Physician Heal Thyself? Competency Traps, Expertise, and Changes in Decision Making After Information Shocks

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Abstract

Although rapid response to exogenous information shocks is critical in knowledge-intensive professional domains, it is often hampered by cognitive flaws in the form of competency traps. We shed light on the theoretical tensions related to trade-offs between agility and exploitation of accumulated knowledge, and rational versus boundedly rational use of new information. Further, we investigate the extent to which variation in types and level of expertise influences response to information shocks, within the empirical context of physician decision making after a new medical guideline release about the efficacy of stents in treating coronary heart disease. Results indicate that physicians do incorporate new information into decisions, and are able to discern between contexts that are appropriate for the applicability of the information. Disturbingly, we also find that the pace of adjustment is not swift, and the ability to discern is adversely affected by the heterogeneity in the physician's patient mix. Importantly, we find that various types of expertise, particularly when such expertise is indicative of mindful retraining, attenuate the strength of competency traps.

Key Words: *expert decision making, competency traps, uncertainty, healthcare, medical guidelines*

1. Introduction

Knowledge intensive professional domains, such as medicine, accounting, and law, often experience information shocks as a result of continued practice as well as advances in research. To the extent that these shocks change the underlying body of knowledge in the field, practitioners must craft swift responses by altering behavior and common practices. Failure to respond correctly, and with speed, can have adverse consequences for progress and welfare at micro (individual), meso (organizational) and macro (societal) levels. For instance, scholars have documented welfare losses associated with continued judicial rulings when legal precedent is overturned (Benesh and Reddick 2002), organizational costs arising from the use of outmoded accounting practices (Hronsky and Houghton 2001), and imprecise prediction of rival behavior in competitive environments (Argote et al. 1990). Within the health care context, such delays may result not only in higher costs of care, but in decreased quality of life and, in extreme cases, loss of life itself (Choudhry et al. 2005, Fries et al. 1993). Despite these penalties, extant research suggests that rapid responses to new information rarely occur (Ahuja and Lampert 2001, Henderson and Clark 1990, Levinthal and March 1993). Instead, decision makers and organizations often exhibit cognitive shortcomings, i.e., they fall prey to competency traps (Levinthal and March 1993), as a result of their desire to continue exploiting existing knowledge which was costly to acquire (March 1991).

In this work, we address three theoretical tensions concerning the response of highly skilled professionals to new information. The first tension relates to the trade-off between agile responses to the availability of new information and habitual exploitation of established knowledge stocks. On the one hand, it is known that highly trained domain specialists incorporate information rapidly in uncertain environments (Chase and Simon 1973, Gobet and Simon 2000, Larkin et al. 1980). On the other hand, new information which challenges existing knowledge is often discounted by agents when the source of new information is "distant" (Levinthal and March 1993); usually in anticipation of the performance degradation which occurs when individual habits and routines are disrupted (March 1991). When confronted with information shocks in professional domains, these agents must manage this difficult dilemma between responding quickly to the changed information regime and exploiting established knowledge reservoirs (Argote and Ingram 2000).

A second tension is concerned with the ability of decision makers to discerningly apply new information and update decision rules. When information is costless to acquire and decision makers are highly skilled, rational expectations theory in economics would predict that this information will be efficiently assimilated into decision-making rubrics (Muth 1961). Countervailing the rationality argument, psychology scholars have noted that decision makers often fail to internalize new information correctly in information intensive environments, instead extracting core messages, i.e. *gist*, that overlooks nuance and detail (Reyna and Brainerd 1991). Understanding whether or not professionals respond to new information with appropriate and relevant changes to decision rules is an important question for policy makers seeking to disseminate new knowledge in a timely fashion.

A third tension relates to how varying degrees of expertise influence response to information shocks. An unresolved question in the literature at the micro individual decision making level is concerned with the performance efficacy of variation in expertise of decision makers, along a continuum of less or more mindful dimensions (Argote 2006). Scholars have noted that expertise and learning mechanisms may consist either of routine habituations or mindful retraining, which grow the cognitive capacity to respond to unanticipated signals (Levinthal and Rerup 2006, Weick and Sutcliffe 2006). Understanding whether differences in dimensions of expertise, ranging from habits formed due to quality of formal education and tenure to more mindful behavior stemming from task-specific knowledge and re-training, have the same or different effects on competency traps can provide important individual and organizational level implications for information processing, decision making, and resultant performance.

We investigate these tensions in a context that is significant in terms of both economic and public welfare: the utilization of coronary stents by physicians in light of new information about their efficacy released through a medical guideline. We pose the following research questions: what is the nature and speed of physician response to an information shock in the form of guideline release? Specifically, do physicians respond to the new guideline, and if so, how quickly? Moreover, is physician response discerning in the application of the new guideline contingent on patient characteristics? Finally, we ask, how does the nature and degree of physician expertise influence response to the new guideline?

Our study makes use of an information shock to prevailing knowledge about coronary stents, formally known as percutaneous coronary interventions (PCI), for the treatment of stable coronary arterial disease (SCAD). In January 2006, the American Heart Association (AHA) and the American College of Cardiology (ACC), the two foremost professional societies in Cardiology, jointly released their updated guideline for the usage of stents (Smith et al. 2006). Using the new guideline release as our research setting offers two distinct advantages. First, for identification purposes, the information shock should be exogenous to the decision maker. The guideline release satisfies this requirement as guideline authorship occurs under strict confidentiality agreements[1] and the studied physicians were not part of the AHA/ACC Task Force. Second, the guideline discerns among two classes of patients, those with low and high severity SCAD, by providing a new recommendation for when stent usage is appropriate, and when these more expensive and invasive treatments should be foregone in favor of less expensive and safer pharmacological options. By differentiating between appropriate and inappropriate conditions for the use of stents, the new guideline also allows us to study the extent to which physicians discerningly utilize stents when treating different classes of patients. Empirically, we measure the response of physicians to this new information using a within-subjects estimate of the effect of medical guideline release on the stenting rate of practicing physicians for heterogeneous patient classes. Our data are drawn from a comprehensive census of hospital admissions in the state of Florida between 2001 and 2010, and contain rich information at the bed-level on patient, physician, and hospital specific factors.

Findings provide both encouraging and cautionary evidence regarding the speed and efficacy of response to information shocks. In contrast to received medical literature (Grimshaw and Russell 1993), we find that physicians do incorporate new information into treatment decisions by altering

[1] http://my.americanheart.org/idc/groups/ahamah-public/@wcm/@sop/documents/downloadable/ucm_319826.pdf

their behavior. However, evidence also suggests that these responses are not swift; resulting in significant public welfare deficits that could have been avoided with a more timely response. Theoretically, this finding provides evidence of "conservatism" and supports the existence of competency traps (Levinthal and March 1993). Moreover, we find that in the aggregate, physicians are discerning in their application of new information, which bodes well for judgment and appropriate use of guidelines across patient classes. However, we also find that the physician's ability to discern between patient classes in terms of stenting use diminishes as the mix of high-severity and low-severity patients increases, i.e. physicians treating a mix of patient classes exhibit less discernment than physicians whose patients are more homogeneous in their level of SCAD. This result is suggestive of the presence of spillovers that may adversely affect social welfare. Finally, we find that higher levels of physician expertise attenuate the strength of competency traps. However, not all indicators of expertise are equally effective. Mindful and active learning from board recertification and task-specific knowledge mitigate competency traps significantly more successfully than past or routine learning reflected in quality of formal education and professional tenure.

Several important implications stem from these findings. Theoretically, while competency traps have been identified as significant individual (Darr et al. 1995) and organizational level (Ahuja and Lampert 2001, Levinthal and March 1993) pathologies, the effect of competency traps in knowledge intensive professions remains under studied. In knowledge-intensive environments, the ability of decision makers to respond appropriately to new knowledge, which is generated frequently, is critical and is likely to be related to differences in the type and level of expertise the decision-maker possesses (Chase and Simon 1973, Larkin et al. 1980). This specific link, especially important in contexts where new knowledge is generated exogenously and not as a direct result of the decision maker's actions (as is the case with outcomes of medical trials or legal precedent), has not been explored rigorously in the literature. Furthermore, our work responds to recent calls (Felin and Foss 2005, Winter 2013) to explore the micro-foundations of routines in contexts where decision makers possess significant agency and are embedded within established organizations.

Practically, to the degree that physician updates to decision processes have been characterized as infrequent and inconsistent (Grimshaw and Russell 1993, Hellinger 1996), the need for a deeper understanding of physicians' reactions to information shocks about the efficacy of commonly used medical treatments is pressing. The documented inability to influence physician decision making in any systematically effective way is a source of persistent frustration for researchers, policy makers, and consumers (Smith 2000). For researchers and policy makers, the concern is that new knowledge regarding state-of-the-art treatments is not being utilized in a timely and effective manner. For patients, the failure of physicians to stay abreast of cutting-edge discovery poses risks of misdiagnosis, ineffective treatment, and even death.

2. Context: The Treatment of Stable Coronary Arterial Disease

2.1 Stable Coronary Artery Disease

Stable Coronary Artery Disease (SCAD) is the narrowing, blockage, or hardening of coronary arteries due to the buildup of plaque—cholesterol and fatty deposits—causing a restriction of blood flow to the heart. Left untreated, SCAD can lead to angina (chest pains), acute myocardial infarction (heart attack), and death. It is currently the leading cause of death in the United States, with half of men and one third of women over 40 developing it during their lifetime (Rosamond 2007). As one would expect, there are multiple severity levels of coronary arterial disease (ranging from minor blockage to complete occlusion of the artery) and recommended treatment regimens depend on diagnosed severity. The widely accepted SCAD classification system developed by the Canadian Cardiovascular Society (CCS)[2] (Table 1) includes four levels, ranging from Class I (minor) to Class IV (debilitating). Our study focuses on a change in the recommended approach for treating *CCS-Class I and II angina*; which results in a "slight limitation to ordinary activity."

Although the disease can sometimes be managed effectively through lifestyle changes (e.g. limiting smoking and alcohol consumption, exercise, and weight management), factors not under the patient's control (such as genetics, hyperglycemia (through diabetes), high cholesterol, and

[2] We use the CCS system to maintain consistency with the AHA / ACC's updated guideline.

hypertension) can also have a significant effect on the condition. Given the disease's scope and impact, both pharmacological and surgical avenues of treatment have been pursued since arteriosclerosis was added to the International Classification of Diseases (ICD) in 1949.

Attempts at pharmacological treatment of SCAD began after the Framingham Heart Study (Dawber et al. 1951) and the identification of high cholesterol as a leading cause of heart disease. However, pharmacological treatment did not begin in earnest until the 1980s, when large randomized trials began to test the efficacy of various drugs. AFASAK (Petersen et al. 1989), one of the many trials which established that aspirin could be used to manage angina, for example, was not released until 1989. At present, pharmacological treatments encompass a variety of options, including Nitrates, Beta Blockers, Calcium Blockers, and other Anti-Anginal drugs. Pharmacological treatments provide benefits inasmuch as they are far less invasive than surgical options and significantly cheaper, given availability of generic alternatives to erstwhile patent protected drugs.

