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ABSTRACT

Medical care often includes provider collaboration. However, the behavior of and desire for clinical teams is partly determined by regulations. We explore such issues in the context of anesthesia care whereby physician-trained anesthesiologists and certified registered nurse anesthetists (CRNAs) perform overlapping services but commonly engage in joint production. Leveraging a Medicare-driven removal of physician supervision requirements for CRNAs, we find only modest reductions in billing for collaborative operating room work. There is a 20-25% increase in claims for CRNA hospital services delivered outside of the operating room—suggesting improved productive capacity—but this is relative to a low baseline.

JEL: I13, I18, J44

Keywords: anesthesia, physicians, certified registered nurse anesthetists, provider regulation, Medicare, quality of care

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1. Introduction

United States (US) medical care is known for inefficiencies (Einav, Finkelstein, and Mahoney 2018a, 2018b; Glied and Sacarny 2018; Chandra and Staiger 2020) and costly care fragmentation (Cebul et al. 2008; Agha, Frandsen, and Rebitzer 2019). In response, many have advocated for payment reforms and professional norms that encourage better coordination and cooperation across providers—e.g., "team-based" models of care delivery (Wagner 2000; IOM 2001, 2010; Grumbach and Bodenheimer 2004; Mitchell et al. 2012; AMA 2014, 2018; Reiss-Brennan et al. 2016)—as potential avenues toward improvement.[1] Such proposals are unsurprising since a given patient's medical care often includes several suppliers, and most bundles of services (e.g., a hospital stay) can only be produced by utilizing multiple providers of varying training backgrounds and skill levels within the same firm.

Efforts to encourage provider cooperation are complicated by contrasting views as to when different types of clinical labor are complements versus substitutes within medical care production functions. Some advocate for using a diverse set of medical workers but simultaneously establishing a clear hierarchy that favors certain provider types, such as physicians, due to perceived training and skill superiority (e.g., AMA 2014, 2018). Others argue that jointly produced services should not prioritize or defer to a particular clinician as the influential decision-maker and instead flexibly adapt to each care delivery context and accompanying constraints (e.g., ANA 2016). The former attitude implicitly treats different provider types as complements while the latter perspective promotes greater opportunities for labor substitution. Reconciling these opposing views is difficult, and related political debates tend to be both frequent and heated.

[1] The increasing use of teams within many industries and firms spanning the full US economy has also been a long-running trend (Lazear and Shaw 2007).

Notwithstanding advocacy efforts by those with vested interests (e.g., an assortment of provider lobby groups), the underlying preferences for collaboration versus competition between different provider types is unclear. US healthcare is highly regulated (Kleiner 2016), and policy restrictions can shape the substitution possibilities between production factors, which also confounds our understanding as to when clinical cooperation is desired by providers and firms. Restrictions on provider substitution could be justified, for example, if doing so corrects underlying market failures tied to care quality (Leland 1979; Shapiro 1986). But the presence of these provider regulations ultimately leaves the scope for and efficiency of jointly produced medical care indeterminate.[2] Empirical evidence is therefore needed to clarify the role of regulation, and crucially, to observe if the production of medical services actually changes when regulatory policies alter incentives to substitute provider labor.

The most common contemporary studies in this area focus on "scope-of-practice" laws for various clinical specializations (e.g., Spetz et al. 2013; Wing and Marier 2014; Buchmueller, Miller, and Vujicic 2016; Kleiner et al. 2016; Langelier et al. 2016; Markowitz et al. 2017; Traczynski and Udalova 2018; Alexander and Schnell 2019), which have also attracted increased policy attention in recent years (ANA 2016; Frogner et al. 2020; Kacik 2020a, 2020b). These state-level laws dictate the clinical remit for a given provider type, and liberalization of these statutes involves granting greater or full clinical independence to a particular provider.[3] We are able to extend this literature by exploring these issues within a clinical context that is highly dependent on team-based models of care and also subject to a unique policy environment.

[2] Related occupational boundaries around tasks and authority for different clinicians have been recurring sources of inter-professional and intra-firm conflict, with the potential to affect internal labor markets and healthcare delivery––e.g., see Abbott (1988), Osterman (2011), and Kleiner (2016).

[3] Of note, scope-of-practice regulations are set by state legislatures and enforced by state-specific clinical licensing boards, with no direct role for the federal government.

Our setting is anesthesia care delivery. Anesthesia services are frequent and necessary components for a variety of medical bundles, such as surgical treatments, diagnostic care, labor and delivery care, and forms of acute and chronic pain management. Four percent ($2.9 billion) of all Medicare spending was directly tied to anesthesia procedures in 2014 alone (Quraishi, Jordan, and Hoyem 2017). Importantly, two distinct provider types, physician-trained (i.e., MD) anesthesiologists[4] and nursing-trained certified registered nurse anesthetists (CRNAs), possess the relevant skills to administer such services but do not always do so independently. More specifically, CRNAs often deliver anesthesia care under the direct supervision of an anesthesiologist. This circumstance is both interesting and ideal for investigating the role of regulation in provider collaboration, given that each provider type is highly specialized, and prior to 2001, Medicare payment rules mandated physician supervision of CRNAs. This policy environment also departs from closely related scope of practice studies. Specifically, contentious *payment rules* (described in Section 2.3), rather than state-determined scope-of-practice rules, imposed by the large, federal insurer created an indirect constraint on anesthesia provider substitution. Via a lengthy political process, Medicare administrators eventually agreed to nullify the requirement on a state-by-state basis, which generates the geographic variation for our subsequent identification strategy (described in Section 3.2).

A priori, it is not obvious to what extent anesthesiologist and CRNA joint production is the result of these indirect regulatory restrictions from Medicare versus optimal care delivery. It is known that productivity and decision-making can be improved by relying on teams of workers in a variety of settings (Alchian and Demsetz 1972; Kandel and Lazear 1992; Boning, Ichniowski,

[4] For ease of exposition, we are considering doctor of medicine (MD) and doctor of osteopathy (DO) as synonymous since both require a four-year medical training program and take part in the postgraduate residency training match within the US. We note that MDs far outnumber DOs in the supply of US physicians, and consequently use the "MD" designation to represent either type of physician.

and Shaw 2007; Lazear and Shaw 2007; Landeo and Spier 2015; Fahn and Hakenes 2019); yet, much of the gains from such collaboration are thought to derive from complementarities across workers with disparate skills and/or information (Lazear 1999; Hamilton, Nickerson, and Owan 2003; Lazear and Shaw 2007). Our descriptive and motivating data in Figure 1 reveal considerable overlap in the tasks performed by these two types of healthcare providers.

The three panels (Figure 1) plot the correspondence in terms of rank-ordered billed procedure frequency for anesthesiologist (MD) services delivered in isolation versus in collaboration with a CRNA, CRNA services delivered in isolation versus in collaboration with an anesthesiologist, and finally independently administered services across each provider type. For all three comparisons, there is a tight correspondence between the specific procedures most commonly performed solo and through jointly produced anesthesia care, as well as care delivered by each provider type in isolation. The data in Figure 1 therefore suggest that CRNAs perform, on average, many similar tasks to anesthesiologists; moreover, there is not clear evidence that what anesthesiologists do independently differs substantially from the types of services they oversee for CRNAs. Taken at face value, the two sources of labor appear highly substitutable, which at least implies that mandating anesthesiologist involvement in CRNA-administered care might impose a hierarchical medical "team" that otherwise would not form.

To shed light on the implications of mandating collaboration rather than encouraging provider competition, we leverage states' petitions to the Medicare program that ultimately removed CRNA supervision requirements tied to Medicare reimbursements for hospital-based care. We implement differences-in-differences analyses using Medicare claims data spanning 2002 through 2013. During this twelve-year period, 16 states terminated their physician supervision mandate for CRNAs providing care to Medicare beneficiaries following the 2001 federal rule

change by the public payer that incentivized states to do so. We exploit granular and detailed information on anesthesia provider billing to quantify any changes to the aggregate use of anesthesiologists and CRNAs, and more specifically, the reliance on anesthesiologist supervision in response to the deregulation events.

We find that CRNAs are not involved in more surgical anesthesia care in the short-run following the policy change, but anesthesiologists are involved in fewer operating room cases—with the reduction entirely concentrated among their supervision duties. Six months after states grant CRNA independence from physician oversight, anesthesiologist supervision billing sharply declines by approximately 11% and largely stabilizes at this reduced level. The implied dissolution of the anesthesiologist supervisor role is found across the spectrum of case complexity but is strongest within hospital inpatient care. Importantly, the observed modest reduction in anesthesiologists' supervision billing suggests a strong and persistent taste for collaborative anesthesia care delivery, even in the absence of a regulatory mandate. We also document increased use of CRNAs for Medicare hospital services outside of the operating room when CRNAs are able to provide these services independently. The effect is comparatively large (20–25%) but relative to a small base. We do not detect a simultaneous substitution away from anesthesiologists for these same, non-operating room medical services, which is consistent with increased overall productive capacity. Quality of anesthesia care also appears unchanged following the policy events. CRNAs unsurprisingly capture higher aggregate Medicare revenues when they no longer have to split payments with anesthesiologists and are able to perform more services overall. However, anesthesiologists maintain their level of Medicare revenues through a combination of task matching and labor supply adjustments that allow them to fully offset the revenue losses from fewer supervision billings.

Overall, we demonstrate that provider preferences and market forces seem to preserve a high affinity for the hierarchical anesthesia team structure among potential labor substitutes—meaning the regulation seems to only weakly bind. This tempers any strong assumption that anesthesiologist supervision is purely the result of regulatory capture and anticompetitive behavior. The deregulation event is also Pareto improving insofar as each labor type appears as well or better off in terms of net Medicare revenues. Policy advocates and opponents typically frame anesthesiologists and CRNAs as locked within a provider "turf war" (e.g., Cromwell 1999; Tawoda 2012; Massarweh and Awad 2017). Our evidence does not align with an industry-wide rivalry, and instead, suggests that other considerations shape the proclivity for anesthesia care joint production that relies on physician supervision.

These findings make several important contributions to the existing literature. First, the preference for joint production in medical settings and the implications for efficiency when mandating specific provider combinations and roles are poorly understood.[5] Second, our results build upon recent work tied to scope of practice laws (noted above) in a healthcare delivery setting where a potential physician competitor gains clinical independence across all relevant service lines instantaneously.[6] And finally, our study relates to a growing body of evidence on how Medicare reimbursements affect the use of different production factors in hospitals. Prior work has considered the impact of Medicare and its reimbursement policies on hospital decision-making,

[5] An important exception within recent work is Agha et al. (2018) where the authors study primary care physician-to-specialist referral patterns and find that primary care physicians with more concentrated referral streams correspond to more efficient care delivery overall. Though, the authors are also examining a more expansive team structure (i.e., different physicians often working at different locations) than our study which is focused on multiple providers caring for the same patient at the same time in the same health care facility.

[6] The existing scope of practice literature in this area has focused on how deregulation affects costs, supply, and quality of care. However, changes in occupational licensing for nurse practitioners or dental hygienists are often limited to specific care delivery domains (e.g., prescribing medications, making diagnoses, performing exams, executing specific procedures, etc.) and staggered in their roll out. The inability to substitute across all product lines may limit changes in joint production overall.

including those pertaining to capital and labor investments as well as how the hospital influences its clinicians' practice patterns (e.g., Finkelstein 2007; Acemoglu and Finkelstein 2008; Sacarny 2018). We complement these findings by documenting how provider labor choices, allocations, and performance evolve when Medicare no longer imposes a provider supervision requirement for hospitals. In other words, we are able to examine the influence of public insurer payment rules, rather than just payment levels, on hospitals' production of medical care.

2. Background

2.1 Anesthesia provider supply

Anesthesiology is a sub-specialization of medicine that requires a three-year residency program following a four-year medical degree and one year of internship training. CRNAs hold baccalaureate nursing degrees, have worked at least one year as an acute care nurse, and have completed two years of specialized nurse anesthetist graduate training. CRNAs are known to be the more common anesthesia provider type in rural areas and some argue that they offer equivalent care quality and are more cost-effective than anesthesiologists (Cromwell 1999; Cromwell and Snyder 2000; Needleman and Minnick 2009; Negrusa et al. 2016; Cintina et al. 2018; Coomer et al. 2019; Mills et al. 2020).[7]

From the mid-1970s through the end of the 20th century, growth of anesthesiologists far outpaced that of CRNAs (Cromwell 1999)—though CRNAs' presence and care delivery roles have since expanded.[8] Using our Medicare claims data (described in Section 3.1), we observe a

[7] It is important to note that there are no cost-savings to Medicare (since 1998) when using alternative anesthesia provider combinations, including CRNAs in isolation. All that is changed is the distribution (i.e., sharing) of payments between the anesthesia providers.

[8] Cromwell (1999) provides a very detailed history of anesthesia provider issues and incentives.

fairly steady increase in CRNAs' share of all anesthesia billings to the public insurer from 2002 through 2013 (Figure 2). By the end of our study period, over 30% of all Medicare reimbursable anesthesia service claims involved CRNA delivered care. Similarly, Figure 2 shows steeper growth in the number of unique CRNAs observed in the claims data compared to anesthesiologists, culminating in effectively an even split across the two provider types during the final years of our data.

2.2 Medicare anesthesia billing policies

Anesthesia providers' procedures and subsequent claims submissions take place within two distinct domains: time-based and service-based billing. The former is predominantly linked to operating room settings (e.g., surgical cases) while the latter most often takes place outside of an operating room (e.g., epidural injections for labor and delivery patients). The total amount of Medicare reimbursement for time-based billing is composed of two factors: the length of the case in minutes and the case complexity (defined in "base units" and specific to the accompanying anesthesia procedure codes relevant to a given case). The traditional (fee-for-service) Medicare program has also created and applied a detailed billing structure for anesthesia care in order to clearly differentiate personal versus collaborative delivery and the associated payments.

