	
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 revascularization	0.147	(0.354)
Death	0.089	(0.285)
No. of patients	50,586	

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 before October 2007.

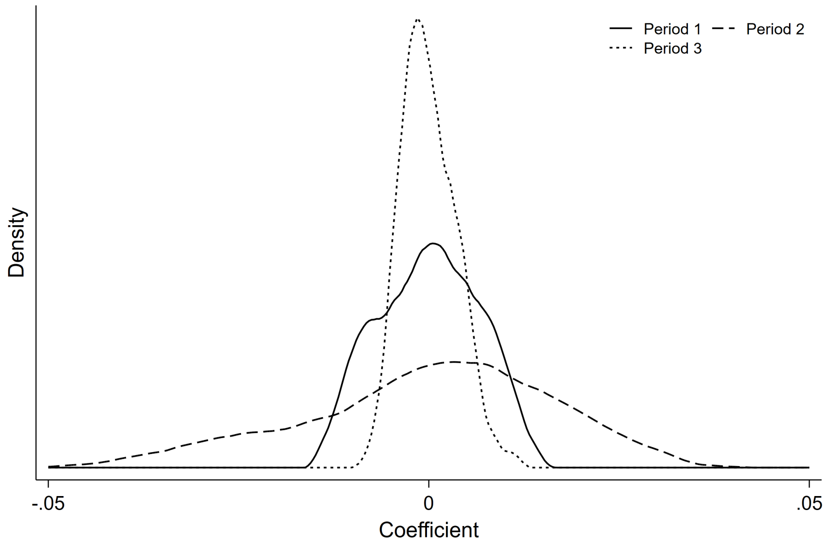
Table 2.
Determinants of DES use

	(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	50,586	50,586	50,586	50,586	50,586	50,586

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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

FIGURE 2.

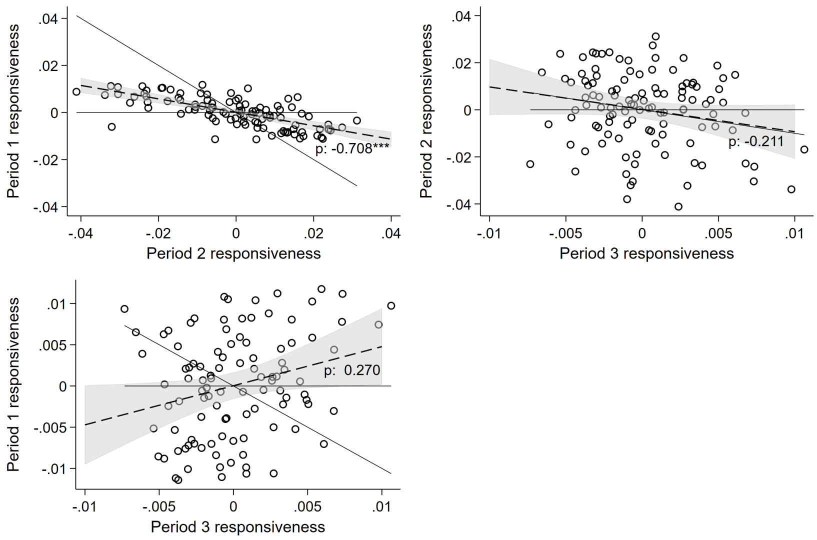
Cardiologist responsiveness in the three periods (centered)



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.

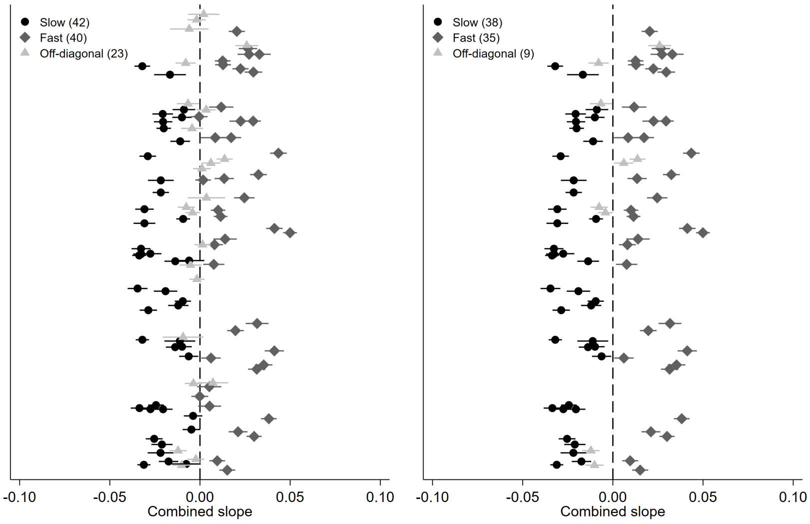
FIGURE 3.