Surgical treatment has an equally long tradition, beginning with the first coronary artery bypass graft (CABG) in 1960 and including the more recent innovation of coronary stents, or percutaneous coronary interventions (PCI) in 1995. Stents requires a physician to make a small incision in the femoral artery (the artery in the upper thigh) and thread a balloon catheter through the body to the point of blockage. After proper placement, the balloon catheter is inflated slowly to compress the blockage and stretch the artery. The stent is then inserted into that location and left permanently to keep the artery open. Medically, the objective of the stent is to minimize arterial restenosis, i.e. blockage building up in the same area or the artery collapsing. As stents significantly reduced the need for highly invasive surgeries like CABG, stenting experienced a meteoric rise in usage after its FDA approval in 1995. Ten years later, 3 million stents were shipped worldwide, with revenues exceeding $5 billion (Wieffering 2011).

2.2 The Information Shock - AHA/ACC PCI Guideline Update

Professional organizations in various medical specialties routinely release guidelines to inform the diagnosis and treatment of specific medical conditions. Given the overlap in their objectives, the AHA and ACC have issued numerous guidelines over the years to diffuse recommendations to medical professionals based on the current state of medical evidence for the treatment of cardiovascular and cardiac conditions. More specifically, the objective of an AHA/ACC practice guideline is "to assist healthcare providers in clinical decision making by describing a range of generally acceptable approaches for the diagnosis, management, or prevention of specific diseases or conditions" (Smith et al. 2006). While guidelines address many conditions with specific recommendations for treatment, the objective in this particular instance was to define the conditions for PCI use that meet the needs of "most patients", thereby reflecting the current state of expert opinion regarding PCI. This update, the first since a prior guideline release in June, 2001 (Smith et al. 2001) recommended that for *CCS – Class II angina*, the use of PCI for treatment was to be pursued only in very limited circumstances, implicitly suggesting that the less invasive (and less expensive) pharmacological treatment was superior for these diagnoses[3].

The release of the 2006 guideline, which alters the knowledge regarding when the use of PCIs is appropriate, serves as the exogenous information shock in our study examining physician response to new information. In essence, the guideline defines new "rules" for when the two treatment options (PCI and pharmacological) should be used[4].

3. Professional Decision Making Following Information Shocks

3.1 Physician Response to Information Shocks

To investigate how physicians respond to information shocks in the form of guideline release we juxtapose two literatures: one, extant work discussing competency traps and the willingness of individuals to alter their decision making routines and, two, existing research on decision making of agents with significant knowledge endowments. As discussed in Levinthal and March's (1993) seminal work, competency traps manifest when individuals or organizations forego the full utilization of new information. This inability or unwillingness to respond to new information

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[3] The 2001 update text can be found here: http://content.onlinejacc.org/article.aspx?articleid=1127281

[4] We note here that, although the guideline update changes suggested practices, there is no malpractice liability the physician is exposed to by electing to disregard the update as stenting is an accepted medical treatment for SCAD (and therefore does not constitute "medical error") (Hofer et al, 2000). That said, recent lawsuits brought against physicians for excessive stenting, under the legal guise of civil conspiracy and unlawful enrichment, have occurred when physicians have performed hundreds or thousands of unnecessary procedures.

retards the process of information diffusion; resulting in sub-optimal behavior in the form of favoring more familiar and well understood options (Ahuja and Lampert 2001). The literature in organizational learning and behavior suggests several reasons why this behavior is not surprising. First, when individuals (Darr et al. 1995) and organizations (Argote et al. 1990, Nelson and Winter 1982) alter their routines, there is often a performance penalty as a result of the knowledge degradation which occurs. Second, as stocks of knowledge are often difficult and costly to acquire, agents are incentivized to exploit those knowledge stocks (March 1991); particularly so in settings where the decision process which results from the new information is unrelated (Schilling et al. 2003) or does not introduce beneficial variety (Staats and Gino 2012). Third, decision makers often discount knowledge when its source is "distant" (Levinthal and March 1993), markedly if the information disconfirms or is at odds with the decision maker's currently held beliefs (Christensen-Szalanski and Bushyhead 1981).

Empirical evidence of these effects is well documented in the medical literature. Research shows that the medical profession is characterized by extensive reliance on care protocols, procedural guidelines, and treatment standards (Woolf 1992). However, even as such routinization reduces the cognitive burden on physicians during practice and improves performance through reduced variation in outcomes (Pisano et al. 2001), excessive routinization also tends to amplify physician resistance to change in practice behaviors (Choudhry et al. 2005). Physician recalcitrance towards altering routines that have become habituated has been shown to result in inferior performance in terms of economic efficiency of treatment (Fries et al. 1993) as well as the clinical care of patients (Choudhry et al. 2005); and continues to occur despite the fact that the ability to react swiftly to new information is essential for the effective practice of medicine.

Theoretically, a plausible alternative to inertia exists. Substantial research suggests that physicians, by virtue of their deep stocks of domain knowledge, will be *less* likely to fall prey to competency traps. To the extent that physicians are highly trained professionals, a result of their formal academic training and residencies, they will likely exhibit above-average performance along three dimensions: objective outcomes (Calderwood et al. 1988, Chen et al. 2006, Nee and

Meenaghan 2006), cognitive effort required to make decisions (Hutton and Klein 1999, Nee and Meenaghan 2006), and likelihood of strategic error (Calderwood et al. 1988, Chase and Simon 1973). More simply, physicians should exhibit a cognitive parsimony that allows them to make superior decisions and do so rapidly (Gobet and Simon 2000, Larkin et al. 1980). Moreover, as a result of the repetition within their training, they should react to unanticipated circumstances and new information swiftly and with more precision than other decision makers (Chase and Simon 1973, Gobet and Simon 2000). Research not only shows that standardizing and repeatedly performing treatments results in superior clinical and financial outcomes (Nallamothu et al. 2006), but that these benefits range across many activities (e.g. diagnosing (Reyna and Lloyd 2006), cardiac surgery (Diwas et al. 2013, Pisano et al. 2001), and common treatment (Bauer et al. 1999)).

How might physicians, highly trained medical professionals, alter their decision-making to respond to new information in the form of a medical guideline? As discussed, the release of the AHA/ACC Guideline represents a shock to the existing knowledge regarding stenting for low severity (CCS Class II and below) SCAD patients. In the face of new knowledge physicians have two choices: they may volitionally ignore the findings and introduce no change in their treatment patterns, or they may revise their behavior to account for the new findings. To the degree that professionals' choices are more likely to become habituated because of the volume of repetition (Duhigg 2012), learning logic would suggest that experts would be susceptible to falling into competency traps in these situations to avoid the loss of established knowledge stocks (March 1991) and prevent knowledge depreciation (Darr et al. 1995). However, the fact that the decision makers with deeper knowledge repositories make superior decisions when confronted with unanticipated circumstances (Calderwood et al. 1988, Chen et al. 2006, Gobet and Simon 2000, Larkin et al. 1980) suggests a substitution of less invasive treatments for low severity SCAD. Therefore, in the absence of a clear *a priori* expectation of which effect is likely to be dominant, we empirically explore the competing predictions.

3.2 Physician Discernment Between Patient Classes

While the vulnerability of physicians to competency traps raises the possibility that they may not react to information shocks in a timely manner, a second concern in the context of information shocks relates to the appropriateness of information assimilation. Neoclassical economics (Becker 1978) suggests that decision makers costlessly incorporate all relevant information into decision making, and the rational expectations hypothesis (Muth 1961) predicts that economic agents' decisions reflects all currently available information. Thus, errors and deviations from optimal behavior, predicated on current information, are only random. This is notably true for highly trained decision makers, who experience a lower cognitive burden when assimilating new information (Calderwood et al. 1988, Chase and Simon 1973). Thus, when an information shock occurs, its implications should be completely reflected in all subsequent decisions. To the extent that physicians are highly trained, they should be able to correctly parse the information from a medical guideline and apply the recommended treatments to different patients appropriately. Further, as medical professionals are required to engage in continuing education by the American Medical Association (AMA) and their state medical boards[5], on-going training suggests that they will react with agility to new medical research and that they should be able to differentiate between patients in its application.

In contrast to this perspective grounded in economic rationality, work on fuzzy trace theory and gist (Brainerd and Reyna 1990, Reyna and Brainerd 1991, Reyna and Lloyd 2006) provides an alternative view of decision making. These scholars contend that when confronted with new information, agents perform an "interim synthesis" (Reyna and Brainerd 1995) and strip communication down to its root components when encoding and internalizing it. In effect, decision makers extract the "gist" of the argument embedded in new information (Brainerd and Reyna 1990, Reyna and Brainerd 1991), especially in environments which are information intensive, such as medicine (Reyna and Lloyd 2006). The "gist" logic implies that physicians will retain the core message in the updated guideline while, albeit unintentionally, overlooking the caveats and details.

[5] http://www.acponline.org/education_recertification/cme/state_requirements/2012ama_requirements.pdf

This may result in physicians extracting the core message that stents are not always a superior treatment for SCAD. Resultantly, physicians will not necessarily discern among patients for whom the findings do and do not apply. Consistent with the predictions of gist theory, we would expect physicians to reduce the use of stenting treatment for *both* low and high severity patients, disregarding the more nuanced parts of the guideline which discern between the two classes of patients. We explore these competing predictions in our empirical analysis.

3.3 Heterogeneity in Physician Expertise

Thus far our focus has been on theorizing about the aggregate response of physicians to information shocks. However, even within highly trained professional fields like medicine, there are varying degrees of expertise. To the extent that physician reaction to guideline release may depend on the relative expertise of that physician, we next investigate the interplay between the knowledge and skill of the physician and his/her reaction to guideline release. In examining this issue, we address unresolved questions in the literature regarding the efficacy of different dimensions of expertise and learning mechanisms (Argote 2006, Levinthal and Rerup 2006, Weick and Sutcliffe 2006). Specifically, extant literature discusses many methods by which decision makers may acquire expertise; ranging from passive, habitual modes to active and mindful learning (Levinthal and Rerup 2006). However, less attention has been paid to whether and how the different dimensions of expertise impact performance (Argote 2006).

From the perspective of passive or routine learning, research highlights two indicators of expertise: the quality of a decision maker's formal training, i.e. educational prestige, and tenure in the profession. To the extent that prestigious institutions endow students with superior training and stocks of knowledge (D'Aveni 1996, Hambrick and Mason 1984), it is unsurprising that graduates of these schools garner superior wages and are highly sought after in the market (Hitt et al. 2001). Once in the workplace, these agents often possess a superior ability to accumulate knowledge from their own "elite" networks of colleagues and classmates (Cohen and Levinthal 1990, D'Aveni and Kesner 1993). The literature on physician decision making similarly highlights the benefits of educational prestige, suggesting that these physicians often serve as opinion leaders and can strongly influence their peers during the diffusion of new medical technologies (Burke et al. 2007).