Since 1989, CRNAs have been able to directly bill for Medicare (Part B)-delivered services (Cromwell 1999); however, there is an imposed sharing rule between anesthesia providers in the context of jointly produced services. CRNAs receive 100% of the Medicare allowed payments when the care is delivered without the involvement of an anesthesiologist; however, the payment falls to 50% when there is medical direction or supervision by an anesthesiologist, who also receives the remaining Medicare provider compensation. Anesthesiologists may "direct" up to four

cases or "supervise" five or more cases simultaneously (Cromwell 1999; Byrd, Merrick, and Stead 2011; Quraishi et al. 2017; Cintina et al. 2018).[9] These overseeing roles have specific definitions but are not easy to verify beyond ascertaining that the corresponding paperwork is complete on a submitted claim. Moreover, the possibility of multiple cases concurrently happening further obscures the precise contribution of the anesthesiologist for a given instance of joint production.[10]

In what follows, and for ease of exposition, we simply refer to jointly produced efforts as "cases with supervision," irrespective of the anesthesiologist's technical classification in terms of directing versus supervising a given case. We also note that, across all years and states in our data (Section 3.1), there is virtually an even divide between solo-delivery and supervision effort for anesthesiologists' time-based activity.

2.3 Medicare rule for states' regulatory opt-out

Prior to 2001, hospitals would forfeit their Medicare Part A facility payments for any care where anesthesia services were delivered to a Medicare beneficiary by a CRNA not under the supervision of a physician.[11] This Medicare payment rule gave hospitals a strong financial incentive to employ both provider types and/or contract with anesthesia groups that could guarantee the presence of a supervising physician. It also created ample opportunities for anesthesiologists to impose the Medicare revenue sharing rule described above for their private financial benefit. The rule was contentious and strongly opposed by CRNAs and other policy advocacy groups.

[9] Medical direction requires more direct care involvement and accompanying documentation for the anesthesiologist to be reimbursed as directing the relevant case(s). Also, the count of concurrent cases includes non-Medicare patients.

[10] For these reasons, we also do not differentiate between directed and supervised cases in our empirics.

[11] Of note, the supervising physician did not have to be an anesthesiologist, but only anesthesiologists could engage in revenue sharing (i.e., simultaneously bill for their supervising activities) tied to CRNA services.

Federal policy momentum toward CRNA practice independence began in earnest during the early days of the Clinton administration and related health care reform activities. Years of political back-and-forth and ultimately Congressional inaction led to a proposed executive branch rule in December of 1997 through the Health Care Financial Administration (HCFA)—the precursor to the Centers for Medicare & Medicaid Services (CMS)—which planned to remove the physician supervision requirement for CRNAs providing care to Medicare patients. Further political and administrative delays ensued; however, HCFA's final rule was published in the *Federal Register* January 18th, 2001 and was intended to take effect sixty days after. On January 20th, 2001 the newly elected Bush administration implemented a moratorium on all regulatory changes put in motion by the outgoing Clinton administration and not yet enacted—which included HCFA's CRNA supervision rule. The supervision requirement was further delayed by six months, and then the Bush administration, along with the newly named CMS, made a substantive pivot away from a blanket federal ruling to a state-specific political decision. State governors would have to consult with their medical and nursing boards, determine that CRNA independence was in their states' best interests, and confirm that implementation of the new Medicare supervision rule would be consistent with state law governing anesthesia provider scope-of-practice. In other words, a state wishing to do so could "opt-out" of Medicare's CRNA physician supervision requirement without its hospitals risking their Part A facility payments. The final rule from CMS occurred on November 13th, 2001 and since then, 17 US states have exercised their regulatory "opt-out" option (Downey 2010).[12] Table 1 lists the specific states and their corresponding date of policy enactment. Hospitals and CRNAs working within these states are no longer bound by any

[12] These rule changes are documented in 42 CFR §482.52(a)(5) and §485.639(c)(2).

supervision requirement according to Medicare rules, and hence CRNAs can retain the full payments from the care they provide to Medicare beneficiaries in all circumstances.

2.3.1 Potential implications from states' opt-out decisions

The downstream opt-out effects on anesthesia provider collaboration are not easy to predict. Teams are thought to perform better when receiving team-based incentives (Che and Yoo 2001; Lazear and Shaw 2007); however, fee-for-service (i.e., piece-rate) payment structures seem more likely to promote competition over provider cooperation, especially since CRNAs are no longer forced to share Medicare revenues with anesthesiologists. Relatedly, CRNA wages are implicitly increasing following the deregulation event, and in the presence of an upward sloping supply curve, the opt-out decision could incentivize greater effort and output among CRNAs.

That said, even without a mandate or concerns over patient safety, the anesthesia supervisory role might still exist if it enhances overall performance and productivity by assigning the responsibility of optimally managing anesthesia labor inputs to the physician. Some anesthesia care needs are known in advance and therefore can be delegated *ex ante* (e.g., provider-case matching and scheduling at the start of a given day). Other anesthesia care is unpredictable, and instantaneous decisions over labor allocations are necessary as acute and emergent cases arrive or surgical schedules become disrupted. More centralized decision-making is likely to better promote efficiency and maximize revenues than *ad hoc* anesthesia provider task-matching and team assignments over the course of a given workday. Consequently, devoting some portion of clinical duties to anesthesia supervision, rather than direct care, could accommodate more administrative management functions by the anesthesiologist and perhaps drive better collective performance.

Hospitals could likewise benefit from improved anesthesia quality assurance and/or productivity gains since hospitals have imperfect control over each of these outcomes. More generally, other factors of production that are dependent on anesthesia services (e.g., hospitals or surgeons) may support the anesthesiologist as the anesthesia quality control officer and/or human resource manager, irrespective of prevailing regulations. Others have relatedly remarked that the supervision functions perhaps best justify the additional years of training borne by anesthesiologists, especially if doing so facilitates greater use of CRNA labor overall (Cromwell 1999). At the same time, the precise contribution of an anesthesiologist's supervisory role may still be poorly defined and difficult to verify. Fuzzy provider responsibilities create opportunities for moral hazard problems, such as shirking (Holmstrom 1982), and weak and inconsistent efforts toward teamwork can be suboptimal from the perspective of the firm (Ishihara 2017). For these reasons, the underlying value of—and hence propensity—for relying on anesthesiologist supervision absent regulation is a priori unclear.

2.3.2 Existing studies

Despite the policy significance and economic implications of opt-out decisions, only a small literature to date has emerged, and as others remark, the empirical investigations and subsequent debates have exclusively centered around two outcomes: anesthesia care quality and surgical care access (e.g., see Vetter, Mascha, and Kilgore 2016). Based on descriptive analyses, CRNA-only staffing models are not more common in opt-out states in the cross-section (Coomer et al. 2019). Dulisse and Cromwell (2010) additionally do not find differences in anesthesia-related mortality or complication rates for Medicare beneficiaries when comparing opt-out and all other US states over the 1998–2005 period, and Sun, Miller, and Halzack (2016) do not detect faster growth in

anesthesia services among states taking advantage of the Medicare opt-out rule. Other (non-opt-out) states actually appear to outpace them in this regard.

Among studies relying on causal research designs (i.e., differences-in-differences), Sun, Dexter, and Miller (2016) find no increase in patients' receipt of urgent surgical interventions using the Healthcare Cost and Utilization Project (HCUP) inpatient database. Schneider et al. (2017) likewise find no improvement in surgical care access or associated costs of care using inpatient and outpatient databases from HCUP. Finally, Sun et al. (2017) observe no change in travel distances for several prominent surgical procedures for Medicare beneficiaries. These are relevant post-policy margins to investigate, but even among the more causally oriented empirical studies, changes to the utilization of anesthesiologist supervision as well as CRNA labor use outside of operating room settings are currently unexplored.

3. Data and Empirical Strategy

3.1 Data

Our key data come from Limited Data Set (LDS) Medicare claims data from 2002 through 2013. We utilize a 5% carrier claims file, which follows all Part B claims tied to physicians, other providers, and suppliers incurred by a randomly selected—and hence representative—subset of Medicare enrolled beneficiaries in a particular year. We observe the quarter of service, type of service, place of service (both in terms of geography and health care facility type), and total allowed charges for the service—which includes payments from the public insurer as well as the beneficiary. Crucially, the data allow us to differentiate between billing for services directly provided by anesthesiologists versus indirectly via their supervisory roles. We do so using the Healthcare Common Procedure Coding System (HCPCS) modifier codes that signal the presence

or absence of an anesthesia provider team and hence the need to activate the pre-established revenue sharing rule. Using these modifier codes, we can identify all services provided by an anesthesiologist (whether solo or supervised) and all services provided by CRNAs.[13]

The HCPCS codes additionally differentiate between anesthesia time-based (i.e., claims from an operating room setting) and anesthesia service-based care (i.e., claims from non-operating room settings). Time is billed for pre-operative, operative, and post-operative anesthesia care and is measured in 15-minute increments. The latter feature allows us to not only quantify the volume of surgical/procedure cases (which involve anesthesia care) but also the duration of cases based on the number of time units the anesthesia provider submits for reimbursement tied to a given encounter. More complex procedures have higher base units per time increment, thereby generating higher payments.[14] Service-based anesthesia care explicitly does not have a time relevant dimension for billing purposes. Among the most frequently performed 20 procedures—accounting for over 40% of all service-based anesthesia claims—the most common procedure types in our administrative data are arterial and venous monitoring, emergency intubations, and anesthetic injections. Because time- and service-based care fundamentally differ in their origin, intent, and reporting within the claims data, we analyze them separately to capture any policy response heterogeneity across these separate domains of anesthesia care. Among anesthesiologists, 47% of time-based claims are tied to medical direction or supervision, compared to only 1% of their service-based procedures. Additional data details for reimbursable anesthesia services and specifically the coding for anesthesiologist supervision are provided in Appendix B.

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[13] Practices may have a tendency to overreport CRNA modifier codes for independent delivery (Dulisse and Cromwell 2010; Bryd, Merrick, and Stead 2011 Vetter et al. 2016). Thus, unlike anesthesiologist claims, CRNA claims cannot be reliably bifurcated into solo versus supervised claims. In our analyses, we focus on total CRNA case involvement, which is well-documented. We provide additional details on the claims modifiers in Appendix B.

[14] Time-based services are calculated with the following formula: (number of base units + number of 15-minute time Increments) multiplied by the conversion factor. Additional details are provided In Appendix B.1.

Our analytic sample is restricted to Level 1 HCPCS codes for anesthesia services provided in hospitals by anesthesiologists or CRNAs. When relevant, we include all anesthesia claims and stratify time-based and service-based claims by the type of health care delivery setting: ambulatory surgery centers (ASCs), hospital inpatient units, hospital outpatient departments, and physician offices. Doing so allows us to assess any underlying heterogeneity, which in turn influences the overall (i.e., not setting specific) results we generate. Because we lack sufficient pre-policy data for states that opted out of CRNA physician supervision in 2001 and 2002, we exclude those states from our analytic samples (see Table 1). We additionally omit Alaska due to asymmetric coding issues that preclude consistent identification of CRNAs in the early years of data. Also, Colorado is excluded since it only removed the supervision requirement for a select and small subset of hospitals in rural areas.

Table 2 provides summary statistics over our full study period (2002-2013) for our key outcomes as well as the underlying patient populations within the Medicare data across opt-out and non-opt-out (i.e., treatment versus control) states. Opt-out states, on average, tend to have fewer time-based anesthesia claims among anesthesiologists as well as CRNAs. Additionally, in opt-out states, CRNAs are involved in roughly 30% of all time-based procedures whereas they account for approximately 40% in non-opt-out states. It is also clear from Table 2 that anesthesia providers devote the bulk of their effort toward time-based procedures (i.e., operating room activities). This is especially true for CRNAs since service-based claims make up only a small fraction of their reimbursable care delivery within the Medicare market. The aggregate patient demographic characteristics do not markedly differ across the two regulatory groupings; however, opt-out states tend to have less racially and ethnically diverse Medicare patient populations, which is not surprising given the subset of states implementing the opt-out policies (Table 1).

3.2 Differences-in-differences analysis

We aggregate our analytic data to the state and quarter-year levels to implement generalized differences-in-differences (DD) analyses that compare deregulating states (i.e., those granting CRNA independence following the 2001 Medicare payment rule change) over our study time period to those states which forgo the opt-out opportunity from Medicare.[15] Our first DD specification is given by:

$$Y_{st} = \delta\left[\mathbf{1}\left(OptOut\right)_{st}\right] + \eta_s + \lambda_t + \tau_s + \Gamma X_{st} + \varepsilon_{st} \tag{1}$$

OptOut is an indicator variable equal to one for treated states in the quarter-year when the state legislature grants CRNA independence and for all subsequent quarter-year time periods. It is zero otherwise. We include state (η) and quarter-year (λ) fixed effects, and the state-specific linear time trends (τ) help ensure that our estimated effects do not reflect differences in underlying time trends between the various treated and control units over our relatively long study period. We also use summary beneficiary demographic characteristics (*X*) for a given state in a given quarter-year. The specific demographic covariates include average Charlson Comorbidity Index (CCI), the average share male, the average share black, the average share Hispanic, and the average share white.[16]

[15] Our data does not allow us to follow providers over time. However, using the differences-in-differences setup in Equation (1), we found that the number of anesthesiologists or CRNAs do not change in response to the policy change.

[16] Note, we do not expect these demographic characteristics to change in response to anesthesia provider regulations; however, they may fluctuate within a state and over time due to new randomly drawn 5% samples in each year of data. We have also found that their presence or absence is largely immaterial for our key DD findings, other than to modestly improve precision at times. Results available by request.