Relationship between actual and predicted cardiologist responsiveness



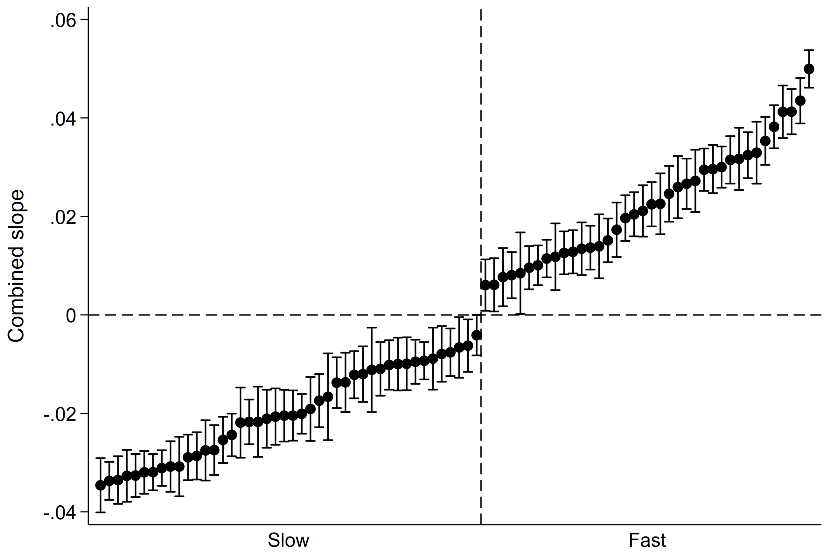
NOTE.— Responsiveness estimates are centered around zero (i.e. the cardiologist-level estimate minus the overall mean shown in column 1 of Table 2. Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively. Each data point corresponds to the relationship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

FIGURE 4.
Uni-dimensional characterization of responsiveness by cardiologist type



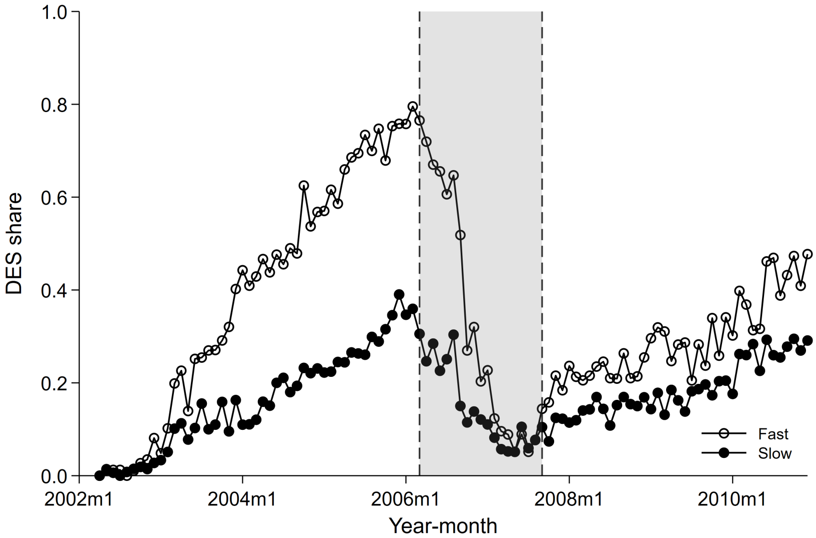
NOTE.— Each observation refers to one cardiologist. The horizontal axis refers to the mean re-centered sum of individual responses in period one and period two as displayed in Figure 1. The left panel includes all cardiologists in our sample. The right panel shows the remaining cardiologists after removing individuals with a combined slope not significantly different from the mean. The legend refers to the two-by-two categorization of cardiologist types as defined in Figure E.1.

FIGURE 5.
Uni-dimensional characterization of responsiveness by cardiologist type



NOTE.— Each observation refers to one cardiologist. Cardiologists are ranked by the mean re-centered sum of individual responses in period one and period two, indicated on the vertical axis. Cardiologists to the left of the vertical line (with negative slopes indicating they have a combined response which is less than the mean for the sample) are classified as "slow" while cardiologists to the right of the vertical line (with positive slopes) are classified as "fast".

FIGURE 6.
DES uptake trends among slow and fast cardiologists in Swedish hospitals



NOTE.— See Figure 5 for definitions of "slow" and "fast" cardiologists. The vertical lines indicate the different time periods we analyze as described in detail in the text.

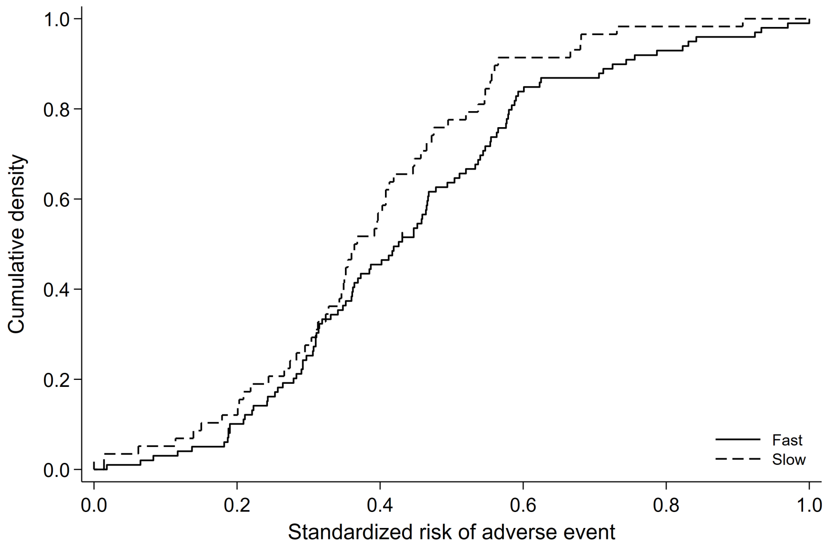
Table 3.