A second form of expertise we consider is tenure, which reflects more opportunities to practice one's professional craft. Extant research highlights many benefits that such practice confers upon decision makers. Not only does it increase the opportunity to learn from on-the-job experiences, it translates into superior performance for the firms of experienced managers (Hambrick and Mason 1984, Lorsch and Tierney 2002). In medicine, professional tenure plays a similar role: physicians with greater clinical experience both enhance their ability to acquire knowledge (McManus et al. 1998), i.e. their absorptive capacity, as well as their clinical outcomes (Diwas et al. 2013, Pisano et al. 2001).

In addition to quality of formal training and professional tenure as important indicators of expertise, we examine two additional dimensions—task-specific knowledge and re-training through board certification, that reflect more active forms of expertise development and learning. While tenure represents the duration of continued practice, it is not necessarily representative of active, task-specific, knowledge acquisition. It is important, therefore, to consider expertise which accumulates from the active continuation of learning as well, i.e. learning-by-doing on the specific and focal task (Argote and Epple 1990, Darr et al. 1995). Ample evidence of the importance of task-based experience exists in extant literature, ranging from examples of gaming or problem solving to engaging in criminal enterprise (Calderwood et al. 1988, Larkin et al. 1980, Nee and Meenaghan 2006). As expertise is inherently domain specific and rarely traverses multiple unrelated domains (Chase and Simon 1973), it could be argued that the physician will gain larger stocks of knowledge from performing the focal task, i.e. stenting, as opposed to performing related tasks or observing others (Diwas et al. 2013, Schilling et al. 2003). To the extent that task repetition in the form of procedure volume has been tied to financial (Nallamothu et al. 2006) and clinical care outcomes (Pisano et al. 2001), the medical literature clearly supports this view that task related experience provides deep knowledge repositories to the physician.

The final form of expertise we consider is active and mindful training in the form of continuing education, viz. board certification. After graduating from medical school and completing their residency (3-7 years), physicians may optionally pursue a fellowship program to increase area-specific knowledge in any number of subspecialties (e.g. obstetrics, cardiology, pediatrics, neurology)[6]. The additional 1 to 3 years of training in the fellowship program leads to board certification and further deepens physician knowledge about the nuances of disease and treatment in the chosen area of specialty. As a result of this more rigorous training, as would be expected, board certified practitioners demonstrate both superior examination scores and superior clinical outcomes (Brennan et al. 2004). Moreover, extensive work in medical education finds that immersive formal training has a long term effect on the ability of physicians to recall and utilize information (Davis et al. 1999, Davis et al. 1995).

How are these different forms of expertise (educational prestige, tenure, task specific knowledge, and board certification) likely to affect physician response to the release of a new medical guideline? On the one hand, irrespective of the type of expertise along the routine vs. mindfulness dimension, physicians with greater expertise may resist the prospect of change in their operational paradigm, thereby enhancing the strength of the competency trap. As noted, this can occur for at least three reasons: one, because the origin of the new information is "distant" from the focal physician, i.e. the physician did not discover the limitations of stenting on their own, and threatens the physician's ability to exploit costly to acquire knowledge (Levinthal and March 1993, March 1991). Two, if the new information is inconsistent with the physician's beliefs, they may discount it because of a confirmation bias resulting from strongly held priors (Christensen-Szalanski and Bushyhead 1981). And three, because the new solution is not only a conceptual departure from standard practice but also involves significantly different activities, i.e. prescribing medication as opposed to inserting a medical device to resolve the problem, the physician is likely to be vulnerable

[6] The ABMS provides an overview of the requirements and process for obtaining board certification. Although all physicians in our dataset are board certified in general medicine, which comes with the licensure to practice at the end of residency, only a subset are additionally trained in cardiology https://www.abms.org/who_we_help/physicians/process.aspx

to familiarity and propinquity traps (Ahuja and Lampert 2001); cognitive traps where the decision makers favor behaviors which are both familiar and similar to contemporary ones.

On the other hand, it is equally plausible that physicians with greater expertise will react more quickly to the new medical guideline, thereby attenuating the strength of the competency trap. The rigorous work which is required to maintain expertise (Calderwood et al. 1988, Chase and Simon 1973), as well as the need by these physicians to maintain their reputations of being current with medical practice and thought, would suggest a greater propensity to not only to assiduously seek out new medical knowledge, but also react to it quickly and appropriately (March 1991). The fact that the guideline fundamentally changes the preferred method for the treatment of low severity SCAD, i.e. surgical to pharmacological as opposed to a newer type of stent, underscores the importance of physician expertise when attempting to overcome habituated behavior (Henderson and Clark 1990, Leonard-Barton 1992). The enhanced expertise these physicians possess would suggest that any new information they encounter would be incorporated into decision making much faster. This logic would imply that all forms of expertise attenuate competency traps (Levinthal and Rerup 2006). To the degree that greater mindfulness results in the stabilizing of attention, and modifies conceptualization of the task to incorporate the new information (Weick and Sutcliffe 2006), we would expect more mindful and active dimensions of expertise to result in greater attenuation of the competency traps. We test this theoretical proposition in our empirical analysis.

4. Data and Methodology

4.1 Data

We use multiple sources to construct a novel, longitudinal, dataset that tracks physician prescription of PCI to patients at the bed level. Our primary data comes from the State of Florida's Agency for Healthcare Administration (AHCA), which records bed-level prescribing practices of physicians within Florida hospitals for every patient admitted from 2001 - 2010; 2001 being the year the previous guideline was released (Smith et al. 2001), and 2010 being the end of data availability. This rich dataset, used extensively in prior literature (Burke et al. 2003, Burke et al. 2007), provides information not only about the focal physician and hospital, but also demographic characteristics about the patient (age/race/sex), their co-morbidities (i.e. the ICD-9 codes), and all medical procedures they receive within the hospital. The longitudinal data enable us to observe treatment decision (PCI vs. pharmacological) for SCAD patients by the physician over time. Although these data come from a single state, we believe it to be an appropriate context for at least two reasons. First, Florida is a large and economically diverse state, and also affords us the ability to see how heterogeneous physicians react to the update over time. Second, as physicians are licensed to practice medicine at the state level, we can reasonably assume that the dataset captures all stenting decisions made by the focal physician. Due to privacy concerns, the data records provide the quarter rather than actual date of treatment. However, for our purposes—the reaction of physicians to the AHA/ACC guideline over time—quarterly periods provide a reasonable window. We match the Florida AHCA with information from US Census Bureau's Small Area Income and Poverty Estimates dataset to include county level socio-economic data, and information from the Area Resource File from the US Department of Health and Human Services to include demographic information about the county in which the physician operates.

4.2 Variable Definitions

4.2.1 Dependent Variable: Our dichotomous dependent variable for treatment choice for a SCAD patient, *Stent,* is coded as 1 if the patient receives a PCI and 0 if not. We use a patient level dichotomous indicator of stent reception rather than physician level number of stenting decisions in a quarter, to control for otherwise unobserved patient heterogeneity.

4.2.2 Independent Variables: Our first two independent variables of interest are two linear splines (*Period1* and *Period2*), which quantify the change in the stenting rate over time. We first explore the data visually. In Figure 1 we plot the raw number of stents that have been implanted in patients during the period of our investigation. In Figure 2 we graph the ratio of stents to stenting opportunities which have been implanted during this same period[7]. A sharp change in the stenting behavior of physicians, even in the absence of additional controls, is evident at the beginning of

[7] Stenting opportunities are defined here as all patients who have been diagnosed with *any* form of SCAD.

2006, both in the raw numbers of stents being implanted as well as the ratio of stent usage to stenting opportunities. This change in behavior corresponds to the release of the new AHA/ACC Guideline for PCI. We see that stent usage is consistently rising prior to the publication of the guideline and experiences a decline after the release of the guideline. To account for this change statistically, we incorporate the linear spline to explore the heterogeneity in physician stenting behavior during the two regimes. Splines are a piecewise specification that permits localized flexibility in the relationship between two variables without allowing for discontinuities within the data (Kennedy 2003). We place the knot of the spline before the first quarter of 2006 to account for the change in behavior expected after the information shock. *Period 1* and *Period 2*, therefore, capture the relationship between stenting and time before and after guideline release.

The other main independent variable, *Severe SCAD*, is a dichotomous variable indicating whether or not the patient is diagnosed with CCS-Class II Angina (or below), i.e., if the guideline was applicable to the patient or not. The variable is coded as 1 if the patient has CCS-Class III angina or above. A description of how SCAD Severity is determined can be found in Appendix 7.1.

In addition to the speed and discernment of response that the spline and severity of illness variables allow us to study, our analysis investigates the effects of degree of physician expertise. Empirically, we measure expertise using four independent variables, each of which capture a different aspect of the expertise construct. First, *Star*, is an indicator of the prestige of the medical school the physician attended. Following Burke et al. (2007), this dichotomous variable is set to 1 if the physician has graduated from a top 50 American medical school in the year of the physician's graduation from medical school, and 0 otherwise. Second, *Tenure*, is an indicator of the experience of the physician and how long she has practiced medicine (operationalized as the number of quarters since the physician graduated from medical school). Third, *Ln(Stents To Date)*, is the natural log of the number of stents the physician has performed, plus one, to date. This variable captures the task level skill of the physician as well as the active investment the physician has made in creating her knowledge stocks regarding stents. Finally, *CardioCert*, is a dichotomous indicator of whether or not the physician is board certified in any of the six following cardiac subspecialties: Thoracic Surgery, Interventional Cardiology, Pediatric Cardiology, Nuclear Cardiology, Cardiovascular Disease Management, or Cardiovascular Medicine[8]. This variable captures the depth of the physician's knowledge and skill in Cardiology which is accumulated by active retraining and recertification.

4.2.3 Controls: To account for variance in treatment decisions caused by other factors, we include a several controls variables that represent four general categories: *patient characteristics* which may affect the physician's decision to stent, *hospital level characteristics* which may be influential in the physicians' decision making process, *local area socio-economic variables*, and *physician level factors*. Patient characteristics, beyond co-morbidities, include four controls: *Age* of the patient*, Race* of the patient, *Day* of the week the patient was admitted, and *Sex* of the patient. Each of these factors is controlled for using dummies for each possible value. To account for patient co-morbidities we include dummy variables for each of the possible diagnoses (ICD-9 codes) within the categories of Hypertension, Diabetes, Obesity, Emphysema, High Cholesterol, Reynaud's Syndrome, Cardiac Arrhythmia, and heart thickening (i.e. co-morbidities traditionally associated with SCAD (Roberts 2008)). A complete listing of the controlled for co-morbidities is available in Table 2.

At the hospital level, we include a dummy control for hospital *ForProfit* status, the number of *Beds* in the hospital, and how busy the hospital was at the time of diagnosis with the number of *Discharges* the hospital made in the focal quarter. We also include a control for the hospital level change in stenting (*HospChange*), operationalized as the percent change in stents implanted from *t-1* to *t*. To account for hospital heterogeneity we also include hospital fixed effects in the model.