We begin by estimating Equation (1) for several outcome measures of interest that reflect the statewide use of these distinct anesthesia provider types within operating room settings, and then importantly, the prevalence of hierarchical team-based anesthesia structures within these same settings. To do so, we first consider how the policy separately affects time-based claims volumes for all anesthesiologists and then separately for all CRNAs as a way to measure each provider type's total involvement in operating room-based anesthesia care. We then further stratify anesthesiologists' time-based activities by solo delivery versus supervision duties. In order to exact their half of the Medicare Part B payments (i.e., impose the public payer sharing rule), anesthesiologists must report the corresponding direction/supervision modifiers on the relevant claim, so this creates a useful measure for quantifying changes in the amount of team-based anesthesia care billed for in the Medicare market after states implement their opt-out decisions.[17] If supervision activity disappears, then we can interpret such a result as revealing that the regulations were both binding and suppressing anesthesia provider competition prior to the deregulation event. Alternatively, if anesthesiologist supervision persists, then other factors must influence the presence and perceived value of a hierarchical team. We also add further nuance to our estimates and interpretations by examining if any changes in anesthesiologist supervision effort systematically differ by case length, case complexity, or delivery setting. Doing so better elucidates whether any joint production changes localize to a particular medical context (e.g., low complexity cases).

[17] We do note that others have highlighted ambiguities around modifier usages on CRNA- (as opposed to physician) specific claims due to administrative idiosyncrasies, which can complicate any interpretation around joint production presence or absence through examining CRNA claims (Byrd, Merrick, and Stead 2011; Vetter et al. 2016). We believe this underscores the value of relying on the anesthesiologist-specific claims and their reporting of supervision activities. See Appendix B for additional details.

We move to service-based anesthesia procedures for our next set of DD analyses in order to investigate another margin that is currently unexplored in the small opt-out literature to date. As previously noted, CRNAs rarely perform these non-operating room anesthesia services; however, the potential for regulatory interference—and hence depressed CRNA service-based productivity––may be particularly influential. Specifically, their limited effort for service-based procedures may have more to do with the inefficiencies engendered by the supervision requirement than CRNA competencies. For instance, service-based procedures (e.g., delivering an anesthetic injection to the spinal column or placing an arterial monitoring device) are likely to require physician supervision for the full duration of the procedure, which contrasts to time-based care where in-room anesthesiologist supervision is only required at certain points during a given case. In other words, anesthesiologists can supervise multiple time-based cases simultaneously, but such multitasking is less feasible with service-based care. Making anesthesiologists and CRNAs (near) perfect complements for service-based procedure delivery under a supervision mandate could restrain the use of CRNAs in this capacity and consequently lower anesthesia service-based procedure productivity (i.e., aggregate output) overall.[18] Paralleling the approach to time-based claims, we also stratify the service-based procedures by specific type as well as health care delivery location to uncover any underlying heterogeneity.

To highlight any dynamics in both sets of anesthesia care policy responses as well as to systematically examine the common trends assumption belonging to the DD design, we employ an event study adaptation to Equation (1) to speak to the validity of the methodology in this context

[18] Opportunities for other (non-anesthesiologist) physicians to serve in the supervising role may also be limited since the physician most relevant to a given patient (e.g., the assigned hospitalist) may be delivering care elsewhere within or outside the hospital and the needed anesthesia procedure may be time-sensitive. Likewise, in the case of anesthetic use in the labor and delivery setting, the other key provider involved in the patient's care could be a nurse midwife, which would not satisfy the physician supervision requirement for the CRNA.

and better pinpoint the timing of provider behavior changes post-policy. The event study specification takes the form:

$$Y_{st} = \sum_{\substack{j=-3^{(+)} \\ j\neq -0.5}}^{3^{(+)}} \delta_j \left[\mathbf{1}\left(y_h - T_s = j\right)\right] + \eta_s + \lambda_t + \tau_s + \Gamma X_{st} + \varepsilon_{st} \tag{2}$$

Paralleling Equation (1), Equation (2) also includes state (η) and quarter-year (λ) fixed effects, state-specific time trends (τ), and a set of aggregate and time-varying patient demographic measures (X). However, Equation (2) additionally incorporates a vector of half-year event-time indicator variables. The event-time variables are defined by subtracting each possible half-year time point (y_h) from the specific time point that an opt-out state implements its rule change (which is contained within the T_s variable). The event-time variables are set to zero for all control states over our study period. We use the half-year immediately preceding opt-out implementation as the reference point prior to the policy treatment. We also include two summary time dummies for the period three or more years before (after) the state's opt-out decision to better account for our relatively long time series over a twelve-year period. The resulting series of event time differences-in-differences parameters (δ_j) subsequently capture differentials in the relevant outcome before and after a given state's exact timing of policy change.[19] A lack of pre-policy differential trending signaled by the coefficients $\delta_{-3^{(+)}}$ through δ_{-1} would indicate that the control

[19] We use half-year event study time dummies to increase precision. Similar results are achieved if we use quarter-year event study time dummies. Time periods more than 3 years before or after treatment are represented by two summary time dummies, as noted above.

(i.e., non-opt-out) states are providing reasonable counterfactuals for the treated states absent the treatment—and hence support the DD research design within our analytic context.

3.3 Interpreting provider behavior from Medicare billing activity

Given our reliance on administrative claims data, it is possible that that our estimates of Equation (1) and Equation (2) will capture only billing changes, as opposed to provider behavior changes (e.g., actual dissolutions of anesthesia care teams). To understand how billing activity may translate to physician behavior and the resulting implications for interpreting our estimates, we consider three, not mutually exclusive, scenarios.

First, it is possible that billing accurately reflects behavior (as mandated by law)—meaning that any observed changes in billing will reflect actual changes in anesthesia provider behavior. However, it is also possible that prior to deregulation, physicians may have been effectively overbilling for supervision efforts in order to comply with the letter, rather than the spirit, of the Medicare payment rule.[20] If true, an observed reduction in billing for anesthesiologist supervision would imply better alignment between reimbursements and pre-existing care delivery realities, as opposed to differences in medical care production. Alternatively, and in the opposite direction, some anesthesiologists may have been involved in CRNA-delivered cases but decided to forgo payment sharing in order to avoid (costly) administrative documentation.[21] Doing so may have

[20] Recall, compliance is largely determined by submitted billing documentation, which leaves the level of anesthesiologist's effort in a given case ambiguous.

[21] Doing so would not necessarily sacrifice the hospital facility payment, so long as another physician involved in the care bundle (e.g., a surgeon) was willing to be responsible for the CRNA supervision duty and accompanying liability risks. For more details about the requirements for documenting the 7 required steps of medical direction, see Byrd, Merrick, and Stead (2011). Rigor in documentation of supervision differ by region depending on the Medicare Administrative Contractor. Of note, previous research documented that between 1999 and 2005, the share of claims where CRNAs reported working independently grew more in states that did not opt out of supervision requirements than in those that did (Dulisse and Cromwell 2010).

been particularly tempting if the anesthesiologist and CRNA were employed by the same firm (e.g., an anesthesiology group practice), which would allow for intra-firm revenue sharing arrangements that are independent from whether Medicare splits the reimbursement across the two providers. Consequently, it is possible that anesthesiologists could have even weaker incentives to report supervision activities for Medicare billing following the removal of the formal CRNA supervision requirement.

Importantly, in either of the two preceding scenarios, our estimates from Equation (1) and Equation (2) will overstate changes in anesthesiologist supervision behavior—and hence joint anesthesia care production—after the CRNA opt-out decision. The upshot is that any supervision observed in the data *post-deregulation* will strongly imply a common preference between anesthesiologists and CRNAs for joint production. The estimated policy effect sizes would be an upper bound for actual provider behavior change, and the taste for teams would be stronger than the analysis of billing changes would otherwise suggest.

We also note that regardless of hypothetical billing idiosyncrasies, CMS enforces the physician supervision of CRNAs, unless states have explicitly opted out. This is made evident by CMS' temporary suspension of CRNA supervision in response to the COVID-19 emergency. This specific exemption was the only federal scope-of-practice change that applied to hospitals and ASCs, and it implies that the requirement for CRNA supervision was nontrivial.[22]

[22] In response to concerns about provider supply during the COVID-19 emergency, scope-of-practice was increased for nurse practitioners at skilled nursing facilities and other non-physician providers at long-term care facilities. More information can be found here: https://www.cms.gov/files/document/summary-covid-19-emergency-declaration-waivers.pdf

4. Effects on Time-Based Provider Use and Anesthesiologist Supervision

Our DD analyses and results reporting begin with state-level changes in overall time-based case volumes belonging to anesthesiologists and CRNAs working within the state. The volume of time-based (i.e., operating room affiliated) anesthesiologist activity falls by 37 claims per quarter-year, on average, shown in column 1 of Table 3; however, this represents a small decline of only 3% relative to the average level among treated states immediately prior to their opt-out decision. CRNAs, by contrast, demonstrate no detectable change in their aggregate operating room case involvement following the deregulation event. The DD estimate in column 2 of Table 3 is not economically meaningful in terms of magnitude, lacks precision, and is negatively signed.

The corresponding event study results are displayed in Figure 3. These results confirm the inferences from Table 3. Treatment and control states behave similarly leading up to the opt-out policy change. Following the state policy intervention, there is a clear decline in anesthesiologists' time-based volumes, which is fairly stable from the year after the opt-out and onward. Panel B of Figure 3 shows the event study estimates slightly oscillating around zero for CRNA time-based volumes both before and after the removal of physician supervision requirements. The effect three-plus years post-policy is the only positive and statistically significant event study coefficient, which could imply a long-run adjustment to the anesthesia provider labor market (i.e., a slow shift toward more CRNA use for operating room surgeries and other procedures), but this is only a speculative interpretation without further supporting evidence. The lack of increased operating room case involvement across both provider types aligns with findings from the few existing studies in this area that focused on overall surgical care access (i.e., finding no obvious positive supply response—see Section 2.3.2).

Importantly, Table 4 decomposes anesthesiologists' time-based claims activity into its two constituent parts: solo delivered services and supervising duties (columns 1 and 2, respectively). There is no CRNA deregulation effect on anesthesiologists' volume of solo-administered, time-based anesthesia cases. This result, coupled with the findings in Table 3 and Figure 3, suggests that CRNAs are not increasing their competition for anesthesiologists' operating room work (i.e., behaving as a physician substitute) once the physician supervision mandate is removed. Instead, the policy effects localize to the anesthesiologist supervision activity. When states opt-out, anesthesiologists' supervision volumes shrink by 34 cases per quarter-year, on average, which translates to an approximately 11% decline relative to their pre-opt-out levels. The event study results in Figure 4 underscore the sharpness of this provider behavior change. For the two and a half years prior to making the opt-out change, there is no differential trending across the treatment and control states: the estimates are very close to zero and statistically insignificant. Within the first deregulation year, however, the supervision volumes have markedly fallen and remain depressed over the next two years. A rebound in supervision case quantities is not observed until three years and beyond the policy change. While the DD estimates from Table 4 and event study estimates in Figure 4 reveal clear policy responses, it is important to note that the reductions in anesthesiologist supervision activity are modest in magnitude, which suggests a meaningful underlying preference for a more team-based approached to anesthesia care delivery. To add nuance to the observed policy effects, we exploit our detailed information on case characteristics (i.e., total anesthesia clinical time per case and base units per case) as well as the healthcare facility setting attached to a given time-based anesthesia encounter. For the former, we classify all time-based encounters as either under 60 minutes or 60 or more minutes in duration. As an alternative measure of complexity, we also show results based on whether a case involves above or below the

median base unit value.[23] The event studies in Figure 5 demonstrate that the supervision reductions are present and sharp among shorter as well as longer cases, and the effect sizes are similar in magnitudes in Panel A and Panel B of Figure 5. Accordingly, there is no systematic difference when stratifying the cases by their associated based units. We see consistent, small declines in Medicare billed supervision among both high and low base unit cases in Figure 6—roughly 2-3% relative decreases compared to pre-treatment years.[24] In other words, there is no indication that anesthesiologist supervision recedes among certain operating room anesthesia encounters (e.g., shorter and less complex cases) while being maintained in perhaps more appropriate contexts (e.g., longer and more difficult to manage cases).

Within Table 5, we observe that the strongest indication of reduced anesthesiologist supervision billing activity is found among hospital inpatient operating room settings (column 1)––a 14% change relative to opt-out states' pre-policy average level. The remaining DD estimates in Table 5 are directionally negative but too imprecise to draw clear inferences. Panel A of Figure 7 displays the corresponding event study for supervision declines among hospital inpatient care. The pattern largely follows what is demonstrated in Figure 4 (the overall result); although, a noteworthy difference between Panel A of Figure 7 and Figure 4 is that the negative and substantive effect for inpatient time-based volumes persists even three or more years after the opt-out decision—indicative of a permanent change in anesthesiologist supervision billing volume for this key healthcare delivery setting. The event study results are more equivocal for hospital outpatient settings (Panel B, Figure 7), and any policy effect appears to be shorter lived.

[23] The distribution of anesthesia case durations is highly skewed so we have adopted the 60-minute threshold as a proxy for relatively short versus relatively longer—and thus likely more complex—cases. We use the median value cutoff for the base units to perform an analogous exercise that provides an alternative measure of case complexity.

[24] Examining changes in the average base unit value for supervised cases also demonstrates no clear policy response. Results available by request.

