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SELECTIVE HEARING:
PHYSICIAN-OWNERSHIP AND PHYSICIANS' RESPONSE TO NEW EVIDENCE

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ABSTRACT

Physicians, acting in their role as experts, are often faced with situations where they must trade off personal and patient welfare. Physicians' incentives vary based on the organizational environment in which they practice. We use the publication of a major clinical trial, which found that a common knee operation does not improve outcomes for patients with osteoarthritis, as an "informational shock" to gauge the impact of physicians' agency relationships on treatment decisions. Using a 100% sample of procedures in Florida from 1998 to 2010, we find that publication of the trial reduced procedure volume, but the magnitude of the decline was smaller in physician-owned surgery centers. Incentives affected physicians' reactions to evidence.

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I. Introduction

Vertical integration between physicians and others types of health care providers can facilitate care coordination but, under the prevailing fee-for-service reimbursement regime, may present physicians with incentives to refer patients for costly care. Physician ownership arrangements are of special concern. Historically physicians owned the offices in which they provided primary care and basic exams but maintained arms-length relationships with hospitals, imaging centers, surgery centers, and other facilities. Beginning in the 1990s and continuing throughout the 2000s, many physicians assumed ownership stakes in non-office facilities. Based on concerns that ownership encourages physicians to recommend high cost, low value services, the US Department of Health and Human Services restricts physician ownership of health care facilities. Some types of physician ownership arrangements are prohibited outright. Others are permitted as long as they adhere to a number of regulatory "safe harbors".

Research on physician ownership of surgery centers (Hollenbeck et al. 2010; Hollingsworth et al. 2010a; 2010b; 2011; Mitchell 2010), cardiac hospitals (Barro et al. 2006; Mitchell 2005; 2008, Nallamothu et al. 2007), imaging centers (Baker 2010; Shreibati and Baker 2012) and pharmacy services (Iizuka 2007; 2012) has generally confirmed the hypothesis that ownership is associated with increased use of health care services. A limitation of most of these studies is that, in the absence of a benchmark for the optimal level of use, it is impossible to assess the impact of alternative practice arrangements on consumer welfare. Physicians in physician-owned facilities provide more care, but we do not know if they provide too much.

In 2002 the *New England Journal of Medicine* published the results of a trial (hereafter, the "Moseley trial") showing that arthroscopic surgery for patients with osteoarthritis of the knee, a widely used procedure at the time, does not improve patient outcomes (Moseley et al. 2002). Physicians perform arthroscopic surgery in hospital-based surgery centers or freestanding centers, most of which are physician-owned. We use the trial as an "informational shock" to compare physicians' treatment decisions in hospital-based and physician-owned ambulatory surgery centers. We find that the Moseley trial affected practice patterns, but the magnitude of the effect was smaller in freestanding centers. The Moseley trial identified a clinical scenario where physicians' financial interests and the interests of their patients diverge. Faced with the same set of scientific facts, physicians in hospital-based and freestanding surgery centers responded differently.

II. Physician Ownership and Treatment Incentives

For every surgery, insurers pay a professional services fee to the surgeon for their labor and a facility fee (or "technical" fee) to the hospital or surgery center to cover the cost of supplies, non-physician labor, and capital. Physician-owners split the profits generated from facility fees based on their ownership shares, providing an extra incentive to induce demand.[1] (It would be illegal under federal anti-kickback laws for a facility to pay a physician based on the profits generated from directly from his own surgeries.) Physician-owned facilities can also incentivize physicians by tying ownership shares to productivity. Reallocating ownership shares on a predetermined schedule based on each owner's procedure volume is illegal. However, reallocating shares during times of transition – when owners bring in a new partner or when an existing partner retires – is legal as long as shares are exchanged at fair market value.

Managers in physician-owned facilities may be better than managers in other types of facilities at eliciting high levels of physician effort (and inducement). Hospitals are large, bureaucratic, multi-product firms. The residual claimants (e.g., shareholders, non-clinical administrators) are far-removed from the delivery of care. By contrast, groups of surgeon-owners face stronger incentives to monitor each others' case volumes, face lower monitoring costs, and have greater ability to reward high-volume surgeons and punish shirkers.

III. Clinical Background

Arthroscopic surgery is a minimally invasive procedure to treat damage to the soft tissue of the knee. A patient undergoing arthroscopic surgery receives several small incisions in the knee. The surgeon inserts a camera (the arthroscope) to inspect the bone, cartilage, and soft tissue in the joint. After validating the initial diagnosis, the surgeon may perform lavage (irrigation of the joint to remove particles that cause inflammation), debridement (to remove

[1] Income effects may offset the direct incentives presented by ownership. If ownership increases physicians' income, they may reduce labor supply and/or efforts to induce demand (McGuire 2000).

damaged tissue), and/or a menisectomy (to remove damaged meniscal tissue). In 2002 the *New England Journal of Medicine* published a trial evaluating arthroscopic surgery for patients with osteoarthritis (Moseley et al. 2002). Patients in the control arm were anestisized and underwent sham surgery. The trial found that patients did not benefit from surgery. There were no differences in pain and functioning between the treatment arms. Because the trial was published in one of the most prominent medical journals, resulted in the publication of a number of commentaries in other journals, and was covered in the popular press (e.g., Kolata 2002), knowledge of the trial among physicians should have been widespread.

Some orthopedic surgeons questioned the external generalizability of the Moseley trial, as is typical following the release of trials that challenge established practices. Medicare and major private insurers accepted the findings and withdrew coverage of arthroscopic surgery for patients with moderate to severe osteoarthritis (CMS 2003; 2004; Aetna 2003). As we describe in section X, it is difficult for insurers to enforce non-coverage policies because insurance claims for knee arthroscopy do not report whether surgery is being performed primarily to treat osteoarthritis or other types of knee problems. While this feature complicates the task of measuring the impact of the trial, it ensures that surgeons retain a great deal of discretion in how they treat patients presenting with knee pain. Since 2002, two additional trials (Kirkley et al. 2008; Katz et al. 2013) have confirmed the finding of the Moseley trial.