As local socio-demographic factors can also influence physician decision making (Burke et al. 2003) we include several controls operationalized at the county level. These include the *Population* of the county, the median household *Income* for the county, the number of people who are *Medicare* eligible within the county, and, finally, the number of people living in *Poverty* in the county. At the physician level, we include, in addition to our expertise variables, we include an indicator of

[8] We use a dichotomous rather than continuous variable for board certification because, while physicians may choose to be board certified across multiple sub-specialties, more than 80% of the certified physicians focus on only sub-specialty.

FreeLancer status, which is set to 1 if the physician serves as an attending physician in multiple hospitals simultaneously (Huckman and Pisano 2006). Finally, we include a physician fixed effect.

We apply four restrictions to the dataset before executing our empirical analysis. First, we remove all patients who are diagnosed with an acute myocardial infarction (i.e. heart attack). As patients who have heart attacks are unambiguously suffering from unstable coronary arterial disease, they fall outside the scope of the investigation. Second, we remove all hospitals which do not perform PCIs from the data as they also fall outside the purview of the research questions. Third, following Burke et al. (2007), we remove all patients under the age of 25 because of their low probability of stent reception. Finally, we remove all patients receiving a coronary artery bypass graft, a far more invasive surgery, from the dataset, thereby restricting the data to patients for whom physicians face the choice of pharmacological treatment or PCI. The resulting dataset is comprised of 3,072,328 observations between the years of 2001 and 2010. Summary statistics for the non-dummy control variables are available in Table 4 and a correlation matrix is presented in Table 5.

4.3 Empirical Specifications

Given the size of the dataset, we use a series of linear probability models to estimate coefficients. While logit or probit models are typically preferred for analyses involving dichotomous outcomes, the computational demands arising from the size of the dataset, the number of covariates, and the need to accurately interpret non-linear interaction terms (Ai and Norton 2003) are considerable. The linear probability model provides an accurate proxy for the effects that we are estimating and also provides for an easier interpretation of interactions. Our first question, whether physicians respond to the information shock, of the new guideline, is addressed using the following base specification:

$$\begin{aligned} LPM(Stent) = {} & \beta_1 Period_1 + \beta_2 Period_2 + \beta_3 Severe\ SCAD \\ & + M_1' Physician\ Controls + M_2' Hospital\ Controls + M_3' Region\ Controls \\ & + M_4' Patient\ Controls + \varepsilon \end{aligned} \tag{1}$$

where M_1 , M_2 , M_3 , and M_4 , are vectors of coefficients associated with the indicated controls. We estimate two models: one without physician fixed effects (Column 1 of Table 6) and a second that includes a physician fixed effect (Column 2, Table 6) and omits the non-time varying physician characteristics (*CardioCert* and *Star*). In these regressions the coefficient of *Period 1* indicates the change in the quarterly utilization of stenting, all else equal, before the information shock and the coefficient of *Period2* captures the physician stenting utilization following the information shock.

To estimate whether physicians discern between high and low severity patients in their stenting utilization after the information shock, we include an interaction of the patient's SCAD Severity with the *Period 2* spline. Results from this analysis are shown in Columns 3 and 4 of Table 6, without and with physician fixed effects respectively. The use of these interactions offers two significant advantages here. First, the interaction of any variable with the *Period 2* spline provides estimates of trends in stent use after the release of the new guideline, i.e. a general long term increase or decrease in stenting. Second, the spline significantly increases the interpretability of results over the alternative approach of interacting the patient severity variable with individual time effects.

To understand how physician expertise (i.e. star status, tenure, task specific experience, and board certification) influences their reaction to the information shock, we next drop the *Severe SCAD* patients and interact the *Period 2* spline with the indicator of physician expertise. Results are available in Tables 7-10. As before, we estimate models with and without physician fixed effects.

4.4 Results

4.4.1 Guideline Response: To ascertain if and with what speed physicians respond to the new guideline, we examine the coefficients in Column 1 and Column 2 of Table 6. As was previously suggested by Figure 1 and Figure 2, there is an overall increase in stenting before the release of the guideline and an aggregate decrease after (a negative and significant coefficient for the *Period 2* spline). The positive and significant coefficient of the *Severe SCAD* dummy variable suggests, as expected, that significantly more stents are implanted in patients who suffer from severe SCAD. From these results we conclude that physicians are reacting to the information shock. However, we note from the graphical representations of these data (Figures 1 and 2) that while physicians do alter their behavior when the guideline is released, the reaction is slow. In other words, we do not observe a sharp abandonment of stenting for the low severity SCAD patients, suggesting that physicians are perhaps vulnerable to competency traps. Furthermore, as the guideline states that the decision to stent in patients with low severity SCAD can be harmful, this has significant implications for both patient and economic welfare. From the patient's perspective, the inappropriate use of stents potentially exposes them to significant risk without increasing quality of care (Smith et al. 2006). From the economic welfare perspective, stents are far more costly compared with pharmacological treatment, creating financial burden for patients as well as insurance carriers.

4.4.2 Discerning Response: For the second research question, whether physicians are discerning in their reaction to the guideline release, we examine coefficients in Column 3 and Column 4 of Table 6. Consistent with the first set of results, we see a gradual increase prior to release of the guideline and a gradual decrease in the stenting rate for non-*Severe SCAD* patients after (as shown by the *Period 1* and *Period 2* splines). Moreover, once the effect of the *Severe SCAD* patients is removed from this group the decline in stenting rate accelerates. Finally, examining the coefficients of the interaction terms (*Period 1 * Severe SCAD* and *Period 2 * Severe SCAD*) we see that stenting rates are increasing both before and after the release of the medical guideline for patients with high severity SCAD, indicating that physicians are discerning in their application of new information even within the information intensive medical environments.

Figure 3 provides a visual representation of these data and plots of the raw number of stents implanted divided by the number of opportunities to stent for each patient class (*Severe* and non-*Severe SCAD*). The vertical line represents guideline release. The figure confirms findings from Table 6: before the guideline release, stents are being adopted significantly faster for *Severe SCAD* patients. Moreover, after guideline release there is a gradual decline in the stenting rate for non-*Severe SCAD* patients while stenting rates continue to rise for *Severe SCAD* patients, but at a slower pace.

Although we do not see a negative spillover between the patient classes, i.e. a decrease in the stenting rate for *Severe SCAD*, we do observe a significant change in the utilization of stents for *Severe SCAD* patients which coincides with the release of the guideline. To the extent that the aggregate rates may mask inter-physician differences in guideline reaction for *Severe SCAD* patients, we conduct additional empirical testing to gain a more fine-grained understanding. One situation where reaction may vary is when physicians are confronted with an increasingly heterogeneous group of patients. Increased heterogeneity in the patient pool, as it relates to severity of the disease, implies that physicians must discern among treatments on a case-by-case basis, rather than applying routine processes across a majority of contiguous patients. As Reyna and Lloyd (2006) suggest, the interim synthesis which leads to gist extraction is more likely to occur when the decision maker is in an environment where heterogeneous, but related, knowledge recall is required with some regularity. Thus, if the physician is treating a homogenous group of patients, i.e. only non-severe patients, then the physician will only internalize information about those patients and apply it unilaterally. If, however, the physician is treating a heterogeneous group of patients, i.e. many patients of both severe and non-severe SCAD, then the physician must both internalize additional information and repetitiously recall when to apply it. Accordingly, we examine whether physician responses vary when they see a more heterogeneous mix of patients by splitting our sample based on patient mix. We create subgroups based on whether the patient mix seen by the patients are at or below mean levels (10.6% Severe SCAD patients), and successive groups based on one, two and three standard deviations away from the mean that correspond to higher variation in patient mix.

Results are available in Table 7a[9] and provide further insights that are not directly observable in the aggregate estimations. Based on the estimates reported in Table 7a, we report in Table 7b the average slope in Period 2 for high severity patients, and the Wald tests for differences across the subgroups. The stenting rate for high severity patients, while positive, becomes significantly smaller as the level of patient mix increases. This finding suggests that while there is aggregate evidence of discernment, as indicated by continued positive slopes for high severity patients after the guideline is released, degree of discernment reduces as patient mix increases. In other words, we see spillovers for physicians who treat a more heterogeneous group of patients, and therefore must switch decision rules frequently.

[9] We report only the results of the fixed effect regressions in the interest of space.

4.4.3 Expert Response: Our final question relates to how physicians of differing expertise react to the release of the new guideline. We focus on the low severity SCAD patients to which the guideline applies, and interact each of the indicators of physician expertise with the *Period 1* and *Period 2* splines. We first consider the results from *Star* physicians (Table 8). Interestingly, results suggest that although *Star* physicians perform significantly fewer stents for non-*Severe SCAD* patients, they adopt stents much faster than non-*Star* physicians (interaction between Period 1 and *Star*), corroborating the findings of Burke et al. (Burke et al. 2007). Furthermore, they react faster to the guideline (as seen in the interaction between *Period 2* and *Star*). These results suggest that even the most passive form of physician variation in expertise, indicated by school of graduation and potential sorting on quality that relates to initial stocks of knowledge, decreases the effect of competency traps.

We next consider tenure as an indication of physician expertise (Table 9). Interestingly, we see that after the release of the guideline, longer tenured physicians abandon the use of stents significantly faster than shorter tenured physicians. When considering expertise related to active and mindful learning, viz. task expertise and board certification (Table 10 and 11 respectively), similar patterns of adoption and abandonment emerge. Not only are these physicians much faster to adopt the utilization of stents, they abandon the use of stents significantly faster after guideline release. These consistent findings across all forms of expertise, i.e. that those with greater expertise react to information with greater rapidity, begs the further question: what types of expertise are more predictive of a swifter response to new information?

Comparison of the coefficients across models poses two challenges. First, two expertise measures (*Ln (Stents to Date)* and *Tenure*) are continuous and, second, they are on different scales. To resolve these issues we dichotomize both measures at the median, breaking them into high and low *Tenured* / *Ln(Stents To Date)*, and re-estimate our models. Results of the comparison of coefficients across models yield several interesting findings. First, board certification has a significantly greater effect on the abandonment rate than all other variables, underscoring the importance of mindful formal retraining and recertification, consistent with the theoretical literature on learning (Levinthal and Rerup 2006, Weick and Sutcliffe 2006). Second, increase in tenure has the smallest cumulative effect on the abandonment rate; which is unsurprising given the small coefficients and marginal significance ($p<0.1$ and $p<0.05$) seen in Table 9. Third, *Star* status and task expertise, while significantly larger than *Tenure* and significantly smaller than board certification, are statistically indistinguishable from each other. However, recall that task expertise is a continuous variable with a high standard deviation that we dichotomized into high and low categories for this analysis. In further analysis where *Ln(Stents to Date)* is disaggregated into quartiles, we find that very high stenting physicians abandon the utilization of stents significantly faster than *Star* physicians (and nearly as quickly as Board Certified physicians).