To summarize, our time-based anesthesia procedure findings reveal an unchanged involvement of CRNAs in operating room cases overall; however, anesthesiologists appear to be billing for less supervision activity. The declines are modest and seem to be evenly spread across a wide variety of cases—though concentrated within the hospital inpatient setting. While the underlying motivation for preserving their supervision efforts is not observable in our data, the results are able to reject regulatory capture as the exclusive mechanism for driving pre-opt-out anesthesiologist supervision involvement. Supervision does not disappear. In fact, much of it persists—suggesting perceived value from the anesthesia provider collaboration even when not formally required to comply with Medicare payment rules.[25]

5. Effects on Anesthesia Provider Service-Based Output

Table 6 transitions to the smaller component of CRNA procedures for Medicare beneficiaries that is also plausibly more negatively affected by regulatory barriers for CRNA independence (i.e., service-based, as opposed to time-based, anesthesia procedures). Across all healthcare delivery settings, we find an increase of 10 service-based procedures per quarter-year among CRNAs' reimbursable activity when the physician supervision requirement is lifted (Panel A, column 1). The deregulation effect is precisely estimated and represents a 23% relative increase over opt-out states' pre-policy mean level. The remaining columns of Table 6 in Panel A decompose the labor supply response by place of service. The overall effect is driven primarily by inpatient care occurring outside of hospitals' operating rooms. A smaller and less precise contribution comes

[25] Of note, experimental evidence finds that endogenously formed (i.e., self-selected) teams can outperform randomly assigned—or what could be construed as 'mandated'—teams and experience fewer free-rider problems (Chen and Gong 2018). Applied to our context, the post-deregulation conduct of the remaining anesthesiologist-CRNA collaborations is perhaps improved if it is the least necessary and/or poorest functioning physician supervisors that experience their overseeing roles reduced or eliminated.

from the hospital outpatient setting while ASCs and physician offices demonstrate no obvious policy response. Panel B in Table 6 focuses on specific procedures within the hospital inpatient setting. The increase in CRNA service-based procedures following states' opt-out decisions largely materializes due to arterial and venous monitoring and anesthetic injection activity.

Figure 8 displays the accompanying event studies for the key findings from Table 6. Panel A presents the overall result, which shows comparable behavior across treatment and control states prior to the policy change and then a consistent positive effect once the opt-out decision is implemented—which is maintained over all subsequent time periods. Panel B narrows to hospital inpatient care and shows no differential pre-trending among opt-out states and then an immediate and persistent increase in CRNA service-based procedures once the regulatory barriers are removed. The event study estimate for three or more years post-policy is similar in magnitude to the initial policy responses and statistically significant as well. Hospital outpatient care (Panel C) demonstrates a less consistent pattern of greater CRNA use beyond the operating room. There is only suggestive evidence of an increase in CRNA service-based activities during the first six months following the deregulation event and then two or more years after. The event study results for the specific inpatient procedures described in Panel B of Table 6 are available in Appendix Figure A1.

Importantly, the greater use of CRNAs for non-operating-room anesthesia tasks does not come at the expense of anesthesiologists' effort within this care domain. The DD estimates for anesthesiologists in Appendix Table A1 show no negative effect on the volume of service-based procedures performed by these providers—both overall and specifically within hospital inpatient settings—which refutes an anesthesia provider substitution interpretation. If anything, there is suggestive evidence of an increase in anesthesiologists' output of service-based procedures in the

deregulation aftermath. Taken together, our findings tied to service-based anesthesia care are consistent with higher statewide productive capacity once CRNAs are no longer mandated to be under physician supervision when delivering care to Medicare beneficiaries. Given that Medicare prices are administratively set, rather than governed by market forces, an outward shift in CRNA labor supply for these specific services may be correcting a previous under-provision of anesthesia care in the Medicare market.

6. Supplementary Empirics

6.1 Robustness of key findings

Our event study results offer the most compelling arguments that our treatment and control states are trending similarly in the lead up to the deregulation event and that the subsequent DD estimates are appropriately representing post-policy provider responses in terms of aligning with the policy change over the short- and long-runs. However, we are cognizant of some of the interpretation issues that arise from a generalized DD analytic context with multiple states receiving treatment (i.e., implementing opt-out policies) at various points in time over a fairly long horizon—as described in Goodman-Bacon (2018). We consequently run a sequence of DD estimations using Equation (1) and Equation (2) that systematically exclude a specific cohort of opt-out states according to the year the opt-out provision was implemented. We complete this exercise for our three main findings from Sections 4 and 5 to inform the sensitivity of our results to the presence or absence of any particular opt-out state or group of states. The specific outcomes are anesthesiologist time-based supervision volume overall, anesthesiologist time-based supervision volume within hospital inpatient settings, and CRNA service-based claims. The series of DD

estimates and their corresponding event studies for these robustness checks are presented in Appendix Table A2 and Appendix Figure A2.

We see that the DD directions and relative magnitudes are largely consistent across all five columns for each of the three key outcomes of interest from our main findings. There is admittedly more variability for the overall time-based supervision volumes (Appendix Table A2, Panel A), with California (i.e., the 2009 opt-out cohort in column 4) playing an influential role in the DD estimate magnitude and precision. Despite the smaller magnitude, the corresponding event study figures in the first column of Appendix Figure A2 demonstrate a marked reduction in supervision following the policy change that remains clearly visible, even when excluding the 2009 cohort. Also, as previously noted (Figure 4), the decline in overall time-based supervision occurs within the close vicinity of the opt-out change, with no statistically significant differences detectable three or more years after the event. This long-run dynamic could account for some of the smaller estimate magnitudes found in Panel A of Appendix Table A2 since the DD estimates for the early policy changing states are better able to capture this long-run (i.e., many years out) phenomenon. This possibility is further supported by our robustness checks for anesthesiologist supervision in the hospital inpatient setting (Appendix Table A2, Panel B). As previously reported for all treatment states (Figure 7, Panel A), this margin demonstrated a persistent long-run effect (i.e., three plus years out); here we also find less sensitivity to the exclusion of California. The corresponding event studies for this outcome in the middle column of Appendix Figure A2 further support the robustness of our interpretation. Additionally, the outward shift in service-based CRNA supply is uniformly strong and statistically significant across all five columns of Appendix Table A2 Panel C as well as in Appendix Figure A2.

6.2 Quality of care

In order to help interpret our prior findings in terms of potential consumer welfare implications, we also examine anesthesia complication rates before and after removing physician supervision of CRNAs using our DD specification belonging to Equation (1). Less physician supervision and allocating CRNAs to more tasks outside of hospitals' operating rooms would not necessarily be welfare improving if it simultaneously compromised patient safety. Yet, within Appendix Table A3, we find no evidence that the quality of anesthesia care is eroded by removing the regulatory barrier to CRNA independence. Adverse events attributed to anesthesia care are rare, and we do not observe anesthesiologist or CRNA performance suffering when collaboration is no longer required. We therefore conclude that the modest reduction in anesthesiologist supervision and expanded utilization of CRNA labor for non-operating room anesthesia care delivery needs is likely to increase beneficiary welfare on net.

6.3 Aggregate Medicare revenues and off-setting behavior

To recapitulate the core findings related to anesthesia provider labor supply (independent as well as collaborative) from Sections 4 and 5, our DD estimates reveal that anesthesiologists modestly bill Medicare for less supervision of operating room cases, while their quantity of solo-delivered time-based care is unaffected. CRNAs witness no change in the quantity of time-based care they are involved in. However, CRNA labor appears to be deployed to more anesthesia tasks taking place outside of the operating room—typically elsewhere within the hospital inpatient setting. This latter effect is relatively large in magnitude, but even after the increase in service-based activity,

time-based anesthesia care still accounts for the overwhelming majority of CRNA effort within the Medicare market. Given these alterations to anesthesia care production and the opt-out implications for anesthesia provider payment sharing rules (Section 2.2), we conclude our empirical investigation by examining post-deregulation changes to aggregate Medicare revenues accruing to each anesthesia provider type.

The DD results in Table 8 unsurprisingly show increased revenues flowing to CRNAs for both their time-based (column 3) and service-based (column 4) claims. The magnitude of the effect is larger for time-based activities in absolute terms; however, in relative terms, the increase among service-based claims is 21% while it is only 6% for time-based CRNA billing. These effects align well with our findings from Section 4 and Section 5 that demonstrated greater CRNA effort outside of the operating room and less sharing of revenues with anesthesiologists as their supervision roles shrink. Interestingly, anesthesiologists maintain stable Medicare revenue in both anesthesia care domains (columns 1 and 2 in Table 8). Column 2 is not unexpected since we did not detect a decline in anesthesiologists' service-based claims for Medicare beneficiaries after the deregulation event. Given the considerable overlap in anesthesiologists' and CRNAs' tasks (see Figure 1), it is unlikely that there is much scope to out-compete CRNAs for higher reimbursing service-based procedures (i.e., strategically alter their mix of services in response to the opt-out policy). The lack of reduction in time-based revenues suggests some degree of offsetting behavior that counterbalances the mechanical declines in payments from the subset of operating room cases that are no longer supervised—and therefore remove the anesthesiologist as a residual claimant on a portion of the associated Medicare reimbursements. Corresponding event study figures are shown in Appendix Figure A3.

We use Equation (2) to explore this further in Figures 9 and 10. Within Panel A of Figure 9, we observe some suggestive evidence that solo-delivered time-based anesthesiologist cases have slightly higher revenues once the CRNA supervision mandate is terminated. Their revenues from supervising duties (Panel B) unsurprisingly dip soon after the deregulation event (though the point estimates are noisy); however, they are restored to pre-policy levels by the second year after opt-out is implemented. The coefficient pattern could be consistent with some strategic sorting and/or negotiation with CRNAs that allows anesthesiologists to generate the same amount of Medicare revenue from fewer jointly produced operating room cases (e.g., collaborating more on longer and/or more complex cases).

Figure 10 offers one plausible mechanism for higher revenues attached to solo-delivered time-based anesthesia encounters. Specifically, we see a growing decline in in the number of shorter (less than 60 minutes) solo-delivered cases following opt-out implementation—meaning that more of their solo cases are lasting at least an hour and are therefore more likely to generate larger total payments to the provider based on established Medicare anesthesia reimbursement rules (Section 2.2).[26] The suggestive results in Figures 9 and 10 are at least consistent with a variety of small and strategic adjustments by anesthesiologists along multiple margins which collectively offset the lost Medicare revenues stemming from fewer opportunities to impose the Medicare sharing rule on CRNAs.

[26] We have also explored changes to associated "base units" (see Section 2.2) as another marker for case complexity as well as an opportunity to strategically increase anesthesiologists' Medicare payments after the deregulation event. However, we did not find any clear evidence that a strategic reallocation or provider competition for higher base unit cases emerges when states implement their opt-out decision.

7. Discussion

A wide variety of industries and firms have become familiar with and proponents of team-based production and problem-solving. US medical care is no exception, with many of its institutional features appearing well-suited for provider teamwork as a means to drive efficient health outcomes for patients. Yet, the prevalence and purpose of medical teams is also shaped by the myriad of regulations found within the healthcare sector. It is consequently difficult to know the degree to which joint production between providers reflects underlying preferences and market forces as opposed to strategic regulatory capture that softens provider competition.

We benefit from a unique setting where our health policy events of interest are predicated on a federal rule change from one of the most influential payors: Medicare. This provides an opportunity to examine how federal payment policy interacts with regulatory decisions that are otherwise within the remit of state law.[27] Our DD and event study estimates demonstrate a sharp and persistent decline in anesthesiologist supervision billing activity within operating room settings—an 11% effect overall—after states eliminate physician supervision requirements for CRNAs. We also observe similar reductions across cases of different lengths as well as complexities. Additionally, and as discussed in Section 3.3, our reliance on Medicare billing for our analyses likely generates an upper bound on true behavior change following states opt-out of supervision requirements. The strong persistence of anesthesiologist supervision post-policy we observe is, if anything, a potential underestimate the collective preference for teams in anesthesia care settings. Key decision-makers seem to value the hierarchical team structure across a variety of anesthesia care contexts, and the underlying supplier demand for collaborative anesthesia care

[27] In other words, without a salient and contentious change in Medicare payment rules for anesthesia care, state governments and local hospitals would have been unable to remove CRNA restrictions on care devoted to the Medicare market.

delivery that we document appears to contradict much of the supposed "turf war" between anesthesiologists and CRNAs often portrayed by advocacy organizations and media outlets.

Yet, the precise motivations for the residual and high degree of physician involvement in CRNA-delivered care remain unclear. Institutional labor economists have long considered the influence of conflicting or competing worker group objectives and the subsequent internal political processes that shape firm behavior and outcomes (e.g., see Osterman, 2011, for a relatively recent review). It is possible that such intra-hospital political dynamics restrain the amount of anesthesia labor and task-matching reallocations after deregulation, especially if anesthesiologists and/or surgeons hold greater influence than CRNAs and tend to prefer the status quo (e.g., see Cromwell 1999; Vetter et al. 2016; Massarweh and Awad 2017; Mills et al. 2020).[28] Historically and still today, hospitals often exercise limited direct control over the highest skilled labor inputs—namely physicians—which further challenges hospital managers' ability to drive process improvements and greater efficiencies (Pauly and Redisch 1973; Cromwell 1999; Cebul et al. 2008). The near independence between these two medical production factors (i.e., capital and labor) could therefore preserve anesthesiologists' supervision role, even in the absence of a policy constraint on hospitals.

Alternatively, non-contractual and informal negotiations between anesthesiologists and CRNAs—as often observed among medical groups more broadly (Encinosa, Gaynor, and Rebitzer 2007)—could maintain much of their pre-existing collaboration while accommodating new revenue sharing rules between provider types, particularly if there is option value from a dedicated reserve of human capital and/or mutual interest in promoting cooperative interaction. Surveys of anesthesia providers find support among anesthesiologists and CRNAs for team-based care (Jones

[28] Related influences could stem from perceptions of medical malpractice liability risk, preferences for physician-to-physician dialogue and joint decision-making during a given case, or perceptions of consumer demand for anesthesiologists' involvement in care delivery.

and Fitzpatrick 2009), and it is noteworthy that aggregate Medicare revenues flowing to anesthesiologists are largely protected even when CRNAs are allowed to practice independently. These empirical facts indicate that each provider type is able to respond in isolation and in conjunction to the post-opt-out regulatory environment in ways that leave each of them as well or better off financially.