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 responder	-0.029**	-0.011**	0.001	-0.003**	-0.029*	-0.004
	(0.014)	(0.005)	(0.005)	(0.001)	(0.015)	(0.003)
Controls	✓	✓	✓	✓	✓	✓
Observations	50,586	50,586	50,586	50,586	50,586	50,586
Mean of outcome	0.250	0.071	0.050	0.011	0.150	0.089
B. Only period 1						
Slow responder	-0.030*	-0.011	0.004	-0.004*	-0.037**	-0.001
	(0.015)	(0.006)	(0.007)	(0.002)	(0.016)	(0.004)
Controls	✓	✓	✓	✓	✓	✓
Observations	19,506	19,506	19,506	19,506	19,506	19,506
Mean	0.250	0.073	0.043	0.007	0.150	0.082
C. Only period 2						
Slow responder	-0.045***	-0.018**	-0.003	-0.000	-0.031**	-0.015***
	(0.013)	(0.007)	(0.009)	(0.002)	(0.014)	(0.005)
Controls	✓	✓	✓	✓	✓	✓
Observations	10,896	10,896	10,896	10,896	10,896	10,896
Mean	0.250	0.069	0.056	0.013	0.140	0.091
D. Only period 3						
Slow responder	-0.019	-0.006	0.0022	-0.003*	-0.019	-0.004
	(0.017)	(0.005)	(0.005)	(0.002)	(0.016)	(0.004)
Controls	✓	✓	✓	✓	✓	✓
Observations	20,184	20,184	20,184	20,184	20,184	20,184
Mean	0.260	0.070	0.054	0.013	0.150	0.095

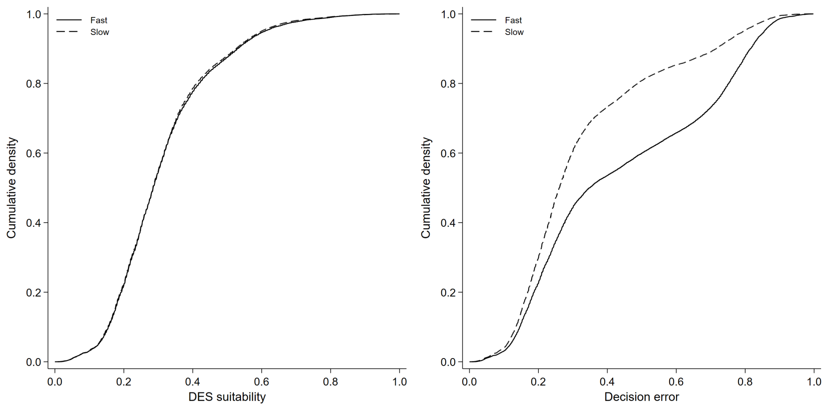
Note.— The table presents the OLS estimates from a regression of patient outcomes on hospital, cardiologist, treatment, and patient characteristics. Robust standard errors, clustered by hospital, presented in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 7.
Cumulative distribution functions of cardiologist quality by type



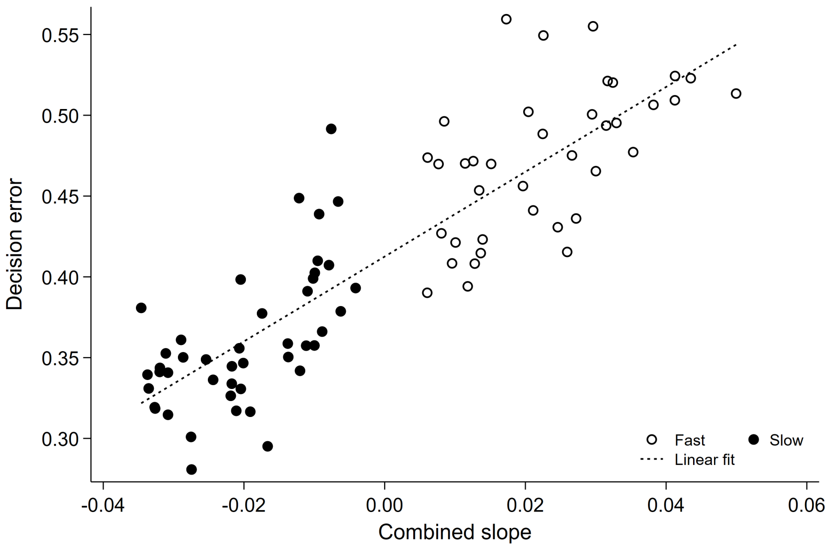
Note.— Empirical cumulative densities of "slow" and "fast" cardiologists (as defined in Figure 4 and Figure 5) with respect to case-mix adjusted cardiologist average patient outcome with respect to the risk of an adverse event as defined in column (1) of Table 3. The risk of an adverse event is standardized to lie between zero and one, where the cardiologist with the lowest (highest) share of adverse events receive a value of zero (one), respectively.

Figure 8.
Patient DES suitability and DES decision error distributions



Note.— Empirical cumulative densities of slow and fast cardiologists (as defined in Figure 4 and Figure 5) with respect to DES suitability (left) and DES decision error (right) of the patient population treated by the cardiologist in period one and period two as displayed in Figure 1. DES suitability is defined by predicted values based on a bivariate logistic regression of the use of DES on a patient as a function of a set of patient case-mix characteristics in period three as displayed in Figure 1. DES decision error is defined as the absolute difference between the DES suitability score and the actual treatment received. A lower value of the decision error corresponds to a lower decision error.