IV. INCENTIVES AND DEMAND INDUCEMENT

We hypothesize that surgeons practicing in freestanding centers, who face stronger financial incentives to perform surgery, were less likely to stop performing knee arthroscopy in patients with osteoarthritis compared to surgeons in hospital-based centers. Prior to publication of the Moseley trial, surgeons could have reasonably believed that all patients with osteoarthritis of the knee would benefit from knee arthroscopy. There was no conflict between physician welfare and physicians' perceptions of patient welfare. After publication, physicians' incentives and patients' interests diverged. Physicians who recommended knee arthroscopy to patients with osteoarthritis were "inducing" demand by encouraging patients to consume unnecessary services (McGuire 2000).

V. Data and Identification of Procedures

We measured trends in arthroscopic knee surgery volume among patients age 18 and older using Florida's State Ambulatory Surgery Database for the period 1998 to 2010. The data capture 100% of outpatient surgeries in Florida and include the information typically found on insurance claims, including basic patient demographics and diagnosis and procedure codes. The data are collected by the state's Agency for Health Care Administration. We identified procedures using Current Procedural Terminology and International Classification of Diseases version 9 (ICD-9) codes (see the appendix for a list of codes). The data include an identifier for the facility where the surgery was performed and whether the facility was a hospital-based or a freestanding ambulatory surgery center.

Osteoarthritis is inconsistently and infrequently recorded as a diagnosis on claims, and so we do not limit the sample to patients with osteoarthritis. Instead, claims typically include codes for "Internal derangement of knee" (ICD-9 code 717.X). We analyze facility-level procedure volumes that reflect the use of surgery in patients with osteoarthritis and patients with other types of knee problems.

We identified 522,635 arthroscopic knee surgeries, of which 233,321 (44%) were performed in freestanding centers. Patients treated in freestanding centers were slightly older (52 versus 50) than patients treated in hospital-based centers. The distribution of insurance type (60% male, about 20% Medicare) was very similar.

VI. Identification of the Impact of Physician-Ownership

We compare changes in the volume of arthroscopic knee surgeries between hospital-based and freestanding surgery centers following publication of the Moseley trial. As with many previous studies of physician ownership (e.g., Hollingsworth et al. 2010a; Mitchell 2005), we only observe patients who received surgery. We do not observe patients who were evaluated for but did not receive arthroscopic surgery. Comparisons of surgery volume trends between hospital-based and freestanding centers may be biased by secular trends in patient demand.

Our main identification strategy is to evaluate trends in the volume of arthroscopic knee surgeries relative to trends in the volume of arthroscopic shoulder surgeries. Arthroscopic shoulder surgery shares many of the characteristics of arthroscopic knee surgery: it is a minimally invasive, outpatient surgery used to treat a variety of conditions, including arthritis. All of the centers in our sample performed arthroscopic shoulder procedures in addition to arthroscopic knee surgery. The intuition behind our approach is that the secular trends that affected the demand for knee surgery over the study period – e.g., the growth of the freestanding surgery center industry, changes in local population demographics – should be captured by trends in the volume of arthroscopic shoulder procedures. Under a fairly innocuous set of assumptions, we can identify the number of knee surgeries that would have been avoided if physicians in freestanding centers behaved like physicians in hospital-based centers post-Moseley.

A simple model is useful for formalizing this argument and the identifying assumptions. For the sake of simplicity, assume there is a single hospital-based center and a single freestanding center. Let k_{Ht} represent the number of knee surgeries in the hospital-based center in period t (1 or 2, corresponding to pre- and post-Mosely periods). Let K_{Ht} represent patient demand in the hospital-based center (i.e., the number of patients with knee problems evaluated for surgery). Let s_{Ht} and S_{Ht} represent the volume and demand for shoulder surgeries in the hospital-based center. The quantities for the freestanding center are defined analogously (k_{Ft}, K_{Ft} , s_{Ft} , S_{Ft}). The treatment rate is the number of patients who received surgery divided by the number evaluated for surgery. The treatment rate for patients with knee pain in the hospital-based center is

$$\frac{k_{Ht}}{K_{Ht}} \qquad [1]$$

The number of surgeries that could be avoided in period 2 if the treatment rate in the freestanding center was the same as the treatment rate in hospital-based centers is

$$k_{F2} - \frac{k_{H2}}{K_{H2}} K_{F2} \qquad [2]$$

The first term is the actual number of knee surgeries in the freestanding center, and the second is the number that would occur if the freestanding center had the same treatment rate as the hospital-based center (k_{H2} / K_{H2}). We can estimate [2] without data on patient demand (K or S) using data on the number of shoulder surgeries,

$$k_{F2} - \frac{k_{H2}}{K_{H2}} K_{F2} = k_{F2} - \frac{\frac{k_{H2}}{s_{H2}}}{\frac{k_{H1}}{s_{H1}}} \frac{k_{F1}}{s_{F1}} s_{F2}, \qquad [3]$$

under three assumptions.[2]

Assumption 1: Within facility types (hospital-based versus freestanding), there is a constant relationship between the number of patients evaluated for knee surgery and the number evaluated for shoulder surgery. For every K patients with knee problems, there are δK with shoulder problems: $\delta_H K_{Ht} = S_{Ht}$ and $\delta_F K_{Ft} = S_{Ft}$.[3]

Assumption 2: The shoulder surgery treatment rate has not changed over time (but it can differ between hospital-based and freestanding centers):

$$\frac{s_{H1}}{S_{H1}} = \frac{s_{H2}}{S_{H2}} = \alpha_H \text{ and } \frac{s_{F1}}{S_{F1}} = \frac{s_{F2}}{S_{F2}} = \alpha_F .$$

Assumption 3: The knee surgery treatment rate was similar in hospital-based and freestanding centers pre-Moseley: $\frac{\acute{k}_{H1}}{K_{H1}} = \frac{\acute{k}_{F1}}{K_{F1}}$.