Nevertheless, we do find evidence of potential distortionary consequences associated with the physician supervision requirements. CRNAs increase their service-based output by 20-25% following the deregulation events. Given that there is not a commensurate reduction in the use of anesthesiologists for these services (i.e., no evidence of provider labor substitution), the physician supervision regulations appear to constrain the overall productivity of anesthesia providers—particularly among hospitals' clinical settings beyond their operating rooms. The subsequent outward shift in CRNA service-based procedure supply within the price-regulated (i.e., Medicare) market is consistent with meeting latent, unsatisfied demand and therefore highlights a potential negative externality borne by beneficiaries when Medicare payment rules mandate physician supervision of CRNAs. This specific margin (i.e., service-based care) has additionally been overlooked by existing opt-out policy studies that have instead focused on aggregate supply of surgical care and associated anesthesia operating room services (i.e., time-based care). So, while our results temper any strong assumption that anesthesiologist supervision is solely anticompetitive behavior, our findings also question the need for the requirement at all—especially if it unnecessarily limits CRNA labor use outside of the operating room.

We do note, however, that it is unknown what, if any, role states' opt-out decisions play in provider-insurer network formation and price negotiations tied to anesthesia care within commercially insured markets. Anesthesiology services, specifically, have been highlighted as a

key contributor to out-of-network billing issues (i.e., "surprise billing") affecting healthcare consumers across the US (Chhabra et al. 2020). The Medicare public insurance program has virtually no network component and prices are administratively set, so our empirics cannot examine these specific contracting margins for additional spillovers from Medicare reimbursement policy. Additionally, we can only observe services specific to the Medicare population, which may not generalize to the behavior of CRNAs specializing in predominantly non-Medicare patient populations (e.g., pediatric or obstetric care). Thus, an important area for future research is to examine the impact of these and related CRNA deregulation initiatives on privately insured consumers' care received and associated costs. It is possible that anesthesia "turf wars" are fiercer and more financially consequential within private, rather than public, healthcare markets.

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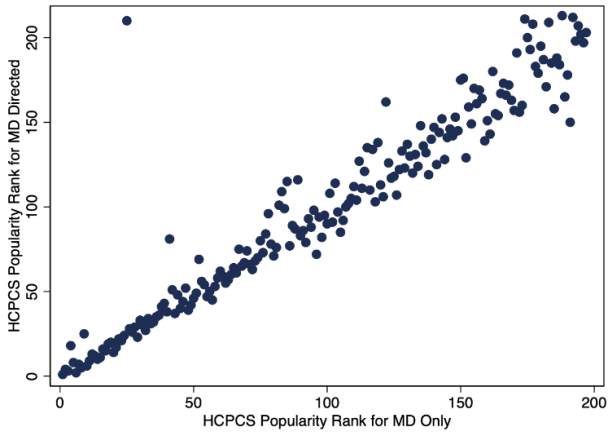
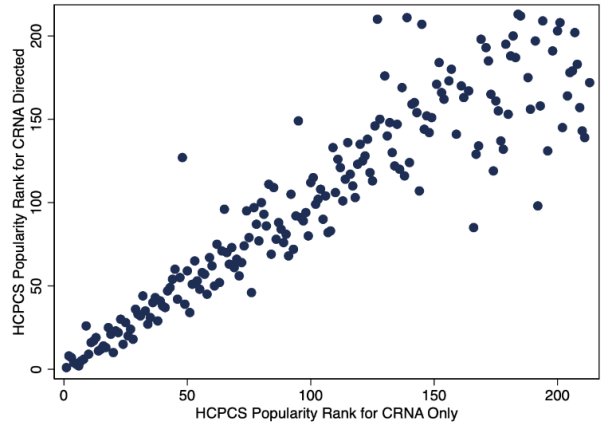
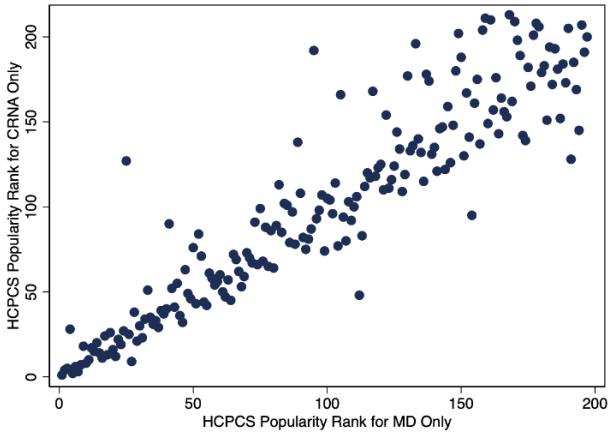
MAIN RESULTS



(a) Services that MDs Perform Solo vs. Supervising



(b) Services that CRNAs Perform Solo vs. Are Supervised



(c) Services that CRNAs Perform Solo vs. MDs Perform Solo

Figure 1. Identifying Anesthesia Provider "Turf"

Notes: Data are from the 5% Medicare claims and include all claims made by anesthesiologists (physician-trained) and Certified Registered Nurse Anesthetists (CRNAs).

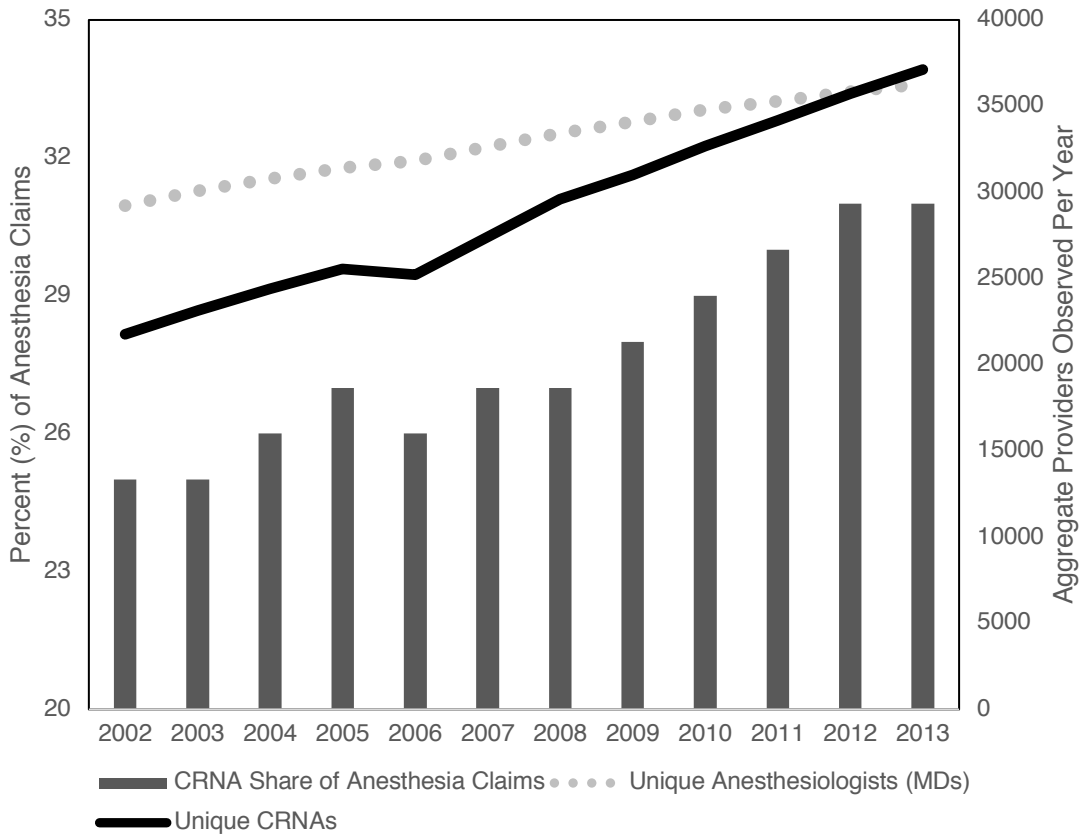


Figure 2. Growth in CRNA Prevalence, 2002-2013

Notes: Data are from the 5% Medicare claims and include all claims made by anesthesiologists (physician-trained) and Certified Registered Nurse Anesthetists (CRNAs). Counts of unique MD and CRNA providers are shown in the grey and black lines, respectively. We are missing provider identifiers in 2007. The gray bars show the share of anesthesia claims that are aministered by a CRNA.

Table 1: Medicare Anesthesia Supervision Deregulation (Opt-Out) States

State	Date of Opt-Out
Iowa	December 2001
Nebraska	February 2002
Idaho	March 2002
Minnesota	April 2002
New Hampshire	June 2002
New Mexico	November 2002
Kansas	March 2003
North Dakota	October 2003
Washington	October 2003
Alaska	October 2003
Oregon	December 2003
Montana	January 2004
South Dakota	March 2005
Wisconsin	June 2005
California	July 2009
Colorado	September 2010
Kentucky	April 2012

Notes: Because we lack pre-treatment data, we drop from our analysis states which changed policies in 2001 and 2002. We additionally drop Alaska, due to asymmetric coding of CRNAs in the early years of data, and Colorado, which allowed for opt-outs only among Critical Access Hospitals and specified rural hospitals.

Table 2: Summary Statistics for Anesthesia Claims by Deregulation Status

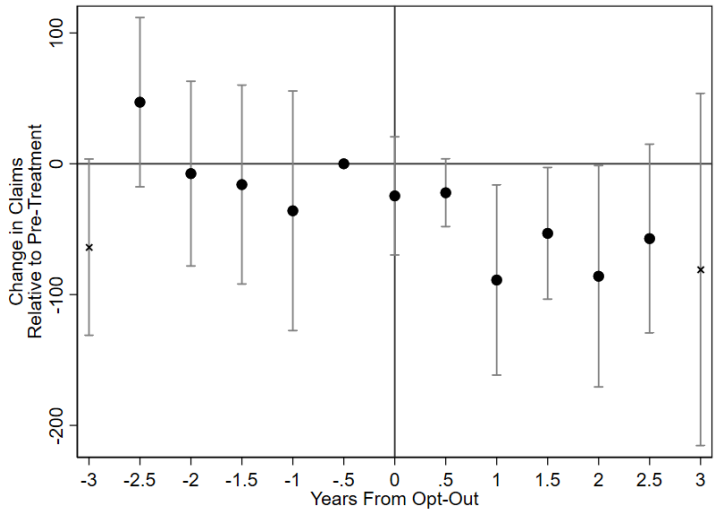
	Opt-Out (Treated)		Non-Opt-Out (Control)	
	Mean	SD	Mean	SD
	(1)	(2)	(3)	(4)
Time-Based Claims				
Anesthesiologist (MD)	1260.2	1705.3	1795.5	1494.0
CRNA	514.9	419.1	1265.1	1140.0
Service-Based Claims				
Anesthesiologist (MD)	814.8	889.2	1084.9	939.4
CRNA	49.6	32.1	42.6	49.4
Patient Demographics				
CCI	0.209	0.073	0.192	0.070
Share Male	0.407	0.131	0.408	0.132
Share White	0.840	0.261	0.768	0.267
Share Black	0.024	0.024	0.095	0.101
Share Hispanic	0.010	0.019	0.009	0.014
Observations (N)	432		1,632	

Notes: Data are from the 5% Medicare claims for 2002-2013, aggregated to the state-half-year level. Both the time-based and service (i.e., procedure)-based claims restrict to Level 1 HCPCS codes. Patient demographics are calculated from anesthesia care associated claims (i.e., not the general Medicare population). CRNA: Certified Registered Nurse Anesthetist. Anesthesiologist refers to physician-trained anesthesia providers.

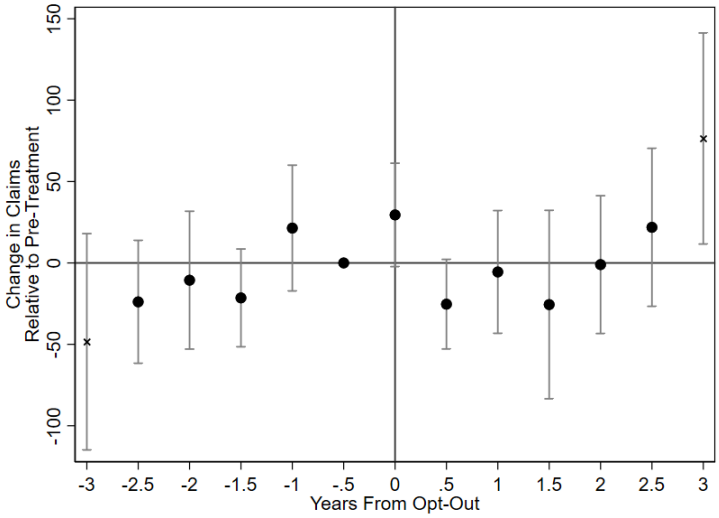
Table 3: Medicare Opt-Out Policy Effects on Time-Based Claims Volume by Provider Type

	Anesthesiologists (MDs)	CRNAs
	(1)	(2)
1(Opt-Out)	-37.01**	-2.16
	(17.75)	(15.53)
Year-Quarter FE	Yes	Yes
State FE	Yes	Yes
State-Time Trend	Yes	Yes
Patient Demographics	Yes	Yes
Observations (N)	2,064	2,064
Pre-Treated Mean	1306.22	548.56

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. Sample mean reported is for treated states in year prior to treatment. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10



(a) MD Time-Based Claims



(b) CRNA Time-Based Claims

Figure 3. Event Study Results for Medicare Opt-Out Policy Effects on Time-Based Claims Volume by Provider Type

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. Analytic sample corresponds to Table 3.