FIGURE 9.
Association between treatment decision error and cardiologist speed of response



NOTE.— Each observation refers to one cardiologist. Linear relationship between cardiologists' decision error and the combined speed of response to news in period one and period two as displayed in Figure 1. DES decision error is defined as the absolute difference between the DES suitability score and the actual treatment received.

TABLE 4.

Correlates of decision error

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Slow (dummy)	-0.112***						
	(0.010)						
Slow (linear)		-0.026***				-0.022***	-0.020***
		(0.002)				(0.002)	(0.003)
Pre-DES adverse events			0.001**				0.001***
			(0.001)				(0.000)
Experienced				0.017		-0.005	0.013
				(0.018)		(0.010)	(0.013)
Female				0.027		0.008	0.021
				(0.025)		(0.012)	(0.015)
Old				0.007		0.012	0.016
				(0.022)		(0.011)	(0.014)
Specialized				0.042		-0.016	-0.023
				(0.027)		(0.013)	(0.019)
Large hospital					0.006	-0.001	-0.021
					(0.013)	(0.010)	(0.012)
Teaching hospital					-0.111***	-0.037***	-0.029**
					(0.014)	(0.012)	(0.014)
Mean	0.418	0.418	0.401	0.418	0.418	0.418	0.401
R-squared	0.642	0.773	0.115	0.063	0.231	0.786	0.850
No. of observations	82	82	40	82	82	82	40

NOTE.— The table presents the OLS estimates from a regression of average cardiologist decision error on cardiologist, hospital, and patient characteristics.‘Pre-DES adverse events’ denote the cardiologists’ rate of adverse events *prior to* the introduction of DES. ‘Specialized’ is a binary variable indicating whether the cardiologist has a specialization in interventional cardiology. Robust standard errors, clustered by hospital, presented in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5.

Correlates of cardiologist type

	(1) Fast	(2) Slow	(3) Difference
Pre-DES adverse events	0.295	0.330	-0.034
Experienced	0.368	0.204	0.163*
Female	0.157	0.090	0.066
Old	0.289	0.272	0.016
Specialized	0.973	0.840	0.132**
Large hospital	0.342	0.340	0.001
Teaching hospital	0.078	0.454	-0.375***
No. of observations	38	44	82

NOTE.— The table presents averages of a set of physician characteristics (columns (1) and (2)) and their differences (column (3)) for "slow" and "fast" cardiologists (as defined in Figure 4 and Figure 5). 'Pre-DES adverse events' denote the cardiologists' rate of adverse events *prior to* the introduction of DES. 'Specialized' is a binary variable indicating whether the cardiologist has a specialization in interventional cardiology. Significance levels are based of a differences in means t-test assuming unequal variances. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix A The 2006 DES controversy

The market share of DES rose rapidly following 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 percent 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 percent in the CYPHER DES group versus 3.9 percent 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 (see, e.g., ESC, 2017). Within one year, the use of DES in the United States fell by nearly 20 percentage points (see Figure F.1). 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) and the American College of Cardiologists / American Heart Association / Task Force on Practice Guidelines (ACC/AHA/SCAI) updated the PCI guidelines at the end of 2007 (King *et al.*, 2008). By that time, however, the use of DES had dropped dramatically in favor of the older Bare Metal Stents (BMS).

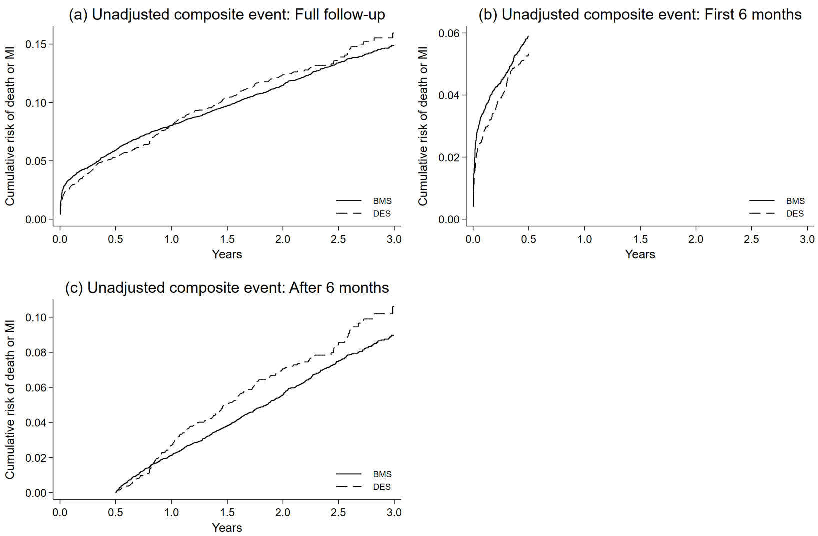
In retrospect, the response to the adverse information on the safety of DES in 2006 can be considered to be an overreaction for a number of reasons (see, e.g., Serruys and Daemen, 2007a). First, the discouraging results presented at the ESC hot-line session in 2006 were based on aggregate pooled data 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 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 A.1 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).

FIGURE A.1.
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 30, 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.