In summary, empirical results support the presence of competency traps as theorized in prior work: while physicians do respond to guideline release, and are discerning in the application of the guideline, the reaction is not swift, creating significant public welfare deficits. Interestingly, while we do not see a negative spillover between different patient classes (i.e., stent abandonment for high-severity patients), significant variation in the treatment of high severity SCAD patients exists after guideline release. Increases in patient mix, i.e. patient heterogeneity, significantly slows further adoption on the part of these physicians. Moreover, results suggest both that both routine and mindful dimensions of expertise attenuate the strength of the competency traps; however more mindful measures of expertise have a stronger effect. Experts who do not engage in active learning, viz. *Stars* and longer *Tenured* physicians, instead react far slower when compared to physicians who are engaged in mindful and active learning.

4.5 Robustness Checks

The main analyses thus far shed important light on the theoretical tensions related to decision making under uncertainty in knowledge-intensive professional domains that this paper addresses. To ensure that alternative explanations for the findings are adequately accounted, we conduct a series of robustness tests to explore the stability of the results.

4.5.1 Within - Subjects Experiment - Two potential concerns exist with our initial estimations of the reaction of physicians to the release of the 2006 AHA/ACC Guideline. The first is that the physicians who are actively practicing medicine during the timeline (2001 – 2010) of our investigation change. Not only are new physicians licensed to practice medicine and receive attending physician placements during this time, but older physicians retire. Second, the extended time frame of this study raises the possibility that the physician is responding to multiple information shocks from various medical trials and professional conferences, or other social changes in the practice of medicine and stenting that may have occurred during this time, and not specifically to the information shock that is our focus.

To mitigate these concerns we replicate our analysis by constructing a two period within-subjects experiment to determine the immediate short-term change in stenting that occurs after the release of the new guideline. To construct the experiment we apply the following restrictions to the dataset. First, we restrict the dataset to the periods immediately before and after guideline release, viz. the 4th quarter of 2005 and the 1st quarter 2006. We then aggregate the stenting rate to the physician – SCAD severity level for each time period. In effect, this provides us with two observations for each physician in each time period, one for *Severe SCAD* patients and one for non-*Severe SCAD* patients. Finally, we remove all physicians from the analysis who are not treating patients of the same type in *both* time periods. Results of the two sample t-tests for the 7349 physicians treating non-*SevereSCAD* patients, and the 2875 physicians treating *SevereSCAD* patients, are available in Table 12.

The results from the within subjects experiment are consistent with previous findings. A simple comparison of means t-test for the non-*Severe SCAD* patients before and after the application of the guideline release (i.e. the treatment) indicates a drop in the stenting rate of nearly 7.5% that is significant ($p<0.10$). Moreover, results corroborate the ability of physicians to be discerning in their application of new information as this decline in the marginal stenting rate is not seen for patients with *Severe SCAD*.

***4.5.2 The COURAGE Trial* –** One potential further confounding effect is the publication of the Clinical Outcomes Utilizing Revascularization and Aggressive druG Evaluation (COURAGE) trial (Boden et al. 2007) in April of 2007. The objective of the COURAGE trial was to quantify the efficacy of stenting as compared to pharmacological therapy for the treatment of low severity

SCAD. Lending further scientific validity to the AHA/ACC Guideline, the trial's results indicated that pharmacological intervention was equally effective as stenting for the treatment of low severity SCAD; thereby providing evidence from a randomly controlled trial which reinforced the guideline[10]. As with the release of the AHA/ACC Guideline, the immediate effect of the release is difficult to predict *ex ante*. On one hand, the further scientific evidence provided by the COURAGE trial may accelerate the decrease in stenting by physicians. Conversely, due to the fact that COURAGE is a single medical trial and the AHA and ACC release periodic updates to the practice of stenting that are based on a synthesis of multiple sources of evidence, it is also plausible that physicians will continue their inertial behavior, awaiting further evidence from other trials and endorsement of the findings from governing bodies. To determine the effect of the COURAGE trial's release on the marginal stenting rate we incorporate a third spline into our original empirical analysis by placing a new knot in the second quarter of 2007 (the release date of the COURAGE trial). Results further substantiate many of our previous results; namely the continued utilization of stents at a slower rate for high severity patients and the abandonment of stents for low severity patients. However, we find that for low severity SCAD patients, the abandonment of stenting is significantly slower after the release of COURAGE; these results are available upon request.

5. Implications and Conclusion

Competency traps have been identified as significant individual and organizational level pathologies. In this study, we examined individual level behavior in a knowledge intensive professional setting by pursuing three questions, each motivated by an unresolved theoretical tension regarding decision making under uncertainty. First, what is the speed of response to information shocks? The tension here relates to whether decision makers in knowledge intensive environments act with agility, or are impeded by habitual behavior that result in competency traps. Second, do decision makers accurately discern between patients in their application of the guideline?

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[10] While information leakage from COURAGE could possibly influence the change in stenting prior to 2007, the strict confidentiality surrounding medical trials, and ample anecdotal evidence, suggests that this is unlikely. We conducted robustness checks to determine if hospitals local to the research centers in Florida involved in the COURAGE trial abandon their usage of stenting before other hospitals; the results suggest no evidence of leakage. These results are available from the authors upon request.

This tension relates to differing predictions from the economics, i.e. rational expectation, and psychology, i.e. gist extraction, literatures. Finally, how does the degree of physician expertise, of various types, attenuate or exacerbate the strength of competency traps? Here, the tension relates to whether degree of expertise and mindful versus passive forms of knowledge acquisition act in the same manner, or have different consequences for response by decision makers.

Empirical analysis of a large data set of physician choices spanning a 10-year period reveals that although physicians respond to the release of the medical guideline, they alter their behavior slowly, suggesting the presence of competency traps. We also find that that these experts are discerning in their application of new medical information. However, discernment is compromised in precisely those circumstances where it matters most: when physicians simultaneously treat many patients of varying severity of heart disease. Finally, results indicate that all types of physician expertise—routine or mindful—attenuate the competency trap, but that active and mindful dimensions have a significantly stronger effect.

Our work advances extant knowledge regarding competency traps (Levinthal and March 1993) by investigating how domain specialists incorporate new knowledge into decision making. While empirical investigations have considered how the longevity of learned behaviors (March 1991) and solution similarity (Ahuja and Lampert 2001) influence the extent of traps, the moderating effect of both extent and type of expertise of individual decision remains understudied. We contribute to the discourse on individual learning, habituated action, and routinized behavior. By examining individual level behaviors that are the micro-foundations of organizational routines (Felin and Foss 2005, Winter 2013), we shed light on how the heterogeneity in type and level of expertise impacts the severity of competency traps experienced by organizations. In particular, we answer Argote's (2006) call for research by examining the effects of varying levels of mindfulness on performance, as measured here by speed of response to new information. Our findings point out that higher levels of all types of expertise are critical in mitigating the effect of competency traps (Levinthal and Rerup 2006). A novel finding is that more active forms of expertise are particularly important in the organizational diffusion of information generated through exogenous shocks (Weick and Sutcliffe

2006). In this manner, our work offers a partial solution to organizational dilemmas observed by Henderson and Clark (1990), where minor changes in the competitive landscape significantly undermine a firm's core competencies. Consistent with but also significantly extending the arguments of others that expertise facilitates a seamless reaction to new information (Chase and Simon 1973, Gobet and Simon 2000, Larkin et al. 1980), our results highlight that mindfulness is of the utmost importance when routines need to be updated (Levinthal and Rerup 2006, Pentland et al. 2012).

From a policy perspective, the speed at which new information is incorporated into physician decision making poses a significant challenge. As adherence to guidelines significantly improves clinical care outcomes (Bristow et al. 2013, Choudhry et al. 2005, Cox 2009) the optimal reaction, from an economic perspective, would be an immediate and sharp drop in the stenting rate. Disturbingly, we find that the response across agents of all levels of expertise is slower than optimal. We compute the economic burden of the slow response. Assuming the final stenting rate for low severity SCAD patients in 2010 of 3.6% is stable, this suggests that roughly 35,500 patients in the sample have been subjected to unnecessary stenting procedures; procedures which would not have been performed had physicians favored more agile responses to the release of the new medical guideline. Financially this translates, at a cost of $17,000 per stenting procedure[11], to an added and avoidable financial burden of more than $603 million in the state of Florida alone. Given how pervasive SCAD and the practice of stenting are, both domestically and globally, the costs associated with this delay easily reach the tens of billions of dollars over the four year period following the release of the guideline.

Disturbingly, examples of physician non-compliance or slow compliance with medical guidelines are commonplace in both the scholarly literature and the popular press. Recent work presented to the Society of Gynecologic Oncology (Bristow et al. 2013) indicates that less than 40% of women diagnosed with ovarian cancer in the United States receive care that is guideline

[11] http://www.bostonscientific.com/

compliant, significantly increasing mortality rates. Instances of such behavior are not constrained to rare conditions like ovarian cancer; studies show that the treatment of a wide range of medical conditions, from high cholesterol (Frolkis et al. 1998) to breast cancer (Cox 2009), experience the problem of physician non-compliance with medical guidelines. From a public welfare perspective, these findings are a cause for concern, and highlight the need for aggressive and mindful education within the medical community. Such education may be instrumental in not only preventing needless spending which does not increase clinical care outcomes, but also avoiding the loss of life associated with poor adherence to medical guidelines.

We acknowledge the limitations of this work and identify fruitful opportunities for extension. First, our investigation only considers physician decision making in the State of Florida. While Florida is a large, ethnically and socio-demographically diverse state it is possible that state level factors impact the decision making of these physicians in a systematically different way. Although our review of extant literature and legal reforms to healthcare, have not revealed any evidence that this is occurring, the concern nonetheless exists. One simple, extension to this work would be to investigate similar questions in a multi-state context and determine what, if any, state level factors influence the decision makers.

A second limitation of this study is the unobservable effect of medical malpractice which may be driving the change in non-*Severe SCAD* patients. As the field of medicine is highly litigious, and the cost of medical malpractice for both hospitals and physicians is a pressing concern, changes to the underlying belief about the efficacy of a procedure can have drastic effects. While this concern is present, we do not believe that it exerts undue influence on the physicians being observed in this study. Malpractice protects against medical errors, and because PCI is an *accepted* treatment for SCAD, its use does not constitute a "medical error" (Hofer et al. 2000). Although stories of overtreatment by cardiac physicians have dominated the news media (Abelson and Creswell 2012) for the last decade it is important to note that these physicians are being investigated on the grounds of Medicare fraud, civil conspiracy, and unlawful enrichment, not medical malpractice, for performing hundreds of unnecessary procedures.