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[2] The equality holds if we apply assumptions 1 and 2 (substitute $s_{Ht} = \alpha_H \delta_H K_{Ht}$ and $s_{Ft} = \alpha_F \delta_F K_{Ft}$), cancel out the $\alpha_H \delta_H$'s and $\alpha_F \delta_F$'s, and then apply assumption 3.

[3] The claim also holds under an alternative version of the assumption: $\delta_1 K_{H1} = S_{H1}$, $\delta_1 K_{F1} = S_{F1}$, $\delta_2 K_{H2} = S_{H2}$, and $\delta_2 K_{F2} = S_{F2}$. In this version, the relationship between the demand for knee and shoulder procedures is allowed to vary over time but not across providers.

Assumption 1 would be violated if the number of patients experiencing knee problems increased at a different rate than the number of patients experiencing shoulder problems. Using the 2002 and 2008 National Health Interview Surveys, nationally-representative surveys conducted by the US Department of Health and Human Services, we estimated that the proportion of adults who experienced "pain, aching, stiffness or swelling" in or around one of their knee joints in the past 30 days increased from 16.4% (16.0% to 17.0%) in 2002 to 19.0% (95% CI: 18.3% to 19.7%) in 2008. The comparable figures for the shoulder joints are 8.6% (95% CI: 8.2% to 9.1%) and 9.3% (95% CI: 8.8% to 9.8%).[4] These imply that the value of δ (the ratio of shoulder to knee patients) was 0.53 (95% CI: 0.47 to 0.58) in 2002 and 0.49 (0.42 to 0.56) in 2008. The difference is qualitatively small and statistically insignificant, supporting the validity of the assumption.

Assumption 2 would be violated if the criteria for determining whether patients with shoulder problems are good candidates for surgery changed over time. There were no major changes in evidence about the effectiveness of shoulder surgery over the period covered by our study. Reflecting the lack of evidence on the effectiveness of shoulder arthroscopy, the American Academy of Orthopedic Surgeons stated in its 2010 treatment guideline for osteoarthritis of the shoulder (Izquierdo et al. 2010), "We are unable to recommend for or against the use of arthroscopic treatments for patients with glenohumeral joint osteoarthritis."

Based on our review of the medical literature, we believe it is unlikely that the publication of the Moseley trial affected physicians' beliefs about the effectiveness of shoulder arthroscopy. Only two of the 599 articles that have cited the Moseley trial according to the *New England Journal of Medicine* website were on the subject of shoulder arthroscopy (Beard et al. 2015; Judge et al. 2014). Both cited the Moseley trial as an example of the type of trial (placebo-controlled) that should be conducted on shoulder surgery, not as a trial that provides evidence about shoulder surgery. Neither the systematic review on the effectiveness of surgery for shoulder osteoarthritis conducted by the well-respected Cochrane group (Singh et al. 2011) nor the shoulder osteoarthritis clinical practice guideline from the American Academy of Orthopedic Surgeons (Izquierdo et al. 2010) cite the Moseley trial.

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[4] Respondents self-reported shoulder and knee problems. Estimates are weighted and standard errors adjusted for the complex survey design. We used Monte Carlo simulation to calculate confidence intervals for ratios.

Conceivably, surgeons who reduced the number of knee surgeries they performed after the publication of the Moseley trial may have performed more shoulder surgeries, making it difficult to interpret changes in the ratio of knee to shoulder surgeries over time. However, orthopedic surgeons could offset decreases in the volume of knee surgeries by performing other types of orthopedic surgeries (e.g., hip replacements), not just shoulder surgeries. Any substitution between knee and shoulder surgeries is probably a small, second-order effect.

Assumption 3 would be violated if patients with knee pain were treated differently at hospital-based and freestanding centers prior to the publication of the Moseley trial. Before 2002, several small randomized trials of debridement (Merchan et al. 1993) and lavage (Ike et al. 1992) found that these therapies reduced knee pain. Knee arthroscopy was a well-accepted, established therapy for osteoarthritis, and orthopedic surgeons in both hospital-based and freestanding centers could have reasonably believed that their interests were aligned with the interests of their patients (Chandra and Skinner 2012).

VII. TRENDS IN PROCEDURE VOLUME

Figure 1 displays trends in the quarterly volume of arthroscopic knee surgeries, overall and, separately, in the 161 hospital-based and 70 freestanding centers that operated continuously between 1998 and 2010 and performed an average of 20 knee arthroscopies annually. These facilities accounted for 73 percent of the arthroscopic knee surgeries in Florida over the study period. Many freestanding surgery centers opened in Florida between 1998 and 2010 and are thus excluded. The figure indicates the date of publication of the Moseley and Kirkley trials and the release of the CMS Decision Memo (2003) indicating that Medicare would withdraw coverage of arthroscopic surgery for patients with osteoarthritis of the knee.

Annual arthroscopic surgery volume in Florida increased from 41 thousand procedures in 1998 to 63 thousand in 2007 before declining to 59 thousand in 2010. The prevalence of symptomatic knee osteoarthritis was increasing over this period (Nguyen et al. 2011). There was a sharp decline in volume in hospital-based centers following publication of the Moseley trial. Most of the post-Moseley decline in procedure volume preceded changes in insurers’ coverage policies.

Table 1 displays annual procedure counts for surgeons who performed at least 20 knee arthroscopies annually. Over the period 1998 to 2001, there were 301 surgeons who performed most of their procedures at hospitals. Surgeons in freestanding centers performed over 92% of their surgeries at their most frequently used freestanding center. The vast majority (>95%) would be classified as owners using the criteria employed by Hollingsworth et al. (2010a) to distinguish between owners and non-owners. The data include surgeon identifiers, but these cannot be linked over time, hence our focus on facility-level analyses.

Figure 2 shows trends in facility-level procedure volumes. Average volume grew rapidly in freestanding centers prior to the publication of the Moseley trial, particularly in 1998 and 1999. Some or many of the freestanding centers in the sample may have opened just prior to 1998, and so the trends in volume probably reflect the volume growth typical for new entrants.