Appendix B Behavior change in response to guidelines

This appendix presents two main findings related to the clinical guideline period. First, we show that cardiologists changed their behavior in response to the introduction of guidelines. Second, we show that this led to a reduction in the probability of experiencing serious adverse clinical events, albeit at the expense of an increase in more minor health conditions.

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 should be used in conjunction with dual anti platelet therapy (DAPT; Socialstyrelsen, 2008). We therefore explore how the use of DAPT changes after the guidelines were implemented for patients with identical observable 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.

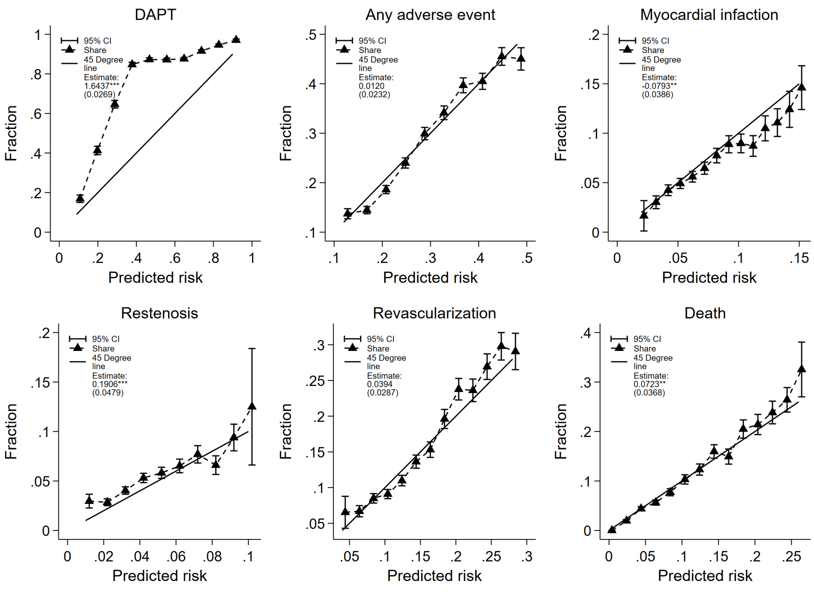
The horizontal axis in Figure B.1 presents this predicted probability, averaged over bins of 0.1, whilst the vertical axis shows the actual fraction of patients receiving DAPT in the post-guideline period in the respective bins. The 45 degree line indicates the expected share of DAPT from the pre-guideline period. Hence, estimates above the 45 degree line imply that DAPT was used more frequently than predicted based on the pre-guideline model parameters.[23] This shows strong evidence that cardiologists dramatically increased their use of DAPT with the introduction of the clinical guidelines.

We next show how the change in cardiologists' behavior affected the risk of experiencing adverse clinical events. The remaining graphs in Figure B.1 explore the probability of experiencing different health problems. 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 decreased significantly in the post-guideline period,

[23] A regression of the binary indicator of the use of DAPT on the predicted DAPT from the pre-guideline period and a dummy for the post-guideline period shows the estimate of the latter is 1.64 and highly significant. This suggests that the use of DAPT is on average 164 percent more likely in the post-guideline period, holding constant the predicted use of DAPT.

although this is not reflected in a reduction in mortality. The reduction 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 behavior post-guidelines, reducing the risk of serious adverse events, albeit at the expense of an increase in more minor health conditions related to BMS.

FIGURE B.1.
Association between post-guideline outcomes and pre-guideline 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-guideline periods. The bottom left estimate refers to the corresponding parameter estimate of a binary indicator for the post-guideline 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 Equations (1) and (1'). This allow us to examine in more detail whether differences in responsiveness are associated with 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:

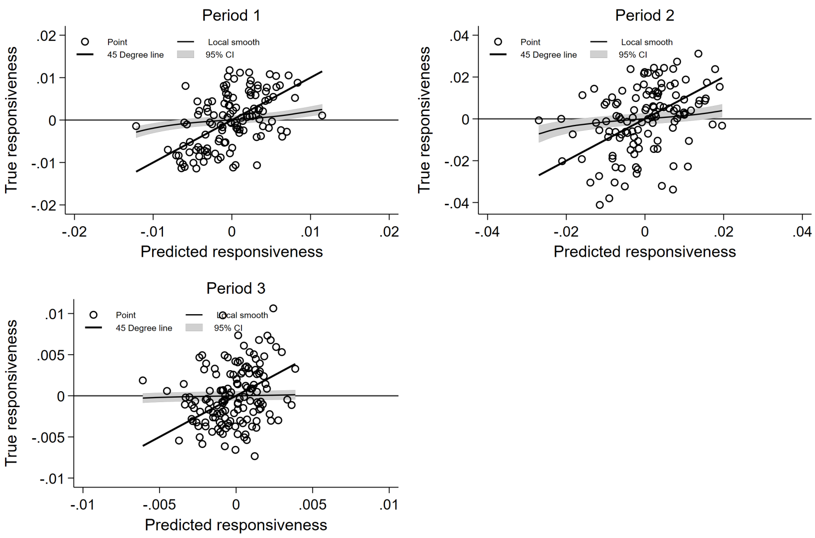
$$A_c^p = \gamma_0 + \gamma_1 \bar{X}_{c(i)}^p + \nu_c \text{ for } p = 1, 2, 3, \tag{4}$$

where A_c^p is the cardiologist- and period-specific responsiveness estimate defined in Section 3.1; $\bar{X}_{c(i)}^p$ 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 picks up whether cardiologists treating, for example, older or unhealthier patients respond faster or slower than cardiologists treating younger or healthier patients. This 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-physician sorting.