In conclusion, decisions made by professionals often have significant social and economic ramifications; particularly so in the domain of medicine where the consequences of faulty decision making can be substantial. To the degree that innovation and discovery are inevitable, and new knowledge is created with regularity, understanding how these information shocks are incorporated into expert decision making is an important question from the perspectives of theory, practice, and policy. We have explored how domain specialists balance between agility and exploitation of knowledge stocks in the presence of new information, and their vulnerability to competency traps. While results support the general assertion of expert responsiveness to new information, findings suggest that even these decision makers fall prey to competency traps. Moreover, results indicate that the strength of these traps is further diminished when physician expertise is accumulated mindfully. Nevertheless, this slow response is cause for concern as it has substantial public welfare implications given the ever increasing costs of medical treatment, and the global prevalence of coronary arterial disease. Additional research on understanding the nature and source of information shocks that elicit optimal changes in decision making from physicians is needed for researchers and policy makers to effectively disseminate medical discoveries to those who practice medicine.

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Table 1: Canadian Cardiovascular Society Functional Classification of Angina Pectoris

Class	Definition	Specific Activity Scale
I	Ordinary physical activity (e.g., walking and climbing stairs) does not cause angina; angina occurs with strenuous, rapid, or prolonged exertion at work or recreation.	Ability to ski, play basketball, jog at 5 mph, or shovel snow without angina
II	Slight limitation of ordinary activity. Angina occurs on walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, in cold, in wind, or under emotional stress, or only during the few hours after awakening, when walking more than two blocks on level ground, or when climbing more than one flight of stairs at a normal pace and in normal conditions.	Ability to garden, rake, roller skate, walk at 4 mph on level ground, have sexual intercourse without stopping
III	Marked limitation of ordinary physical activity. Angina occurs on walking one to two blocks on level ground or climbing one flight of stairs at a normal pace in normal conditions.	Ability to shower or dress without stopping, walk 2.5 mph, bowl, make a bed, play golf
IV	Inability to perform any physical activity without discomfort.	Anginal symptoms may be present at rest. Inability to perform activities requiring 2 or fewer metabolic equivalents without angina

Source: http://www.clevelandclinicmeded.com/medicalpubs/diseasemanagement/cardiology/coronary-artery-disease/

Table 2: Co-Morbidity Controls

Hypertension	**Chronic bronchitis or emphysema**
Malignant Essential Hypertension	Chronic Bronchitis
Benign Essential Hypertension	Mucopurulent chronic bronchitis
Unspecified Essential Hypertension	Obstructive chronic bronchitis
Diabetes	without exacerbation convert
Diabetes without complication	with (acute) exacerbation convert
Diabetes with ketoacidosis	with acute bronchitis convert
Diabetes with hypersmolarity	Other chronic bronchitis convert
Diabetes with coma	Unspecified chronic bronchitis
Diabetes with renal manifestation	Emphysema Emphysematous bleb
Diabetes with ophthalmic manifestataion	Emphysema Other emphysema
Diabetes with neurological manifestation	Bronchiectasis without acute exacerbation
Diabetes with peripheral circulatory disorders	Bronchiectasis with acute exacerbation
Diabetes with other manifestations	Extrinsic allergic alveolitis Farmers' lung
Diabetes with unspesified complication	Extrinsic allergic alveolitis Bagassosis
Obesity	Extrinsic allergic alveolitis Bird-fanciers' lung
Unspecified Obesity	Extrinsic allergic alveolitis Suberosis convert
Morbid Obesity	Extrinsic allergic alveolitis Malt workers' lung
Overweight	Extrinsic allergic alveolitis Mushroom workers' lung
Obesity Hypoventilation Syndrome	Extrinsic allergic alveolitis Maple bark-strippers' lung
Localized adiposity	Extrinsic allergic alveolitis "Ventilation" pneumonitis
Hypervitaminosis A	Other specified allergic alveolitis and pneumonitis
Hypercarotinemia	Unspecified allergic alveolitis and pneumonitis
Hypervitaminosis D	**Misc**
Other hyperalimentation	Pure hypercholesterolemia
Arrhythmia	Thyrotoxicosis without mention of goiter or other cause
Cardiac Arrhythmia	Reynaud's Syndrome
Heart beat under 60 per minute	Peripheral Vascular Disease
Heart beat very fast (150+)	Impairment of the conduction between heart atria and ventricles
Rapid heat beat from ventricular issue	Thickening of the heart

Table 3: Variable Definitions

Variable Name	Definition
Stent	Dichotomous indicator of stent reception
Patient Specific Characteristics	
Sex	Patient Gender (1 - Male / 0 - Female)
Severe SCAD	Patient diagnosed with CCS Class III or above SCAD
Physician Specific Characteristics	
Tenure	Physician Experience (In Quarters)
LnStentsToDate	Ln(Stents Physician Has Performed To Date)
CardioCert	Physician Board Certified in Cardiology (1 - Yes / 0 - No)
Star	Physician Attended Top 50 Medical School)
FreeLancer	Physician is Freelancer (1 - Yes / 0 - No)
Hospital Specific Characteristics	
HospChange	Percent Hospital Change in Stenting (t-2 to t-1)
ForProfit	Hospital for profit status (1 - Yes / 0 - No)
Beds	Number of Beds in Hospital
Discharges	Number of Discharges Hospital has made in focal quarter
Area Specific Characteristics	
Income	Median income of focal county
Population	Population of Focal County
Poverty	Poverty level in Focal County
Medicare	Number of Citizens Who are Medicare Eligible in Focal County

Table 4: Summary Statistics
Sample N – 3072328

Variable	Mean	Std. Dev.
Stent	0.1001	0.3002
Patient Specific Characteristics - 3072328 Patients		
Gender	0.5549	0.4970
Severe SCAD	0.1066	0.3086
Physician Specific Characteristics - 345344 Physician Quarter Observations		
Tenure	56.8953	37.3001
LnStentsToDate	2.6970	4.1217
CardioCert	0.1379	0.3448
Star	0.2186	0.4133
FreeLancer	0.2517	0.4340
Hospital Specific Characteristics - 5347 Hospital Quarter Observations		
HospChange	-0.0005	0.0100
ForProfit	0.6041	0.4891
Beds	337.1371	235.7388
Discharges	3776.9460	2572.1362
Area Specific Characteristics - 1248 County Quarter Observations		
Income	42944	6598
Population	439808	399610
Poverty	62711	79459
Medicare	84390	79549

Table 5: Correlation Matrix

		1	2	3	4	5	6	7	8
1	*Stent*								
2	*Gender*	0.0671							
3	*Severe SCAD*	0.3068	0.0211						
4	*Tenure*	0.0168	-0.0058	-0.0049					
5	*Ln (StentsToDate)*	0.3919	0.0414	0.1619	-0.0225				
6	*CardioCert*	0.3815	0.0794	0.1554	0.1522	0.4342			
7	*Star*	0.0499	0.0316	0.01	0.1252	-0.0232	0.1508		
8	*HospChange*	0.0098	-0.001	0.013	0.0014	0.0035	0.0138	0.0013	
9	*FreeLancer*	-0.0021	-0.0148	0.0179	-0.1188	0.2154	-0.0247	-0.1319	0.006
10	*ForProfit*	0.0137	0.0282	-0.0054	-0.0569	0.0072	0.0262	0.0672	-0.0141
11	*Beds*	0.1053	0.0381	0.0114	0.0226	0.1435	0.1171	0.0985	-0.0367
12	*Discharges*	0.1255	0.0372	0.0128	-0.0207	0.1959	0.0984	0.0853	-0.0448
13	*Income*	-0.0068	0.0159	-0.0731	-0.0281	-0.0066	-0.0551	-0.0382	-0.0697
14	*Population*	0.0469	-0.0003	-0.0076	0.0099	0.1043	0.0129	-0.0689	-0.0126
15	*Poverty*	-0.0241	-0.0204	-0.0202	0.0407	0.0294	-0.038	-0.1043	-0.0024
16	*Medicare*	-0.011	-0.0126	-0.0135	0.0435	0.0437	-0.0325	-0.1113	-0.0049

		9	10	11	12	13	14	15
9	*FreeLancer*							
10	*ForProfit*	-0.0865						
11	*Beds*	-0.1301	0.3943					
12	*Discharges*	-0.103	0.4006	0.8743				
13	*Income*	0.0205	-0.0102	-0.0341	0.0453			
14	*Population*	0.0905	-0.0493	0.1333	0.1748	0.3256		
15	*Poverty*	0.0477	-0.0142	0.2648	0.1609	-0.145	0.4343	
16	*Medicare*	0.0837	-0.1085	0.1377	0.0787	-0.0025	0.6375	0.8696

Table 6: Change in Stenting Based on Patient Class
Hospital, Age, Race, and Co-Morbidity Dummies Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)
Dependent Variable	Stent	Stent	Stent	Stent
Period 1	0.00208***	0.00247***	0.00113***	0.00151***
	(5.72e-05)	(7.01e-05)	(5.86e-05)	(7.10e-05)
Period 2	-0.00331***	-0.00198***	-0.00342***	-0.00213***
	(4.07e-05)	(5.84e-05)	(4.15e-05)	(5.88e-05)
Period 1			0.00590***	0.00601***
* Severe SCAD			(8.76e-05)	(8.28e-05)
Period 2			0.00383***	0.00446***
* Severe SCAD			(0.000103)	(9.74e-05)
Severe SCAD	0.212***	0.204***	-0.149***	-0.166***
	(0.000483)	(0.000462)	(0.00497)	(0.00471)
Gender	0.0137***	0.0122***	0.0136***	0.0121***
	(0.000297)	(0.000282)	(0.000297)	(0.000281)
Ln(Stents to Date)	0.0417***	0.0186***	0.0418***	0.0184***
	(0.000106)	(0.000201)	(0.000105)	(0.000200)
CardioCert	0.167***		0.168***	
	(0.000469)		(0.000468)	
Star	0.00579***		0.00568***	
	(0.000415)		(0.000414)	
HospChange	0.312***	0.251***	0.316***	0.255***
	(0.0146)	(0.0138)	(0.0146)	(0.0138)
Tenure	-0.000108***	0.000142***	-0.000110***	0.000133***
	(4.33e-06)	(3.99e-05)	(4.32e-06)	(3.98e-05)
FreeLancer	-0.0323***	-0.00404***	-0.0322***	-0.00381***
	(0.000337)	(0.000463)	(0.000337)	(0.000462)
ForProfit	-0.0331***	-0.0383***	-0.0391***	-0.0428***
	(0.00955)	(0.0129)	(0.00953)	(0.0129)
Beds	-7.83e-05***	-6.70e-05***	-6.99e-05***	-5.62e-05***
	(1.37e-05)	(2.02e-05)	(1.37e-05)	(2.02e-05)
Discharge	4.89e-06***	4.28e-06***	4.93e-06***	4.29e-06***
	(3.25e-07)	(3.36e-07)	(3.24e-07)	(3.35e-07)
Income	2.47e-06***	7.34e-07***	2.54e-06***	7.66e-07***
	(1.02e-07)	(1.03e-07)	(1.02e-07)	(1.03e-07)
CntyPopulation	-6.75e-09	3.09e-08***	-4.05e-09	3.22e-08***
	(8.56e-09)	(9.25e-09)	(8.54e-09)	(9.22e-09)
Poverty	1.59e-07***	3.97e-08***	1.45e-07***	2.38e-08
	(1.50e-08)	(1.52e-08)	(1.50e-08)	(1.51e-08)
Constant	-0.267***	-0.199***	-0.214***	-0.143***
	(0.0148)	(0.0151)	(0.0148)	(0.0151)
Fixed Effects	No	Yes	No	Yes
Observations	3,072,328	3,072,328	3,072,328	3,072,328
R-squared	0.295	0.387	0.298	0.390