The left panel of Figure 2 shows trends in quarterly, facility-level arthroscopic shoulder surgery volumes. Procedure volume did not decline following publication of the Moseley trial, consistent with the idea that the Moseley trial did not affect physicians' or patients' perceptions of the benefits of shoulder surgery.

VIII. The impact of the Moseley trial

VIII.A. Difference-in-difference-in-difference estimate

Before presenting our preferred specification, which examines changes in the ratio of knee to shoulder surgeries, we present the traditional triple difference estimator. Table 2 shows average quarterly procedure volume among the 161 hospital-based and 70 freestanding centers before and after publication of the Moseley trial. The first panel displays arthroscopic knee procedures. We drew 1,000 bootstrap samples, with sampling at the level of the surgery center, to obtain standard errors and confidence intervals. Average volume decreased in hospital-based centers and increased in freestanding centers. The difference-in-difference estimate of the impact of the Moseley trial on quarterly knee arthroscopy volume is -16.9 [95% CI: -27.6, -6.3] procedures (= [32.6 – 38.9] – [68.0 – 57.3]).[5]

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[5] If we had observations for all patients with knee pain, not just those who had surgery, we could proceed with a standard regression-based difference-in-difference estimate that includes controls for patient

The bottom panel of Table 2 repeats the difference-in-difference analysis for arthroscopic shoulder procedures. The difference-in-difference estimate is -9.0 [95% CI: -14.9, -3.1] procedures, reflecting the secular shift in volume from hospital-based to freestanding centers. The difference-in-difference-in-difference estimate is -8.0 [95% CI: -15.5, -0.4] procedures per quarter (= -16.9 - [-9]). The interpretation is that the Moseley trial reduced the volume of arthroscopic knee procedures in hospital-based centers by 8 procedures relative to trends in freestanding centers.

VIII.B. Preferred specification

The difference-in-difference-in-difference estimator imposes an additivity assumption that may be problematic in our case. It assumes that, in the absence of an effect, the difference-in-difference estimator for shoulder surgery would be of the same magnitude as the difference-in-difference estimator for knee surgery. This assumption seems inconsistent with the observation that the number of knee surgeries is greater than the number of shoulder surgeries at any point in time. Trends in knee and shoulder surgery volumes operate on different scales and from much different baseline levels. As an alternative to the standard difference-in-difference-in-difference estimator, we estimate a model that examines trends in the ratio of knee to shoulder surgeries. The model is

$$y_{it} = \alpha_0 + \alpha_1 H_i + \alpha_2 s_{it} + \alpha_3 H_i s_{it} + \alpha_4 M_t^{post} s_{it} + \alpha_5 H_i M_t^{post} s_{it} + u_i + \varepsilon_{it} \,. \qquad [6]$$

This model is our preferred specification. Here y_{it} is the number of arthrosopic knee procedures in center i in quarter t and s_{it} is the number of arthrosopic shoulder procedures. H_i is an indicator for whether a center is hospital-based, M_t^{post} is an indicator for the post-Moseley

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characteristics. However, we only observe the characteristics of patients who had surgery. These may have changed over time in direct response to the Moseley trial (for example, if older patients were more likely to abstain from surgery post-Moseley), and so it does not make sense to include them in a regression model.

period, and μ_i is a center-level random effect. The coefficient on the interaction of the hospital-based center and post-period indicators, α_5, is of interest.

The model can also be written as

$$y_{it} = \beta_0 + \beta_1 H_i + \beta_2 H_i M_t^{pre} s_{it} + \beta_3 H_i M_t^{post} s_{it} + \beta_4 F_i M_t^{pre} s_{it} + \beta_5 F_i M_t^{post} s_{it} + \mu_i + \varepsilon_{it}, \qquad [7]$$

where $F_i = 1 - H_i$ is an indicator for freestanding centers and $M_t^{pre} = 1 - M_t^{post}$ is an indicator for the pre-Moseley period. This form has an intuitive interpretation. The parameter β_2 represents the number of knee surgeries per shoulder surgery in hospital-based centers pre-Moseley (e.g., k_{H1} / s_{H1}). The parameter β_3 represents the number of knee surgeries per shoulder surgery in hospital-based centers post-Moseley (e.g., k_{H2} / s_{H2}). The parameters β_4 and β_5 are defined analogously for freestanding centers. The difference-in-difference estimator is $\theta = \alpha_5 = (\beta_3 - \beta_2) - (\beta_5 - \beta_4)$.

We estimated the model via least squares. Quarterly arthroscopic knee surgery procedure counts are skewed, but counts of shoulder surgery procedures are also skewed and correlated with knee surgery procedure counts. The skew in the residual from the regression is much lower than the skew in the raw procedure counts and the distribution is bell-shaped, though a Shapiro-Wilk test rejects the null that the residual is normally distributed ($p < 0.001$). In the baseline specification we treat μ_i as a random effect. We do not require fixed effects for purposes of identification because provider type is a time-invariant clinic characteristic. Standard errors are clustered at the facility level. The sample size is 12,012 facility-quarter observations (231 facilities × 4 quarters × 13 years).

Column A in Table 3 displays estimates from the model described by equation [7]. Freestanding centers performed 1.78 and hospitals 1.76 arthroscopic knee procedures per arthroscopic shoulder procedure before the publication of the Moseley trial. Practice patterns were similar. Following publication of the Moseley trial, freestanding centers performed 1.25 and hospitals 0.94 arthroscopic knee procedures per arthroscopic shoulder procedure.

We estimate $\theta = -0.33 = (0.94 - 1.78) - (1.25 - 1.76)$. The p-value is 0.027 based on a Wald test. The interpretation is that the publication of the Moseley trial had a stronger influence on practice patterns in hospital-based centers.