Figure C.1 relates the prediction from estimation of Equation (4) to actual cardiologist responsiveness using average patient characteristics for each period. Specifically, the figure plots the dependent variable in Equation (4) on the vertical axis as a function of the prediction from Equation (4) 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 systematic patient-physician sorting is unlikely to be a problem 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.

Correlation within cardiologist responsiveness across periods



Note.— The figure illustrates the relation between actual cardiologist responsiveness and predicted responsiveness using average patient characteristics. 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 quartiles 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 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 (parameter p and j scripts omitted):

$$m^j_{icht} = \sum_{k=1}^{4} \delta_k Q^p_k + \zeta_c Z^p_c + \zeta_x X_{it} + \zeta_h H_h + \mu_{icht} \text{ for } p = 1, 2, 3, \tag{5}$$

where m^j_{icht} is the j^{th} outcome for patient i, treated by cardiologist c in hospital h in year-month t, $Q^p_k = \mathbb{1}[q^p_{k-1} < A^p_c \leq q^p_k]$ is an indicator variable 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.[24] Our main interest lies in the period-specific coefficients δ_1–δ_4, which reflect differences in patient outcomes associated with being treated by cardiologists at different quartiles of the responsiveness distribution.[25]

Figure D.1 presents the results for period one, whilst Figure D.2 and Figure D.3 present the results for the subsequent two periods (i.e., the period of

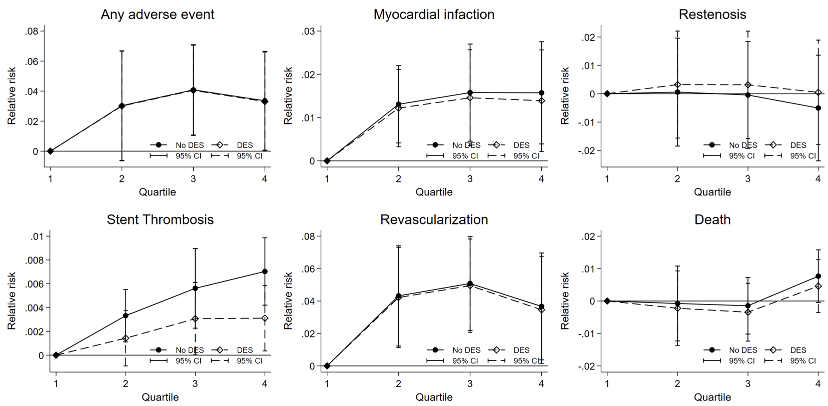
[24] This equation is similar to Equation (2), replacing the mutually exclusive cardiologist types by the quartiles of the responsiveness distribution. In addition, Z^p_c also includes the estimated intercept parameters α^c_p from (1) in order to control for the initial level of DES take-up in each period.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

[25] 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 (5) 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.

bad news and the guideline period). The figures are plotted by outcome and present the ordered quartile-specific coefficients together with corresponding 95 percent confidence intervals.

The upper left panel of Figure D.1 shows that the risk of any type of adverse event 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.

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

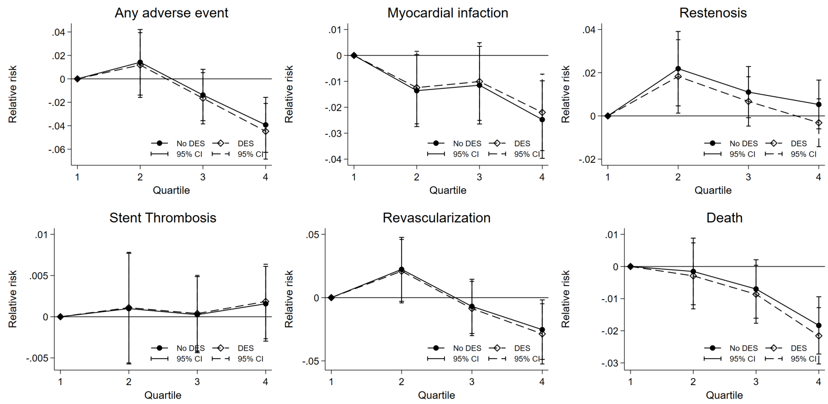


NOTE.— The figure presents OLS estimates from a regression of patient outcomes on a set of dummy variables for being treated by a cardiologist at different quartiles of the period-specific responsiveness distribution adjusted for hospital, cardiologist, and patient characteristics as described in Equation (5). Robust 95 percent 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 20 percent 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.