Table 4: Medicare Opt-Out Policy Effects on Time-Based Claims Volume Stratified by Anesthesiologists' Role

	Anesthesiologist Is Solo Provider	Anesthesiologist Providing Medical Direction or Supervision
	(1)	(2)
1(Opt-Out)	-1.37	-34.52**
	(17.58)	(16.52)
Year-Quarter FE	Yes	Yes
State FE	Yes	Yes
State-Time Trend	Yes	Yes
Patient Demographics	Yes	Yes
Observations (N)	2,064	2,064
Pre-Treated Mean	1011.17	295.28

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, restricted to those belonging to anesthesiologists (physician-trained), and aggregated to the state-half-year level. Procedure code modifiers are used to distinguish claims where the anesthesiologist is directly delivering from those where the anesthesiologist is supervising a CRNA. MD claims are classified as MD only (no modifier or modifier AA), MD medical direction (modifiers QY and QK), and MD supervision (modifier AD). Sample mean is for treated states in year prior to treatment. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10

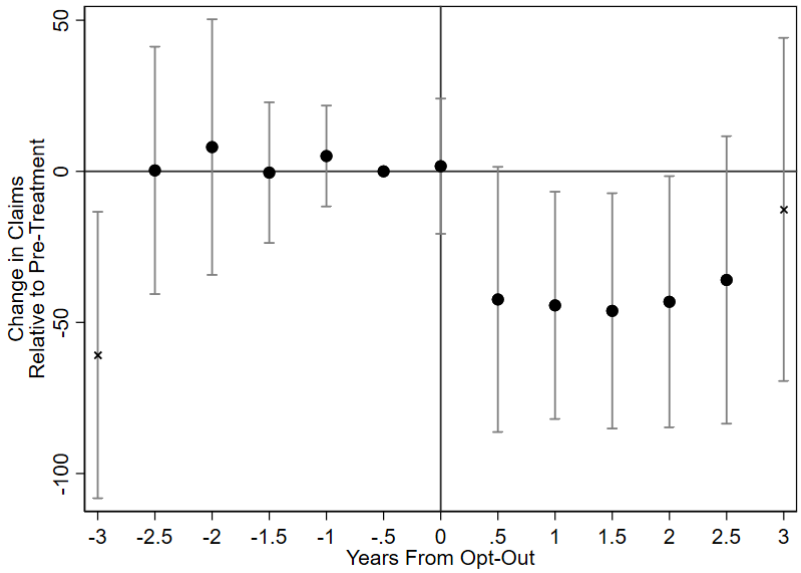
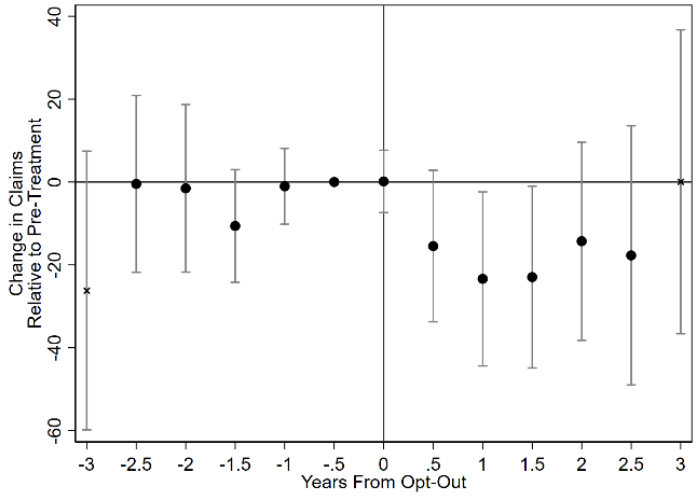
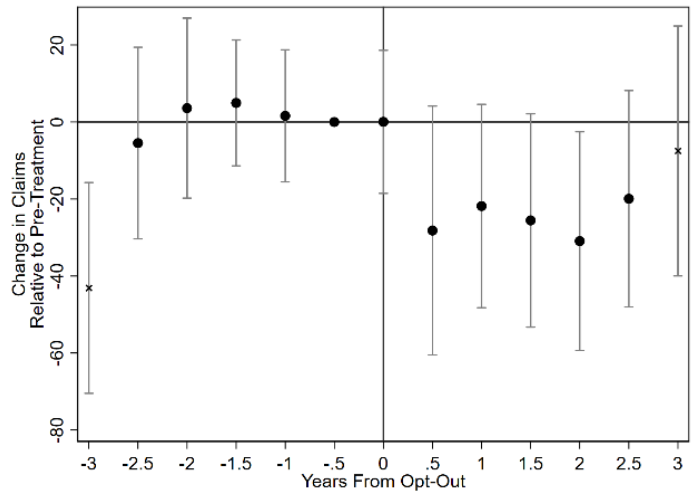


Figure 4. Event Study Results for Medicare Opt-Out Policy Effects on Anesthesiologists' Time-Based Claims Volume for Supervising CRNAs

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. Analytic sample corresponds to Table 4, Column 2.



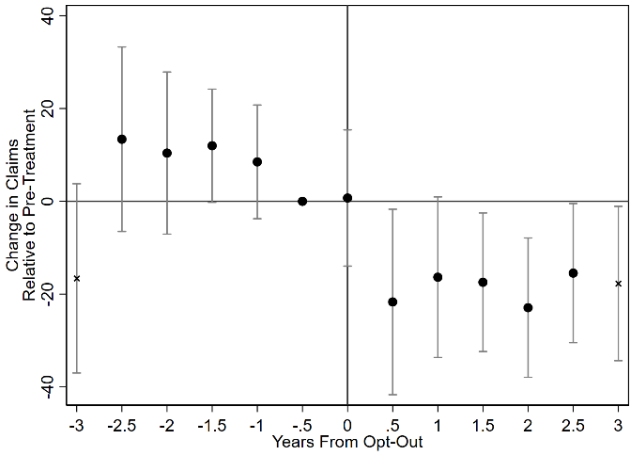
(a) MD Direction or Supervision Cases Less Than 60 Minutes



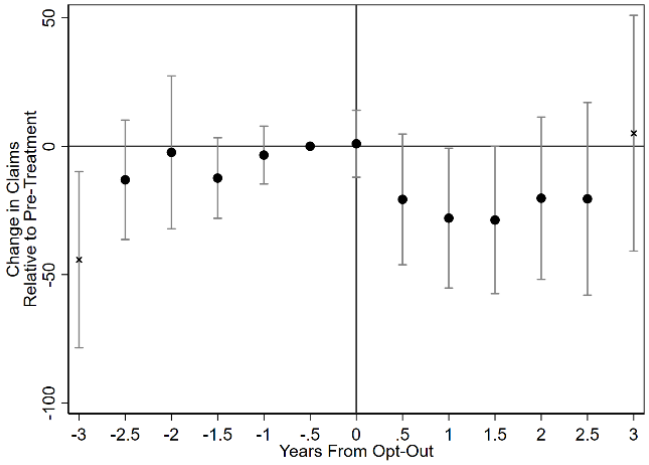
(b) MD Direction or Supervision Cases 60 Minutes and Longer

Figure 5. Event Study Results for Medicare Opt-Out Policy Effects on Anesthesiologists' Time-Based Claims Volume for Supervising CRNAs Stratified by Shorter and Longer Cases

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event.



(a) MD Direction or Supervision for High Base Unit Cases



(b) MD Direction or Supervision for Low Base Unit Cases

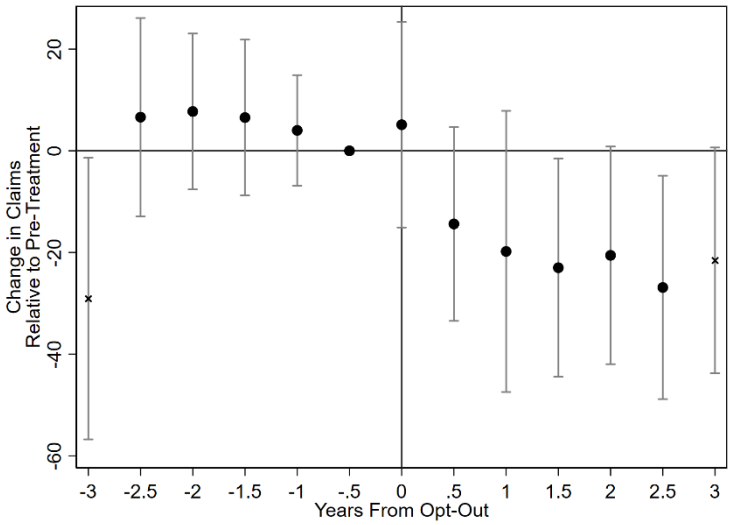
Figure 6. Event Study Results for Medicare Opt-Out Policy Effects on Anesthesiologists' Time-Based Claims Volume for Supervising CRNAs Stratified by Base Units

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. High and low distinguish above and below the median base unit values, respectively, among all time-based claims in our analytic data.

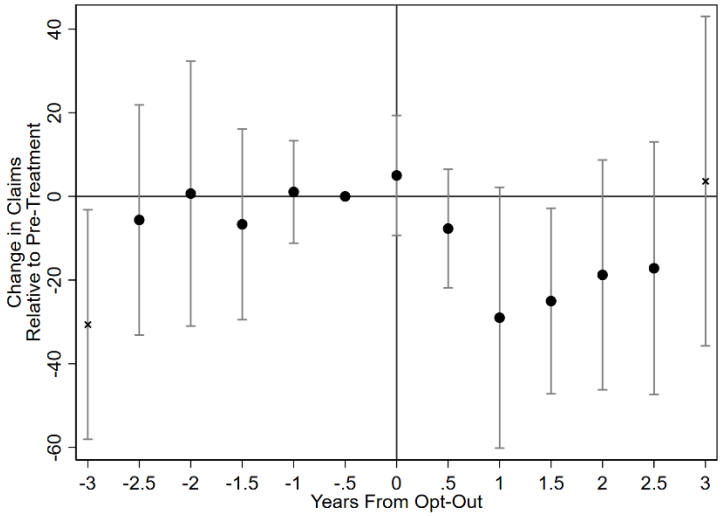
Table 5: Medicare Opt-Out Policy Effects on Anesthesiologists' CRNA Supervision Time-Based Claims Volume by Care Delivery Setting

	Hospital Inpatient	Hospital Outpatient	ASC	Office
	(1)	(2)	(3)	(4)
1(Opt-Out)	-19.38**	-10.63	-13.41	-0.428
	(8.611)	(10.47)	(8.350)	(0.363)
Year-Quarter FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes
Observations (N)	2,064	2,064	2,064	2,064
Pre-Treated Mean	141.61	153.67	29.39	0.67

Notes: Data are from the 5% Medicare claims from 2002-2003, restricted to those belonging to anesthesiologists' (physician-trained) claims linked to supervising CRNAs, and aggregated to the state-half-year level. "ASC" stands for Ambulatory Surgery Center. Sample mean is for treated states in year prior to treatment. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10



(a) Hospital Inpatient Setting



(b) Hospital Outpatient Setting

Figure 7. Event Study Results for Medicare Opt-Out Policy Effects on MD Supervision of Time-Based Cases, by Hospital Place of Service

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. Analytic sample corresponds to Table 5, Columns 1 and 2.

Table 6: Medicare Opt-Out Policy Effects on CRNAs' Service-Based Claims Volume by Care Delivery Setting and Type of Service

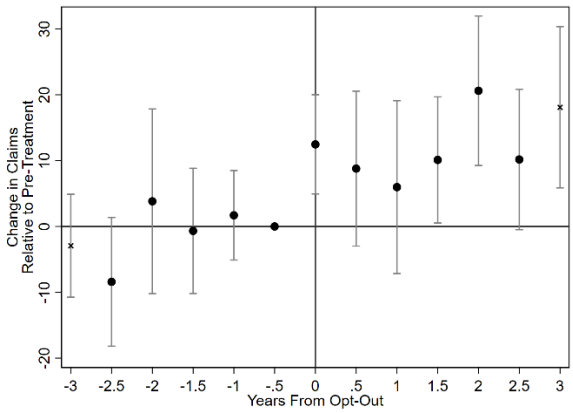
Panel A: All CRNA Service-Based Claims

	Overall	Hospital Inpatient	Hospital Outpatient	ASC	Office
	(1)	(2)	(3)	(4)	(5)
1(Opt-Out)	10.21***	7.062***	2.883*	-0.141	-1.359
	(3.55)	(2.447)	(1.482)	(2.444)	(0.964)
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes	Yes
Observations (N)	2,064	2,064	2,064	1,951	2,052
Pre-Treated Mean	44.39	29.06	14.39	4.67	1.33

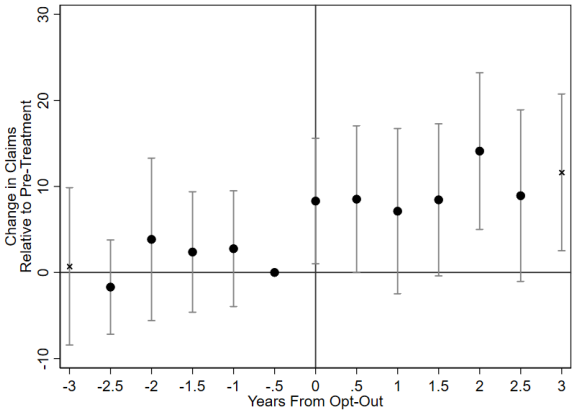
Panel B: Restricted to 20 Most Common Hospital Inpatient Services in CRNA Service-Based Claims

	Arterial/Venous Monitoring	Emergency Intubation	Injections	All Others
	(5)	(6)	(7)	(8)
1(Opt-Out)	3.49***	0.44	1.82***	1.03
	(1.14)	(0.35)	(0.60)	(1.41)
Year-Quarter FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes
Observations (N)	2,064	2,064	1,951	2,052
Pre-Treated Mean	15.78	2.56	3.83	5.00