Using the estimated parameters, we constructed the right-hand side of equation [3]. We estimate that freestanding centers would have performed 3,000 fewer arthroscopic knee procedures annually (95% confidence interval: 2,133 to 3,866) over the period 2003 to 2007 (from a base of about 34,000 procedures) if the post-Moseley treatment rate in freestanding centers was the same as the treatment rate in hospital-based centers.

Figure 3 shows estimates of θ from alternative specifications of the model described by equation [6]. Model 1 is the baseline model. Model 2 omits the hospital indicator. Models 3 and 4 treat μ_i as a fixed effect. Model 4 weights the regressions by pre-2002 surgery volume. Model 5 includes all facilities, including those that entered after 1998. Model 6 omits 1998 and 1999 from the analysis. Model 7 omits 2009 and 2010, where procedure volume was subject to the influence of the Kirkley trial and the recession.

Models 8-10 examine procedure counts within age groups. These results indicate that the baseline estimate is not driven by differences in the age composition of patients treated in hospital-based versus freestanding centers. Overall, the results show that the estimate of θ is insensitive to alternative model specifications.

Models 11 and 12 stratify the analysis by insurance type: private versus other. About half of patients in the other category have Medicare, and about one-third have Medicaid. The results indicate that after the Moseley trial, freestanding centers were more likely to perform arthroscopy in privately insured patients than hospital-based centers. However, practice patterns were similar for patients with other types of insurance. One explanation is that physicians face stronger incentives to induce demand for privately-insured patients because private insurers pay more than Medicare and Medicaid.[6]

[6] Across all services, Medicare payments to physicians are 79% of the payments made by preferred provider organizations, the most common form of private insurance (MEDPAC 2015).

X. SURGERY RATES BY PROCEDURE TYPE

There are two broad categories of arthroscopic knee surgery: debridement and menisectomy. Examining trends by procedure type provides an additional source of identification. Insurers' costs of monitoring appropriateness are much lower for debridement compared to menisectomy. Thus, we expect that physicians would focus their inducement efforts on menisectomy.

Figure 4 depicts a stylized treatment pathway for patients with knee pain who are evaluated for arthroscopic surgery. Consider a patient with knee pain where the surgeon suspects the pain is due to arthritis (A). The surgeon recommends that the patient undergo an arthroscopy (B). During surgery, the physician determines if the patient has damaged meniscal tissue (C). The mensci are cartilaginous disks that cushion the knee joint. If so, he performs a "meniscectomy" to remove torn tissue (E). Otherwise, he performs a debridement procedure (D). A meniscectomy was performed on 81 percent of the patients randomized to arthroscopic surgery in the Kirkley trial.

Now consider a patient where the surgeon suspects pain is caused by a torn meniscus (F). Typically, the surgeon will order a magnetic resonance imaging scan (MRI) (G) to confirm the results of the physical examination. If the MRI shows a torn meniscus (H), he performs a menisectomy (E).

Following arthroscopic surgery, the surgeon submits an insurance claim for a debridement procedure or a menisectomy. Post-Moseley, insurers scrutinize claims for debridement procedures closely. However, when an insurer receives a bill for a menisectomy, there is no information on the claim that permits the insurer to determine whether the patient was originally treated for osteoarthritis (pathway A-B-C-E), in which case the procedure is not covered, or a torn meniscus (pathway F-G-H-E).

Some insurers require documentation that the patient has a torn meniscus before authorizing payment for arthroscopic surgery. Surgeons may order an MRI (G) for a patient who is a candidate for surgery (A) to document meniscal damage. Many older patients have asymptomatic meniscal tears (Englund et al. 2008). For this reason, surgeons are advised not to rely exclusively on radiological evidence when deciding whether to perform a menisectomy. Nevertheless, surgeons can use imaging studies to justify performing a menisectomy (E) on a patient with arthritis. Based on the information included on insurance claims, insurers cannot distinguish between treatment pathways A-G-H-E and F-G-H-E. They must pay the claim or risk denying payment for medically appropriate care.

Figure 5 depicts trends in debridement procedures and menisectomies. Use of debridement declined steeply following publication of the Moseley trial in both hospital-based and freestanding centers. Use was declining in hospital-based centers prior to the Moseley trial. The trendline for freestanding centers displays two notable trend breaks. The first occurs immediately following publication of the Moseley trial. The second occurs after CMS issued a decision memo stating its intent to discontinue coverage for arthroscopic surgery for patients with severe osteoarthritis. It appears surgeons in freestanding centers reacted to changes in coverage policy. Use of meniscectomy declined following publication of the Moseley trial in hospital-based and freestanding centers. However, by 2004 procedure volume had rebounded to pre-Moseley levels in freestanding centers.

Model [B] in Table 3 re-estimates equation [7] for debridement procedures only. Pre-Moseley, hospital-based and freestanding centers performed 0.26 and 0.25 debridement procedures per arthroscopic shoulder procedure, respectively. Post-Moseley, the comparable figures are 0.05 and 0.06. The differential decline in hospital-based centers is insignificant ($\theta =$ -0.029, p = 0.39).

Model [C] in Table 3 re-estimates equation [7] for menisectomies only. Pre-Moseley, hospital-based and freestanding centers performed 1.53 and 1.51 debridement procedures per arthroscopic shoulder procedure. Post-Moseley, the comparable figures are 0.9 and 1.19. The differential decline is significant ($\theta =$ -0.31, p = 0.02).

The results are consistent with the hypothesis that surgeons in freestanding centers decreased use of the procedure (debridement) where insurers' monitoring costs are low, but continued to perform the procedure (menisectomy) for which it is relatively difficult for insurers to determine medical appropriateness.

XI. THE KIRKLEY TRIAL

In 2008 the *New England Journal of Medicine* published the results from a trial that randomized patients with osteoarthritis to arthroscopic surgery plus physical and medical therapy or physical and medical therapy alone (Kirkley et al. 2008). The Kirkley trial concluded "surgery…provides no additional benefit to optimized physical and medical therapy." Compared to the Moseley trial, the Kirkley trial had broader enrollment criteria, including females and patients with mild osteoarthritis, and procedures were performed by multiple surgeons.