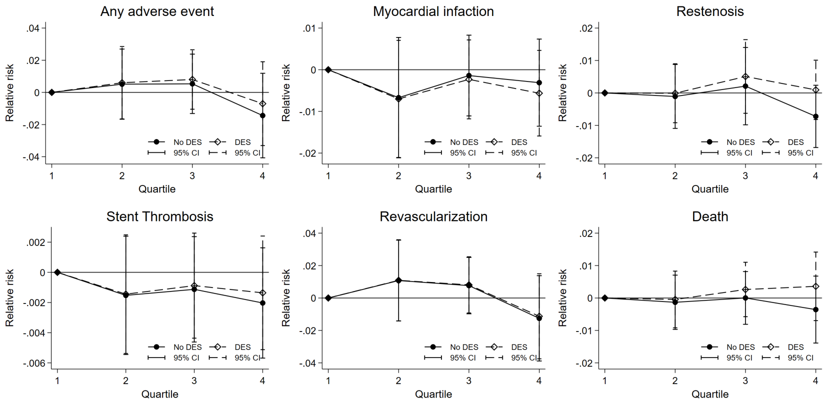
FIGURE D.2.
Effect of cardiologist responsiveness on patient outcomes in period two



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 (5). Robust 95 percent 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 (5). Robust 95 percent confidence intervals, clustered by cardiologist, presented as vertical lines around each point estimate.

Appendix E Robustness to alternative definition of cardiologist type

In this definition, we define four "types" of cardiologists, rather than 2. As before, we group cardiologists in "fast" and "slow" responders according to whether they were above or below the period-specific median responsiveness. We use these to define four types, shown in Figure E.1.

FIGURE E.1.
Definition and sample size of cardiologist types

		Period Two	
		Slow	*Fast*
Period One	*Slow*	Slow responders ($n = 42$)	Overemphasize bad news ($n = 12$)
	Fast	Overemphasize good news ($n = 11$)	Fast responders ($n = 40$)

NOTE.— The figure displays the four categories of cardiologists used in the analysis according to the combination of normalized responsiveness estimates in period one and two. 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. We only include cardiologists observed in all three periods, which restricts our sample to 50,586 patients treated by 105 cardiologists.

The top left corner of Figure E.1 shows the number of "slow responders". These are cardiologists who were slow to respond 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 good news in period one, but slow to respond to the news of negative side effects in period two. 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, similar to Equation (2), but allowing for four mutually exclusive “types”. Panel A of Table E.1 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 percent 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 E.1 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 C.1, it is clear that the guidelines reduced variation in physician behavior and with that, also in clinical outcomes.[26]

[26]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-guideline period.

Table E.1.

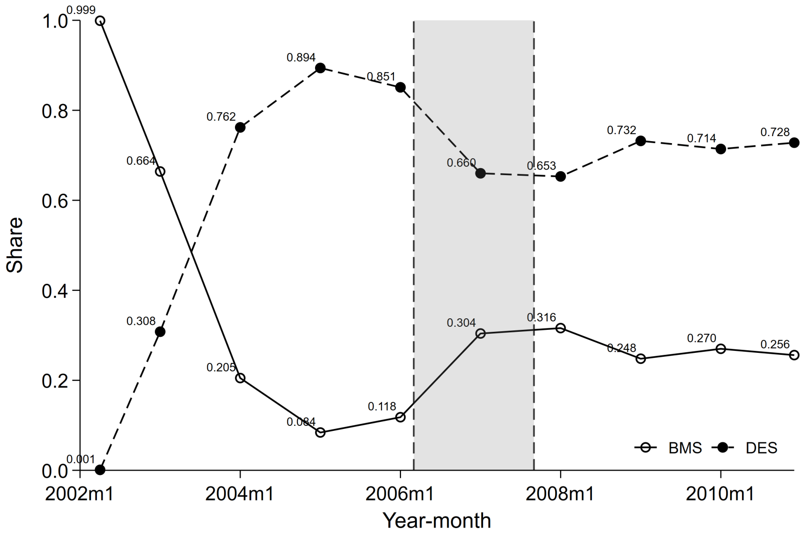
Effect of cardiologist type on patient outcomes

	(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	50,586	50,586	50,586	50,586	50,586	50,586
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	19,506	19,506	19,506	19,506	19,506	19,506
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	10,896	10,896	10,896	10,896	10,896	10,896
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	20,184	20,184	20,184	20,184	20,184	20,184
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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

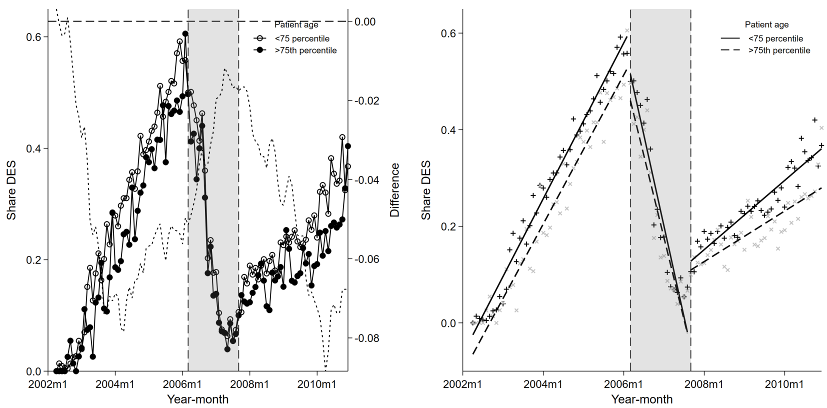
Appendix F Additional Tables and Figures