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7a: Change in Stenting Based on Patient Mix – Sample Constrained by Mix of Patients Seen
Patient Mix Indicates Percent High Severity SCAD Patients Treated by Physician in Quarter
Patient Mix (μ – 10.6% / σ – 13.2%)
Controls Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Stent	Stent	Stent	Stent	Stent	Stent	Stent	Stent
	Patient Mix <= 10.6%		10.6% < Patient Mix <=23.8%		23.8% < Patient Mix <=37.0%		Patient Mix > 37.0%	
Period 1	0.00112***	0.000993***	0.00270***	0.00195***	0.00411***	0.00288***	0.00593***	0.00430***
	(6.78e-05)	(6.78e-05)	(0.000196)	(0.000197)	(0.000431)	(0.000437)	(0.000710)	(0.000733)
Period 2	-0.000262***	-0.000380***	-0.000877***	-0.00161***	-0.00192***	-0.00329***	-0.000113	-0.00302***
	(5.10e-05)	(5.11e-05)	(0.000175)	(0.000177)	(0.000415)	(0.000430)	(0.000724)	(0.000779)
Period 1		0.00583***		0.00462***		0.00419***		0.00302***
* Severe SCAD		(0.000171)		(0.000167)		(0.000269)		(0.000362)
Period 2		0.00542***		0.00499***		0.00477***		0.00536***
* Severe SCAD		(0.000138)		(0.000194)		(0.000388)		(0.000554)
Severe SCAD	0.254***	-0.143***	0.210***	-0.0813***	0.168***	-0.0832***	0.168***	-0.0120
	(0.000751)	(0.0102)	(0.000893)	(0.00959)	(0.00152)	(0.0150)	(0.00204)	(0.0199)
Constant	-0.0136	-0.00344	-0.0963**	-0.0472	-0.364***	-0.283***	-0.733***	-0.629***
	(0.0138)	(0.0138)	(0.0379)	(0.0379)	(0.0908)	(0.0908)	(0.149)	(0.149)
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,925,135	1,925,135	732,895	732,895	260,574	260,574	153,724	153,724
R-squared	0.319	0.321	0.368	0.371	0.382	0.384	0.375	0.376

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7b: Comparison of Period 2 High Severity Adoption Slope Based on Patient Mix

	Patient Mix <=10.6%	10.6% < Patient Mix <=23.8%	23.8% < Patient Mix <=37.0%	Patient Mix > 37.0%
Period 2 Slope for Severe SCAD	0.005040	0.003380	0.001480	0.002340

Wald Test Results

	10.6% <= Patient Mix <23.8%	23.8% <= Patient Mix <37.0%	Patient Mix >= 37.0%
Patient Mix <10.6%	6.9726***	8.6448***	4.7291***
10% <= Patient Mix <23.8%		4.3799***	1.7718
23.8% <= Patient Mix <37.0%			-1.2715

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Interaction Period 2 and Star Status
Hospital, Age, Race, and Co-Morbidity Dummies Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)
Dependent Variable	Stent	Stent	Stent	Stent
Period 1	0.00162***	0.00148***	0.00177***	0.00168***
	(5.31e-05)	(5.50e-05)	(6.27e-05)	(6.42e-05)
Period 2	-0.00134***	-0.00124***	-0.00106***	-0.00100***
	(3.67e-05)	(3.83e-05)	(5.02e-05)	(5.16e-05)
Period 1		0.000719***		0.000463***
* Star		(7.15e-05)		(7.11e-05)
Period 2		-0.000580***		-0.000310***
* Star		(7.25e-05)		(7.28e-05)
Gender	0.0101***	0.0101***	0.00924***	0.00924***
	(0.000273)	(0.000273)	(0.000252)	(0.000252)
CardioCert	0.189***	0.189***		
	(0.000431)	(0.000431)		
Star	-0.00170***	-0.0422***		
	(0.000381)	(0.00412)		
Tenure	-0.000321***	-0.000321***	0.000129***	0.000127***
	(3.97e-06)	(3.97e-06)	(3.49e-05)	(3.49e-05)
Ln(Stents to Date)	0.000302***	0.000302***	4.38e-05***	4.36e-05***
	(7.25e-07)	(7.25e-07)	(1.82e-06)	(1.82e-06)
HospChange	0.354***	0.354***	0.225***	0.224***
	(0.0136)	(0.0136)	(0.0125)	(0.0125)
FreeLancer	-0.00392***	-0.00390***	-0.00124***	-0.00125***
	(0.000302)	(0.000302)	(0.000414)	(0.000414)
ForProfit	-0.0413***	-0.0418***	-0.0518***	-0.0523***
	(0.00879)	(0.00879)	(0.0116)	(0.0116)
Beds	-6.58e-05***	-6.61e-05***	-8.61e-05***	-8.64e-05***
	(1.27e-05)	(1.27e-05)	(1.81e-05)	(1.81e-05)
Discharge	4.75e-06***	4.74e-06***	4.48e-06***	4.46e-06***
	(2.97e-07)	(2.98e-07)	(2.99e-07)	(2.99e-07)
Income	-2.36e-06***	-2.35e-06***	-1.46e-06***	-1.45e-06***
	(9.26e-08)	(9.26e-08)	(8.89e-08)	(8.89e-08)
CntyPopulation	8.11e-08***	8.35e-08***	8.17e-08***	8.32e-08***
	(7.96e-09)	(7.96e-09)	(8.35e-09)	(8.35e-09)
Poverty	-1.66e-07***	-1.73e-07***	-6.85e-08***	-7.29e-08***
	(1.37e-08)	(1.37e-08)	(1.34e-08)	(1.34e-08)
Constant	0.00979	0.0168	-0.0224*	-0.0219
	(0.0136)	(0.0136)	(0.0134)	(0.0134)
Physician Fixed Effects	No	No	Yes	Yes
Observations	2,744,709	2,744,709	2,744,709	2,744,709
R-squared	0.248	0.248	0.382	0.382

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Interaction Period 2 and Physician Tenure
Hospital, Age, Race, and Co-Morbidity Dummies Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)
Dependent Variable	Stent	Stent	Stent	Stent
Period 1	0.00162***	0.00173***	0.00177***	0.00185***
	(5.31e-05)	(6.70e-05)	(6.27e-05)	(7.64e-05)
Period 2	-0.00134***	-0.00127***	-0.00106***	-0.000943***
	(3.67e-05)	(5.09e-05)	(5.02e-05)	(6.53e-05)
Period 1		-2.16e-06***		-1.41e-06*
* Tenure		(7.98e-07)		(8.29e-07)
Period 2		-1.30e-06*		-1.87e-06**
* Tenure		(7.09e-07)		(7.49e-07)
Gender	0.0101***	0.0101***	0.00924***	0.00924***
	(0.000273)	(0.000273)	(0.000252)	(0.000252)
CardioCert	0.189***	0.189***		
	(0.000431)	(0.000431)		
Star	-0.00170***	-0.00169***		
	(0.000381)	(0.000381)		
Tenure	-0.000321***	-0.000181***	0.000129***	0.000224***
	(3.97e-06)	(4.67e-05)	(3.49e-05)	(5.97e-05)
Ln(Stents to Date)	0.000302***	0.000302***	4.38e-05***	4.36e-05***
	(7.25e-07)	(7.26e-07)	(1.82e-06)	(1.82e-06)
HospChange	0.354***	0.354***	0.225***	0.224***
	(0.0136)	(0.0136)	(0.0125)	(0.0125)
FreeLancer	-0.00392***	-0.00390***	-0.00124***	-0.00126***
	(0.000302)	(0.000302)	(0.000414)	(0.000414)
ForProfit	-0.0413***	-0.0409***	-0.0518***	-0.0509***
	(0.00879)	(0.00879)	(0.0116)	(0.0116)
Beds	-6.58e-05***	-6.47e-05***	-8.61e-05***	-8.59e-05***
	(1.27e-05)	(1.27e-05)	(1.81e-05)	(1.81e-05)
Discharge	4.75e-06***	4.69e-06***	4.48e-06***	4.44e-06***
	(2.97e-07)	(2.98e-07)	(2.99e-07)	(2.99e-07)
Income	-2.36e-06***	-2.37e-06***	-1.46e-06***	-1.47e-06***
	(9.26e-08)	(9.26e-08)	(8.89e-08)	(8.89e-08)
CntyPopulation	8.11e-08***	8.07e-08***	8.17e-08***	8.11e-08***
	(7.96e-09)	(7.96e-09)	(8.35e-09)	(8.35e-09)
Poverty	-1.66e-07***	-1.67e-07***	-6.85e-08***	-6.89e-08***
	(1.37e-08)	(1.37e-08)	(1.34e-08)	(1.34e-08)
Constant	0.00979	0.00244	-0.0224*	-0.0276**
	(0.0136)	(0.0138)	(0.0134)	(0.0137)
Physician Fixed Effects	No	No	Yes	Yes
Observations	2,744,709	2,744,709	2,744,709	2,744,709
R-squared	0.248	0.248	0.382	0.382