The left panel of Figure 2 shows that procedure volume declined around 2008, but the size of the decline was larger in freestanding surgery centers. Model [D] in Table 3 tests the impact of the Kirkley trial on center-level volume. We restrict the analysis to the period 2004 to 2010. We selected 2004 because it appears that results from the Moseley trial were fully incorporated into practice by this time.

If surgeons fully adjusted practice patterns following publication of the Moseley trial, then the 2008 Kirkley trial should have had no impact on practice patterns. If physicians continued to recommend knee surgery for patients with osteoarthritis, then we would expect that procedure volume would decline following publication of the Kirkley trial. The results indicate that hospital-based centers performed 0.74 arthroscopic knee surgeries per shoulder surgery pre-Kirkley and 0.64 post-Kirkley. Freestanding centers performed 1.22 arthroscopic knee surgeries per shoulder surgery pre-Kirkley and 1.0 post-Kirkley. The differential change is $\theta = 0.11$ (p = 0.116), indicating that there was a larger, though non-significant, relative decline in knee surgery volume in freestanding centers. Results from the other specifications described in Figure 3 are similar. Given the non-significance of the result, we cannot draw too much from this analysis. However, the sign of θ is consistent with the idea that, having induced demand at higher rates following publication of the Moseley trial, surgeons in freestanding centers shifted toward the more conservative practice patterns of their hospital-based peers. Publication of the Kirkley trial would have made it increasingly difficult for physicians to cling to their beliefs in the effectiveness of surgery. Physicians who continued to recommend surgery would face an even higher utility penalty for inducing demand.

XII. Conclusions

Publication of a trial that found that arthroscopic knee surgery does not benefit patients with osteoarthritis affected practice patterns. However, the magnitude of the effect was smaller in freestanding ambulatory surgery centers, where surgeons face stronger incentives to induce demand and greater peer monitoring of effort. In contrast to prior studies on physician ownership, we are able to tie differences in practice patterns to evidenced-based medical practices.

Estimates of the impact of ownership on practice patterns must be interpreted in light of the fact that surgeons are not randomly assigned to work in hospital-based or physician-owned surgery centers. Physician-owned centers may differentially attract older doctors who are less likely to change practices in response to new evidence or "greedy" doctors, i.e., doctors who are more willing to sacrifice patient welfare for their own financial gain. Some studies circumvent this problem by examining how entry by physician-owned facilities affects market-level volume (Barro et al. 2006; Hollenbeck et al. 2011; Hollingsworth et al. 2010b; 2011). These studies suggest that ownership has a casual impact on practice patterns. Market-level surgery rates increase following entry and are higher in markets where physician-owned facilities perform a larger share of procedures.[7]

Many medical procedures diffuse into clinical practice without having been subject to rigorous testing. Clinical trials of established medical procedures can identify therapies that are no better than less expensive alternatives. However, even well-done studies are open to differing interpretations. Our results indicate that the organizational environment in which physicians practice affects how they react to new evidence.

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[7] We cannot separately identify the impact of selection effects versus other channels through which ownership affects treatment decisions. However, while selection effects and reimbursement incentives may appear to be distinct theories of physician behavior, they are closely related. Analogous to genotype-environment interactions in biology, physician "greed" is a genotype that manifests itself under reimbursement schemes that require physicians to trade off patient and personal welfare.

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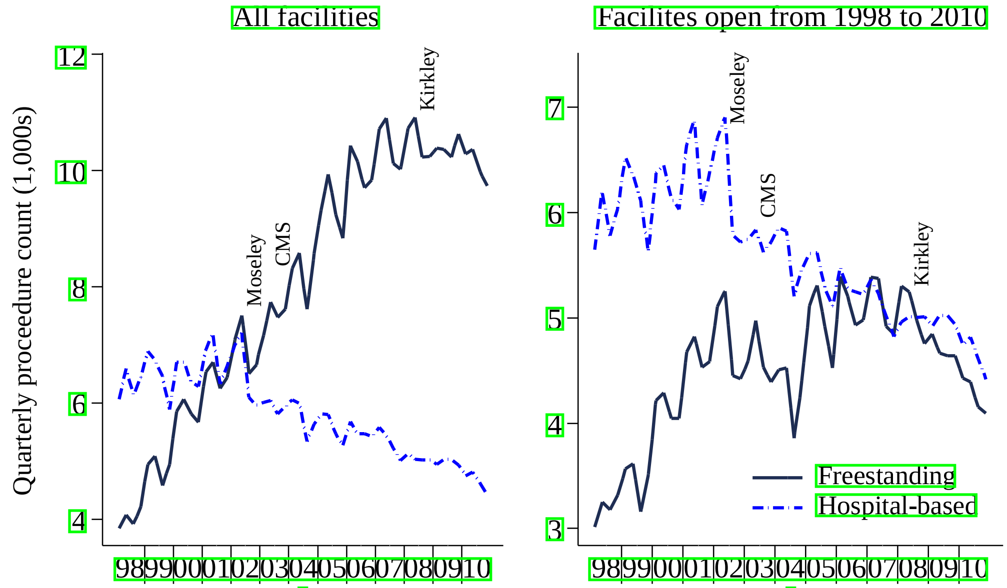
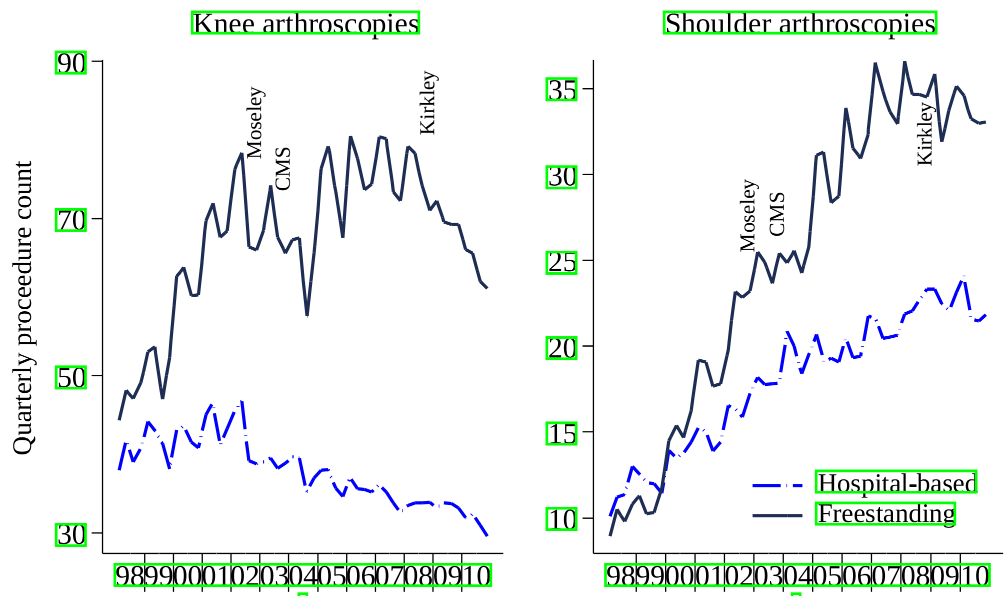
Figure 1: Quarterly arthroscopic knee surgery procedure volume