FIGURE F.1.
US trends in BMS and DES take-up



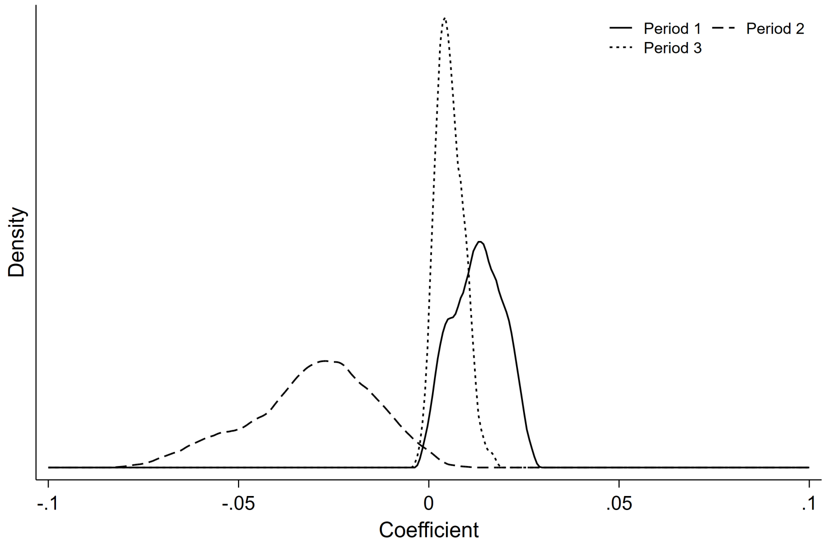
NOTE.— The vertical lines indicate the different time periods we analyze as described in detail in the text. The shares sum to one.

FIGURE F.2.
Trends in DES take-up by patient age



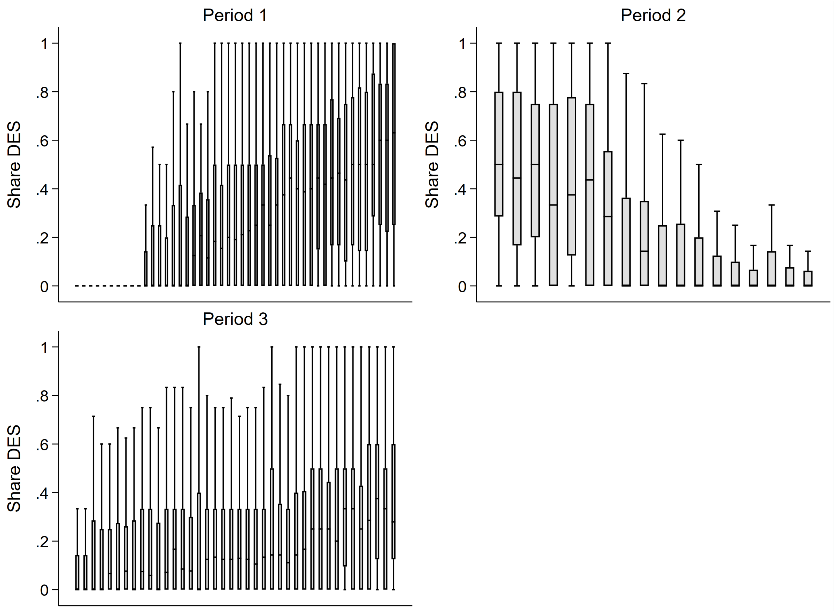
NOTE.— The figure shows the raw (panel a) and estimated (panel b) trends in DES take-up by time period and patient age. The dotted line measured on the right y-axis in panel (a) indicates the average group difference over time. The trends in panel (b) are estimated with a piece-wise linear spline defined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

Figure F.3.
Cardiologist responsiveness in the three periods (uncentered)



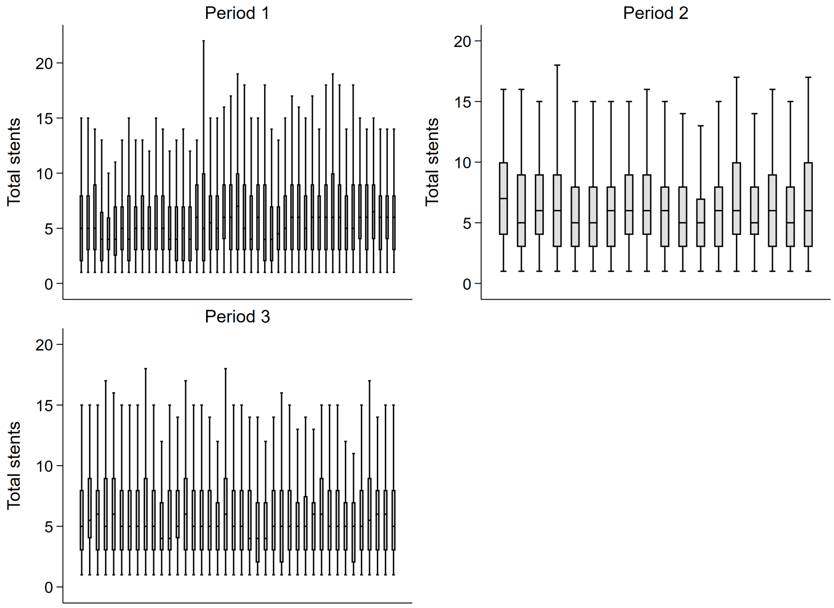
Note.— Densities are based on the number of cardiologists observed in each period: 120, 119, and 140 respectively.

Figure F.4.
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 F.5.
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.

Table F.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)
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)
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)

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Table F.1.
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	Mean	SD
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	50,586	

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.

Table F.2.

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	50,586	50,586	50,586	50,586	50,586	50,586	50,586	50,586	50,586

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; columns (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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.