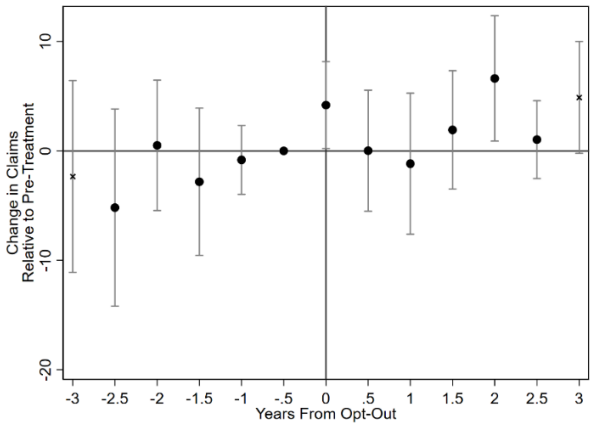
Notes: Data are from the 5% Medicare hospital claims from 2002-2013, restricted to CRNA service-based (procedure) claims, and aggregated to the state-half-year level. "ASC" stands for Ambulatory Surgery Center. Sample mean is for treated states in year prior to treatment. Standard errors clustered at the state level. Panel B is restrited to definitions of the top 20 codes performed, accounting for 12% of CRNA claims. The detailed definition is provided in Appendix Table B. *** P value at 0.01 ** P value at 0.05 * P value at 0.10



(a) Overall



(b) Hospital Inpatient Setting



(c) Hospital Outpatient Setting

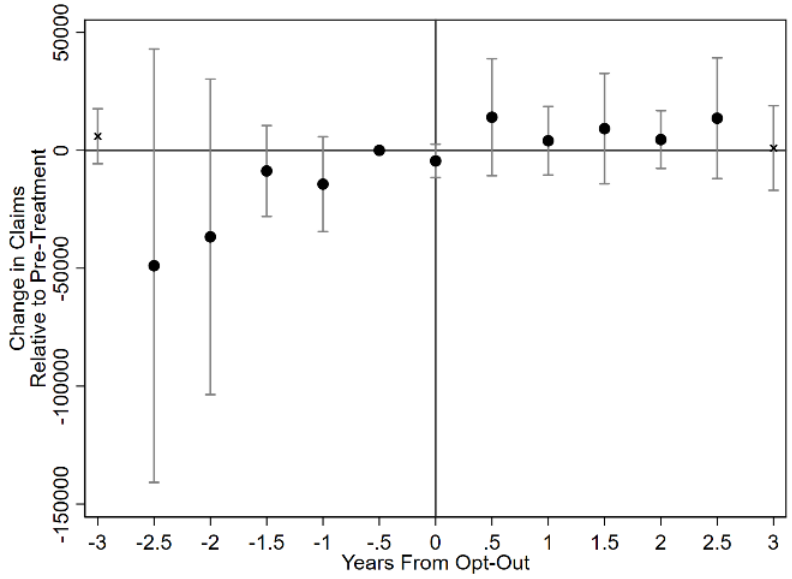
Figure 8. Event Study Results for Medicare Opt-Out Policy Effects on CRNA Service-Based Claims Volume, by Hospital Place of Service

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. Analytic sample corresponds to Table 7, Columsn 1 and 2.

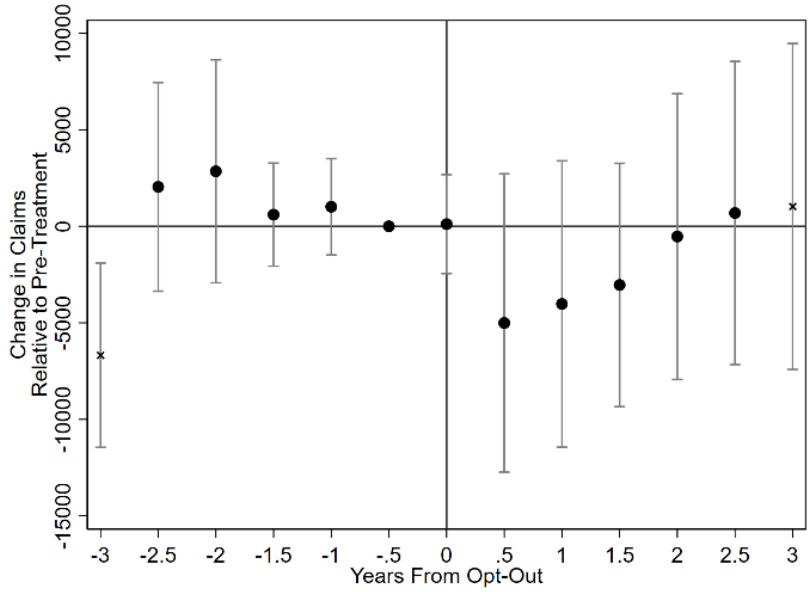
Table 8: Medicare Opt-Out Policy Effects on MD And CRNA Aggregate Medicare Revenues

	Anesthesiologists (MDs)		CRNAs	
	Revenues From Time-Based	Revenues From Service-Based	Revenues From Time-Based	Revenues From Service-Based
	(1)	(2)	(3)	(4)
1(Opt-Out)	16,589	4,035	4,654**	380.3**
	(16,501)	(2,919)	(2,064)	(155.4)
Year-Quarter FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes
Observations (N)	2,064	2,064	2,064	2,064
Pre-Treated Mean	264,552	52,094	75,100	1,834

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, restricted to those belonging to anesthesiologists (physician-trained), and aggregated to the state-quarter-year level. Sample mean is for treated states in year prior to treatment. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10



(a) MD Revenues from Solo Time-Based Cases



(b) MD Revenues from Supervision Time-Based Services

Figure 9. Event Study Results for Opt-Out Effects across Domains of Anesthesiologist (MD) Medicare Revenues

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The ($t = 0$) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event.

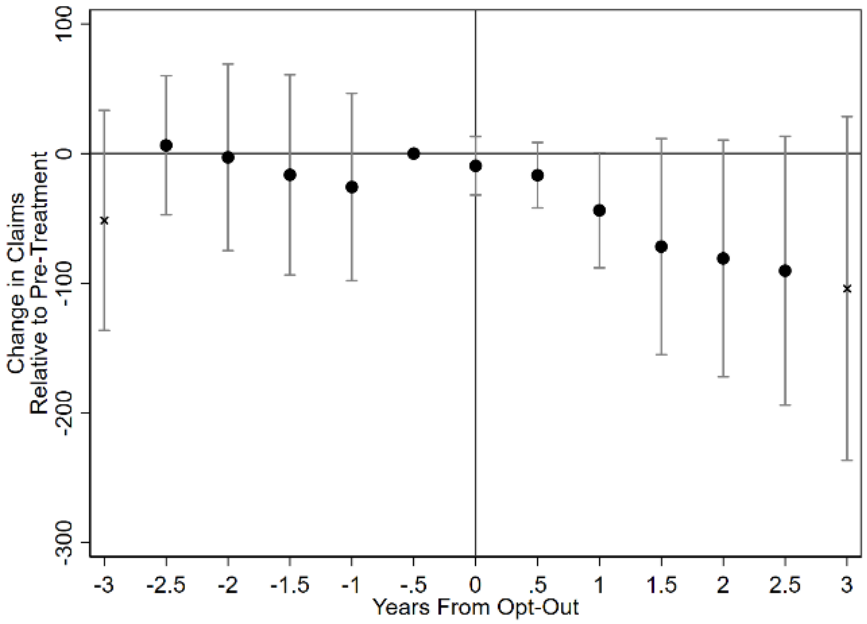


Figure 10. Event Study Results for Opt-Out Effects on the Volume of Anesthesiology (MD) Solo Cases Shorter than 1 Hour

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event.

APPENDIX RESULTS

Appendix A

APPENDIX TABLE A1: MEDICARE OPT-OUT POLICY EFFECTS ON SERVICE-BASED CLAIMS VOLUME FOR ANESTHESIOLOGISTS

	Total Hospital	Hospital Inpatient
	(1)	(2)
1(Opt-Out)	107.6*	31.83
	(54.74)	(31.08)
Year-Quarter FE	Yes	Yes
State FE	Yes	Yes
State-Time Trend	Yes	Yes
Patient Demographics	Yes	Yes
Observations (N)	2,064	2,064
Sample Mean	884.89	540.11

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. Sample mean is for treated states in year prior to treatment. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10

APPENDIX TABLE A2—ROBUSTNESS OF AVERAGE TREATMENT EFFECT FOR KEY OUTCOMES ACROSS STATES WITH HETEROGENEOUS TREATMENT TIMING

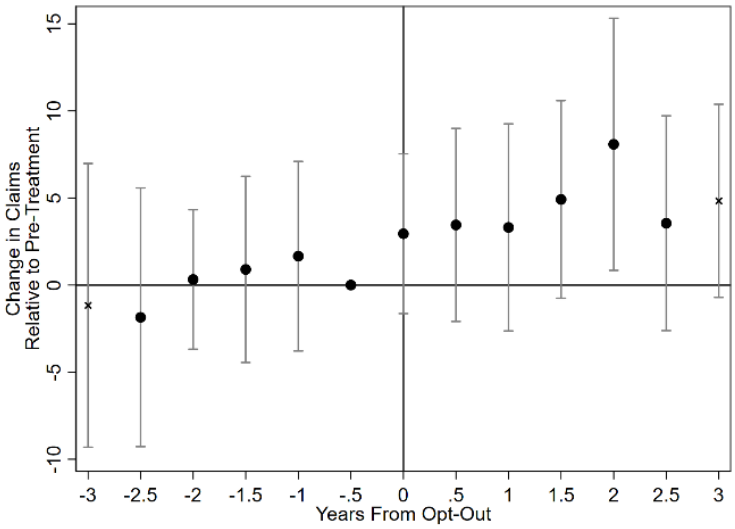
	Excluding 2003	Excluding 2004	Excluding 2005	Excluding 2009	Excluding 2012
	(1)	(2)	(3)	(4)	(5)
	A. Anesthesiologist Supervision on All Time-Based Claims				
1(Opt-Out)	-39.69**	-32.49*	-30.88	-18.92	-30.72
	(18.04)	(17.26)	(19.04)	(16.20)	(20.08)
Pre-Treated Mean	391.6	332.2	265.2	283.9	235.8
	B. Anesthesiologist Supervision on Inpatient Time-Based Claims				
1(Opt-Out)	-25.36**	-19.02**	-21.51**	-13.13*	-20.47**
	(9.573)	(9.056)	(9.748)	(7.591)	(10.13)
Pre-Treated Mean	178	159	124	131	127
	C. CRNA Service-Based Claims				
1(Opt-Out)	7.275***	10.57***	11.53**	10.76**	9.442**
	(2.080)	(3.783)	(4.349)	(4.014)	(4.044)
Pre-Treated Mean	51.3	46.8	41.9	46.8	41.9
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes	Yes
Observations (N)	1,872	2,016	1,968	2,016	2,016
No. of States	39	42	41	42	42

Notes: Data are from the 5% hospital Medicare claims from 2002-2013, aggregated to the state-half-year level. Each reported number comes from a separate regression that controls for year-quarter fixed effects, state fixed effects, patient demographics, and a state by time trend. The dependent variable is time-based counts by anesthesiologists. Each column drops one year of treatment state cohorts. Sample mean is for treated states in year prior to treatment. See Table 1 for details on which treated states are dropped in each column. Standard errors clustered at the state level. *** P value at 0.01 ** P value at 0.05 * P value at 0.10

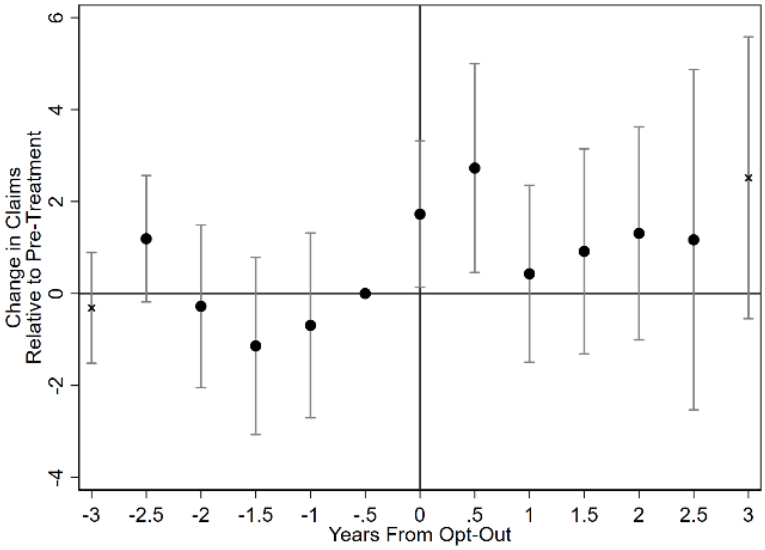
APPENDIX TABLE A3: ANESTHESIA COMPLICATIONS PER 1,000 MEDCIARE BENEFICIARIES RECEIVING ANESTHESIA CARE BY PROVIDER TYPE

	Anesthesiologist Solo Provider		CRNA Solo Provider	
	Hospital Inpatient	Hospital Outpatient	Hospital Inpatient	Hospital Outpatient
1(Opt-Out)	-1.09	5.60	0.89	-0.26
	(0.87)	(5.51)	(0.92)	(0.61
Year-Quarter FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
State-Time Trend	Yes	Yes	Yes	Yes
Patient Demographics	Yes	Yes	Yes	Yes
Observations (N)	2,059	2,059	2,020	2,020
Sample Mean	1.3	1.6	2.5	1.5

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level and span 2002-2013. Standard errors clustered at the state level. Coding for anesthesia complications are documented in Appendix B. *** P value at 0.01 ** P value at 0.05 * P value at 0.10