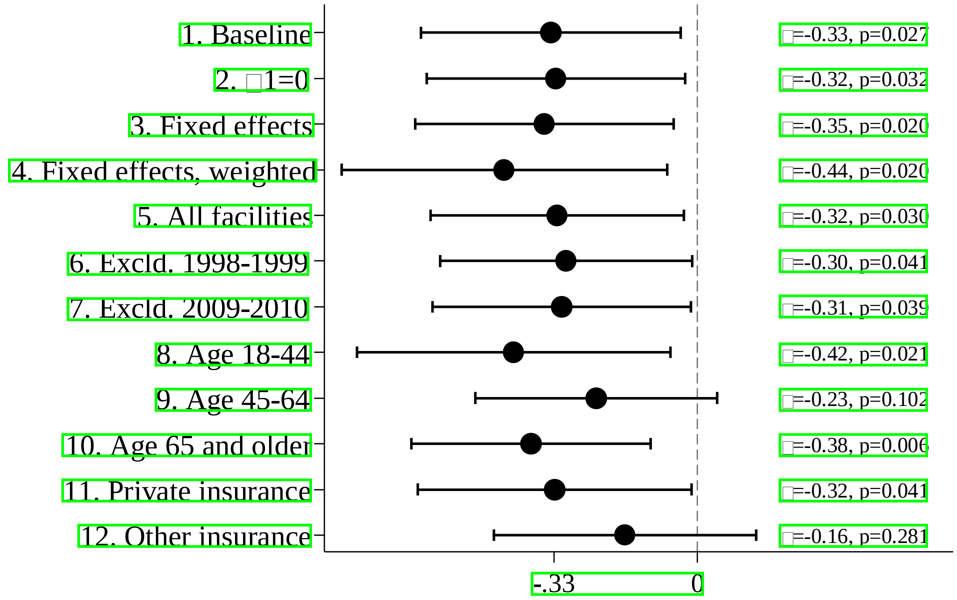
Source: Authors' analysis of the Florida State Ambulatory Surgery Database. Moseley: publication of the Moseley trial; CMS: change in CMS coverage policy; Kirkley: publication of Kirkley et al. trial.

Figure 2: Quarterly average facility-level volume



Source: Authors' analysis of the Florida State Ambulatory Surgery Database. Moseley: publication of the Moseley trial; CMS: change in CMS coverage policy; Kirkley: publication of Kirkley et al. trial.

Figure 3: Estimates of □ from alternative specifications



Error bars represent 95% confidence intervals.