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Interaction Period 2 and Log Stents to Date
Hospital, Age, Race, and Co-Morbidity Dummies Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)
Dependent Variable	Stent	Stent	Stent	Stent
Period 1	0.00162***	-0.000425***	0.00177***	0.000657***
	(5.31e-05)	(5.28e-05)	(6.27e-05)	(6.37e-05)
Period 2	-0.00134***	0.000862***	-0.00106***	-0.000500***
	(3.67e-05)	(4.44e-05)	(5.02e-05)	(5.99e-05)
Period 1		0.000597***		0.000300***
* Ln(Stents to Date)		(2.08e-06)		(3.19e-06)
Period 2		-0.00188***		-0.000748***
* Ln(Stents to Date)		(1.29e-05)		(1.54e-05)
Gender	0.0101***	0.0102***	0.00924***	0.00922***
	(0.000273)	(0.000269)	(0.000252)	(0.000252)
CardioCert	0.189***	0.149***		
	(0.000431)	(0.000447)		
Star	-0.00170***	0.00440***		
	(0.000381)	(0.000376)		
Tenure	-0.000321***	-0.000227***	0.000129***	0.000132***
	(3.97e-06)	(3.93e-06)	(3.49e-05)	(3.49e-05)
Ln(Stents to Date)	0.000302***	0.000221***	4.38e-05***	6.66e-05***
	(7.25e-07)	(7.92e-07)	(1.82e-06)	(2.03e-06)
HospChange	0.354***	0.234***	0.225***	0.183***
	(0.0136)	(0.0134)	(0.0125)	(0.0125)
FreeLancer	-0.00392***	-0.0225***	-0.00124***	-0.00331***
	(0.000302)	(0.000307)	(0.000414)	(0.000414)
ForProfit	-0.0413***	-0.0517***	-0.0518***	-0.0412***
	(0.00879)	(0.00866)	(0.0116)	(0.0115)
Beds	-6.58e-05***	-6.73e-05***	-8.61e-05***	-8.05e-05***
	(1.27e-05)	(1.25e-05)	(1.81e-05)	(1.80e-05)
Discharge	4.75e-06***	4.86e-06***	4.48e-06***	4.44e-06***
	(2.97e-07)	(2.93e-07)	(2.99e-07)	(2.99e-07)
Income	-2.36e-06***	1.44e-06***	-1.46e-06***	5.23e-07***
	(9.26e-08)	(9.22e-08)	(8.89e-08)	(9.17e-08)
CntyPopulation	8.11e-08***	3.19e-08***	8.17e-08***	4.76e-08***
	(7.96e-09)	(7.84e-09)	(8.35e-09)	(8.35e-09)
Poverty	-1.66e-07***	1.64e-07***	-6.85e-08***	6.27e-08***
	(1.37e-08)	(1.35e-08)	(1.34e-08)	(1.35e-08)
Constant	0.00979	-0.0583***	-0.0224*	-0.0697***
	(0.0136)	(0.0134)	(0.0134)	(0.0134)
Physician Fixed Effects	No	No	Yes	Yes
Observations	2,744,709	2,744,709	2,744,709	2,744,709
R-squared	0.248	0.270	0.382	0.384

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Interaction Period 2 and Board Certification
Hospital, Age, Race, and Co-Morbidity Dummies Omitted
Period 1 (2001 – Guideline Release) Period 2 (Guideline Release – 2010)

	(1)	(2)	(3)	(4)
Dependent Variable	Stent	Stent	Stent	Stent
Period 1	0.00162***	0.00106***	0.00177***	0.000834***
	(5.31e-05)	(5.48e-05)	(6.27e-05)	(6.40e-05)
Period 2	-0.00134***	-0.000603***	-0.00106***	-0.000439***
	(3.67e-05)	(3.78e-05)	(5.02e-05)	(5.11e-05)
Period 1		0.00261***		0.00495***
* CardioCert		(7.17e-05)		(7.29e-05)
Period 2		-0.00695***		-0.00383***
* CardioCert		(8.05e-05)		(7.91e-05)
Gender	0.0101***	0.00996***	0.00924***	0.00921***
	(0.000273)	(0.000272)	(0.000252)	(0.000252)
CardioCert	0.189***	0.0596***		
	(0.000431)	(0.00411)		
Star	-0.00170***	-0.00136***		
	(0.000381)	(0.000380)		
Tenure	-0.000321***	-0.000311***	0.000129***	0.000120***
	(3.97e-06)	(3.97e-06)	(3.49e-05)	(3.49e-05)
Ln(Stents to Date)	0.000302***	0.000301***	4.38e-05***	1.49e-05***
	(7.25e-07)	(7.28e-07)	(1.82e-06)	(1.97e-06)
HospChange	0.354***	0.342***	0.225***	0.226***
	(0.0136)	(0.0135)	(0.0125)	(0.0125)
FreeLancer	-0.00392***	-0.00435***	-0.00124***	-0.000921**
	(0.000302)	(0.000301)	(0.000414)	(0.000414)
ForProfit	-0.0413***	-0.0465***	-0.0518***	-0.0428***
	(0.00879)	(0.00878)	(0.0116)	(0.0115)
Beds	-6.58e-05***	-6.26e-05***	-8.61e-05***	-9.53e-05***
	(1.27e-05)	(1.26e-05)	(1.81e-05)	(1.80e-05)
Discharge	4.75e-06***	4.48e-06***	4.48e-06***	4.42e-06***
	(2.97e-07)	(2.97e-07)	(2.99e-07)	(2.99e-07)
Income	-2.36e-06***	-1.96e-06***	-1.46e-06***	-1.15e-06***
	(9.26e-08)	(9.26e-08)	(8.89e-08)	(8.90e-08)
CntyPopulation	8.11e-08***	8.84e-08***	8.17e-08***	7.01e-08***
	(7.96e-09)	(7.95e-09)	(8.35e-09)	(8.35e-09)
Poverty	-1.66e-07***	-1.53e-07***	-6.85e-08***	-6.97e-08***
	(1.37e-08)	(1.36e-08)	(1.34e-08)	(1.34e-08)
Constant	0.00979	0.0208	-0.0224*	-0.0152
	(0.0136)	(0.0136)	(0.0134)	(0.0134)
Physician Fixed Effects	No	No	Yes	Yes
Observations	2,744,709	2,744,709	2,744,709	2,744,709
R-squared	0.248	0.250	0.382	0.383

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12: Results of Within-Subjects Experiment
Untreated Indicates Pre Guideline Release – Treated Indicates Post Guideline Release

	Mean	Std Dev	N	T-Value	P-Value
Non Severe SCAD Untreated	0.067	0.188	7349	1.65	0.099
Non Severe SCAD Treated	0.062	0.180	7349		
Severe SCAD Untreated	0.337	0.401	2875	1.42	0.155
Severe SCAD Treated	0.352	0.400	2875		

Figure 1: Ratio of Stents to Stenting Opportunities

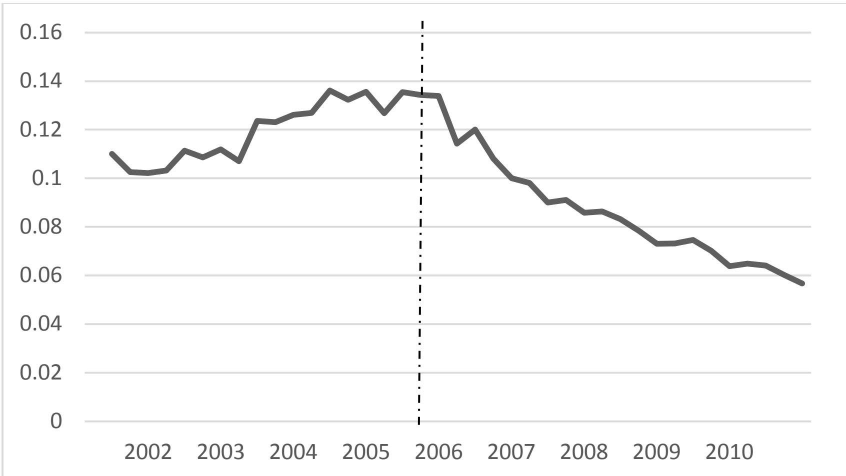


Figure 2: Raw Stenting Rate over Time

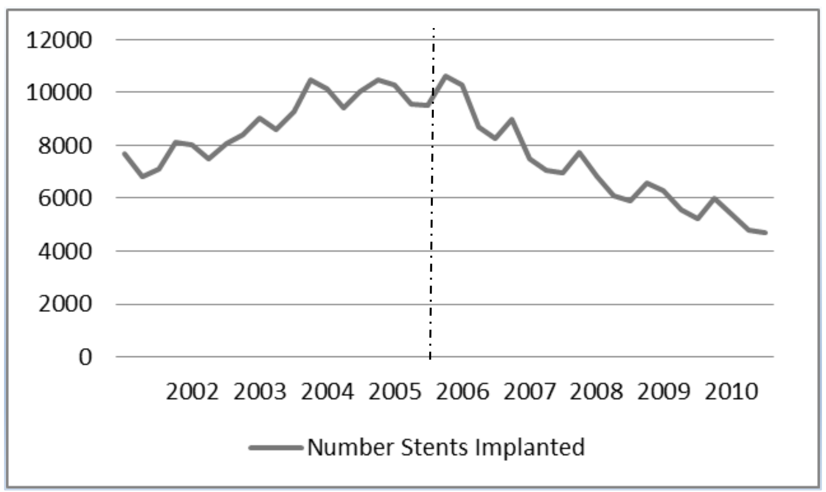
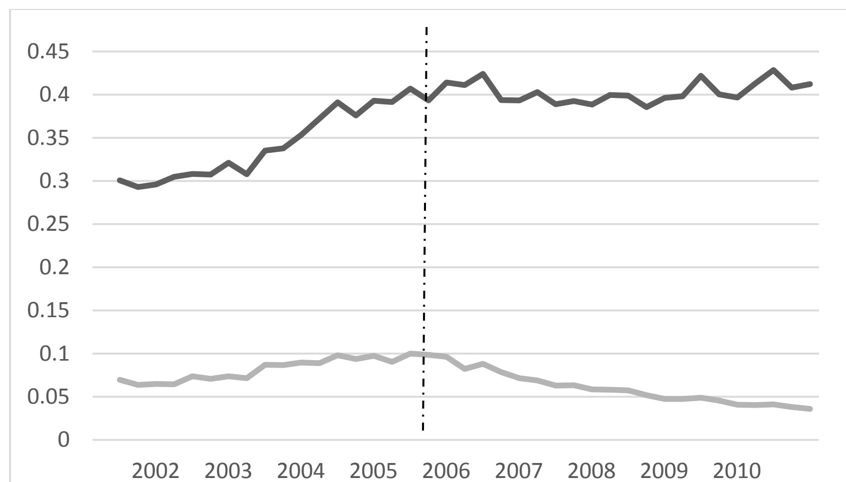


Figure 3: Percent Stents Implanted by SCAD Severity
Y-Axis: Number Stents Implanted / Stenting Opportunities
X-Axis: Time by Quarter: 2001 – 2010



Appendix

7.1 Determination of Patient SCAD Severity

To determine the severity of the patient's SCAD, and by extension the relevance of the guideline release to the patient's treatment decision, we use International Statistical Classification of Disease and Health Related Problems Version 9 (ICD-9) diagnosis codes available in AHCA dataset. Published by the World Health Organization, ICD-9 is "the standard diagnostic tool for epidemiology, health management, and clinical purposes.[12]" We use ICD-9 codes not only to determine the severity of the patient's SCAD, but also to control for other conditions and co-morbidities present (the full list of controls is outlined in Table 2). Following the CCS Functional Classification of Angina Pectoris (Table 1) on coronary arterial disease we classify a patient as having *Severe SCAD*, i.e. CCS-ClassIII angina or above, if the patient suffers from any of the following conditions: intermediate coronary syndrome, an acute coronary occlusion without myocardial infarction, or angina decubitus[13]. Intermediate coronary syndrome is severe SCAD according to the ICD-9 description. Acute coronary occlusion without myocardial infarction is a complete blockage of one of the arteries which supplies the heart with blood, and angina decubitus is resting chest pain, which is CCS Class III per the descriptions provided in Table 1.

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12 http://www.who.int/classifications/icd/en/

13 A complete listing of the current ICD-9 classifications is available at http://www.icd9data.com/