Figure 4: Treatment pathways for patients with knee pain

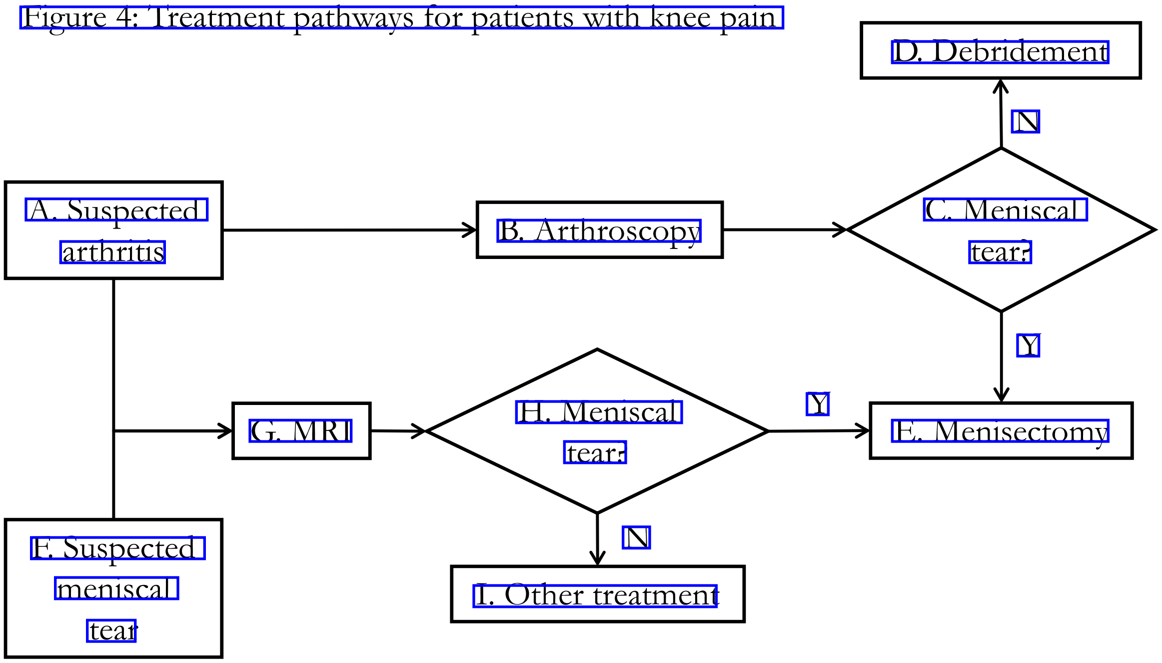
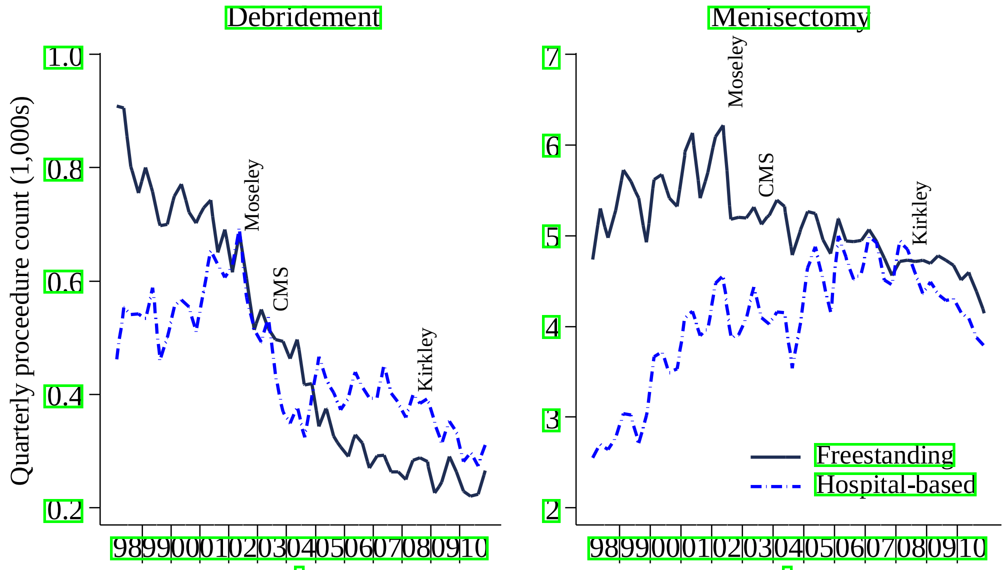


Figure 5: Quarterly arthroscopic knee surgery procedure volume, by procedure type



Source: Authors' analysis of the Florida State Ambulatory Surgery Database.
Moseley: publication of the Moseley trial;
CMS: change in CMS coverage policy; Kirkley: publication of Kirkley et al. trial.

Table 1: Surgeon volume among surgeons performing at least 20 arthroscopic knee procedures annually

	Hospital-based N = 161			Freestanding N = 70		
	1998-2001	2002-2007	2008-2010	1998-2001	2002-2007	2008-2010
Annual knee arthroscopies at main facility	52.4	61.4	66.2	75.8	78.9	82.9
Annual knee arthroscopies, total	59.9	67.1	71.4	85.6	86.6	88.3
Share performed at main facility	0.93	0.95	0.97	0.92	0.93	0.96
Surgeons	301	253	203	166	215	206

Table 2: Difference-in-difference-in-difference estimate

	Pre Moseley Jan. 1998-July 2002	Post Moseley July 2002-Dec. 2010	Difference
	Mean procedures per facility per quarter [95% CI]		
Knee arthroscopies			
Hospital	38.9 [33.4, 44.4]	32.6 [27.6, 37.7]	-6.3 [-10.9, -1.7]
Freestanding	57.3 [44.6, 70.1]	68.0 [51.2, 84.8]	10.7 [1.3, 20.1]
DD			-16.9 [-27.6, -6.3]
Shoulder arthroscopies			
Hospital	12.3 [10.1, 14.5]	18.9 [15.5, 22.2]	6.6 [4.1, 9.1]
Freestanding	13.9 [9.6, 18.2]	29.5 [21.5, 37.5]	15.5 [10.3, 20.8]
DD			-9.0 [-14.9, -3.1]
DDD			-8.0 [-15.5, -0.4]

DD: Difference-in-difference.
DDD: Difference-in-difference-in-difference.

Table 3: Random-effects estimates of the impact of center type, time period, and shoulder arthroscopy volume on quarterly knee arthroscopy volume

	Post-Moseley			Post-Kirkley
	[A]	[B]	[C]	[D]
Variable	All procedures	Debridement	Menisectomy	All procedures
	β (SE)			
Constant	33.11 (4.99) **	4.01 (1.04) **	27.70 (3.92) **	33.44 (7.32) **
Hospital-based center	-16.09 (5.45) **	-2.69 (1.06) *	-13.39 (4.36) **	-15.18 (7.59) *
A: Hospital-based center×Pre×Shoulder arthroscopies	1.78 (0.17) **	0.26 (0.03) **	1.53 (0.15) **	0.74 (0.09) **
B: Hospital-based center×Post×Shoulder arthroscopies	0.94 (0.15) **	0.05 (0.01) **	0.90 (0.14) **	0.64 (0.09) **
C: Freestanding center×Pre×Shoulder arthroscopies	1.76 (0.20) **	0.25 (0.05) **	1.51 (0.16) **	1.22 (0.22) **
D: Freestanding center×Post×Shoulder arthroscopies	1.25 (0.12) **	0.06 (0.03) **	1.19 (0.09) **	1.00 (0.23) **
Θ = (B-A) - (D - C)	-0.33 (0.15) *	-0.03 (0.03)	-0.31 (0.13) *	0.11 (0.07)
R-squared (overall)	0.68	0.42	0.69	0.76
Interclass correlation coefficient	0.55	0.44	0.56	0.71
N	12,012	12,012	12,012	6,468
Years	1998-2010	1998-2010	1998-2010	2004-2010

**p<0.01, *p<0.05

Note: "Pre" and "Post" refer to the periods before and after publication of the Moseley trial.