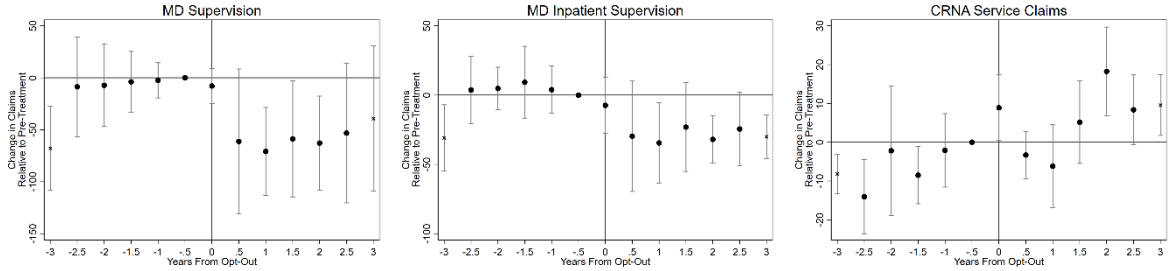
(a) CRNA Inpatient Arterial Monitoring Claims



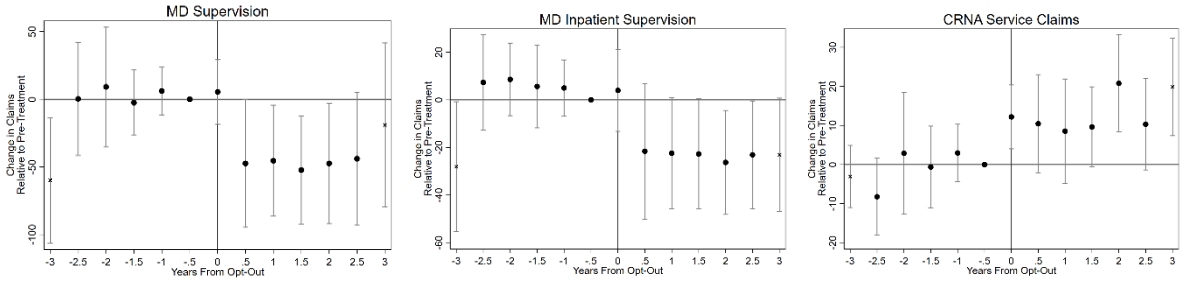
(c) CRNA Inpatient Injection Claims

APPENDIX FIGURE A1—EVENT STUDY RESULTS FOR MEDICARE OPT-OUT POLICY EFFECTS ON CRNAS' INPATIENT SERVICE-BASED CLAIMS (Table 7B)

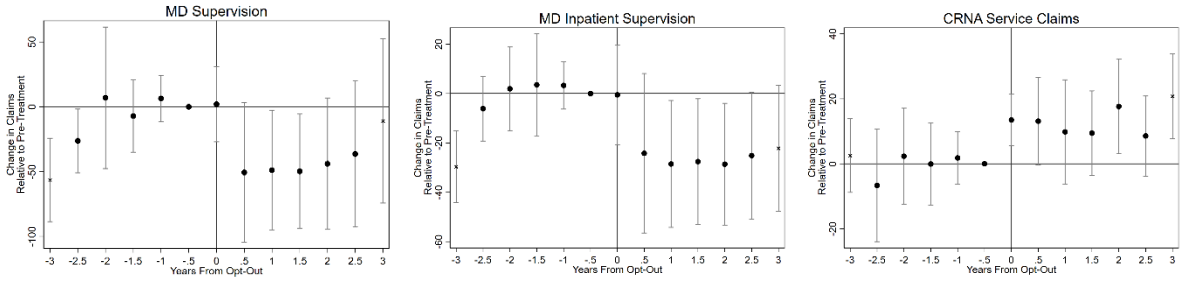
Notes: *Notes*: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event. Analytic sample corresponds to those in Table 7, Columns 5 and 7.



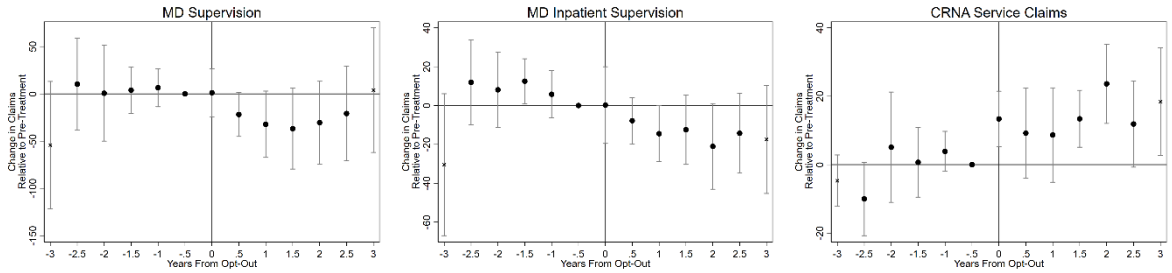
A. Excluding 2003



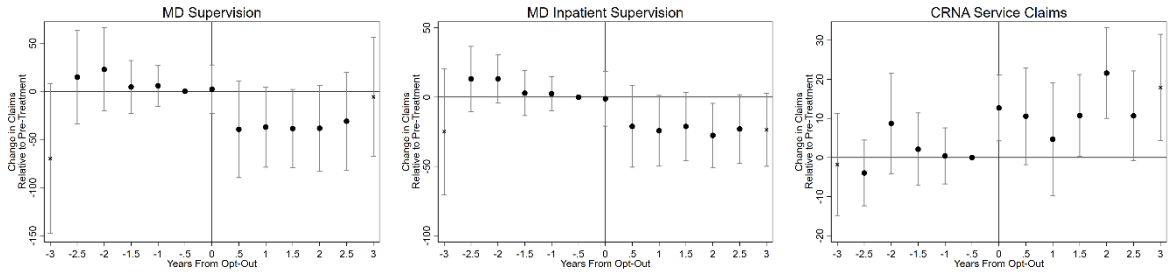
B. Excluding 2004



C. Excluding 2005



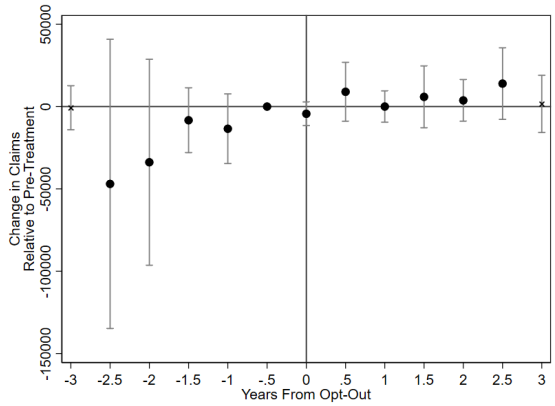
D. Excluding 2009



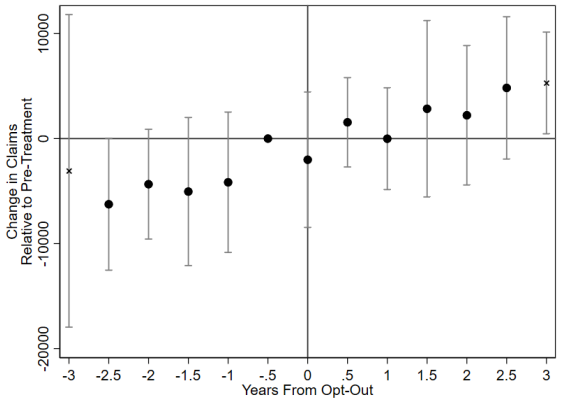
E. Excluding 2012

APPENDIX FIGURE A2: ROBUSTNESS OF EVENT STUDIES FOR KEY OUTCOMES ACROSS STATES WITH HETEROGENEOUS TREATMENT TIMING

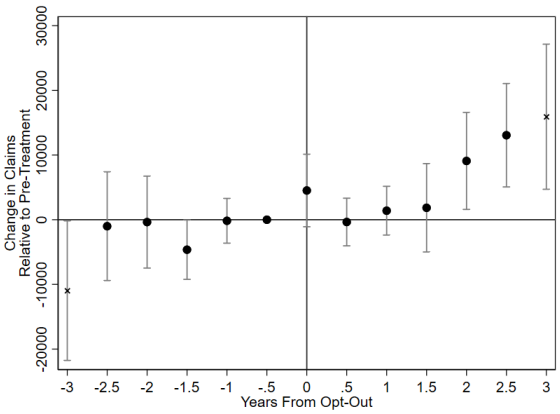
Notes: Figures here correspond to the results in Appendix Table A2. See notes in Figure A1. Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event.



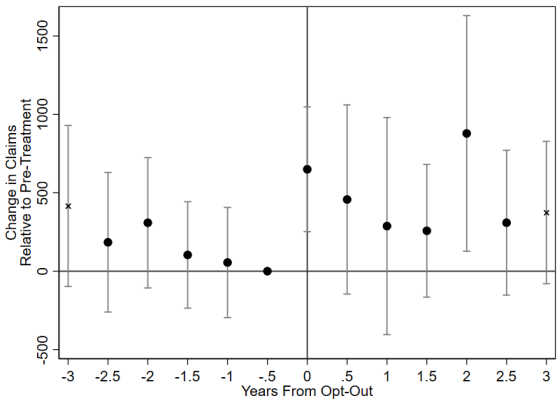
Panel (A): MD Payment, Time-Based Claims



Panel (B): MD Payment, Service-Based Claims



Panel (C): CRNA Payment, Time-Based Claims



Panel (D): CRNA Payment, Service-Based Claims

APPENDIX FIGURE A3: EVENT STUDIES FOR MD AND CRNA PAYMENTS

Notes: Data are from the 5% Medicare hospital claims from 2002-2013, aggregated to the state-half-year level. The (t = 0) time point reflects the first 6-months when the state's deregulation (opt-out) policy is in effect. The –3 and +3 coefficients are aggregate indicator variables for all time periods (+/–) three years from the opt-out policy event.

Appendix B

B.1. Time-Based Claims

Within the Medicare carrier claims file, we used an indicator (MTUS_IND) to differentiate between time- and service-based codes. Time-based codes predominately align with anesthesia HCPCS 00100-00199, 99100-99150. Payment (i.e., allowed Medicare charges) for these codes are based are calculated by: (base units + time units) x conversion factor. Base units are HCPCS-specific and akin to relative value units (RVUs). Time-units are reported in 15-minute increments by the provider. The conversion factor is common across all HCPCS codes but differs across location. These time-based procedures are used to follow pre-operative, operative, and post-operative anesthesia procedures. Providers are required to document start anesthesia and end times carefully. For example, if a provider has discontinuous block of time between prepping a patient for surgery and the surgery start times, the clock should be stopped during the discontinuous time.

To differentiate between time-based solo and supervised or directed cases, we use the modifier associated with each claim. These modifiers and their associated payment levels are documented in Appendix Table B1.

Table B1: Time-Based Modifier Codes and Associated Payments

Performed by	Payment to Anesthesiologist	Payment to CRNA
Anesthesiologist solo (Modifier AA)	100%	No payment
Medical Direction (Modifiers QK/QY and QX)	50%	50%
Medical Supervision (Modifiers AD and QX)	3-4 base units	50%
CRNA solo (Modifier QZ)	No payment	100%

Among time-based claims, 47% of anesthesiologist and 58% of CRNA claims had associated modifiers. Claims without modifiers are performed solo, a fact which we verified by looking at the allowed charge and finding that 100% of allowed payments were reimbursed for those cases.

Some argue that CRNA independent anesthesia delivery—billed under the HCPCS modifier code "QZ"—is overreported to ease the administrative burden on the involved providers, especially if the anesthesiologist and CRNA work for the same medical group (Byrd, Merrick, and Stead 2011; Vetter et al. 2016). The frequent use of the QZ modifier prior to states opting out of supervision requirements, as well as the observation that use of this modifier is three times as high in non-opt-out states as in opt-out states (Dulisse and Cromwell 2010), suggests that this modifier is used for many cases that may in fact involve physician supervision. Assuming these billing practices are time-constant, these coding practices will not bias our results since we capture changes in billing practices within a state over time. Still, due to these reporting concerns, we do not stratify CRNA claims by solo versus supervision modifier codes and only stratify the anesthesiologist claims.

B.2. Serivce-Based Claims

Different from time-based procedures, service-based procedures predominately align with other HCPCS 001000-89398; 90281-99099; and 99500-99607. These service-based claims are largely performed individually: only 0.01% and 0.99% of anesthesiologist and CRNA service-based claims, respectively, have a modifier code. Because of the rarity of medical supervision for these services, we do not differentiate between solo versus supervised cases. These codes are reimbursed according to the standard Medicare fee-for-service Part B payments.

B.3. Identification of Top Inpatient CRNA Service-Based HCPCS Codes

To better understand which service-based codes CRNAs were billing, we focus on the 20 most frequently billed codes in the hospital inpatient setting. We categorize these 20 codes into four mutually exclusive groups based on clinical similarity: aerterial and venous monitoring, emergency inbutations, injections, and all others. The HCPCS codes and descriptions associated with each of these categories are shown in Appendix Table B2.

Table B2: Classification of Top-20 Inpatient CRNA Service-Based Codes

Rank	HCPCS	Category
1	36620	Arterial or venous monitoring
2	99100	Other procedure
3	31500	Emergency intubation
4	62311	Injection
5	01996	Other procedure
6	36410	Arterial or venous monitoring
7	36556	Arterial or venous monitoring
8	64447	Injection
9	99140	Other procedure
10	64415	Injection
11	93503	Arterial or venous monitoring
12	62319	Injection
13	76942	Arterial or venous monitoring
14	64448	Injection
15	36000	Arterial or venous monitoring
16	64445	Injection
17	99231	Other procedure
18	36489	Arterial or venous monitoring
19	64450	Injection
20	36569	Arterial or venous monitoring

B.4. Measurement of Complications

We identified potential complications from anesthesia using information from the American Society of Anesthesiologists.[1] We mapped those complications to ICD-9 diagnoses

[1] https://www.asahq.org/whensecondscount/anesthesia-101/effects-of-anesthesia/

codes. Minor complications included nausea and vomiting, drug-induced headaches, headache following lumbar puncture, hypothermia due to anesthesia, and disturbance due to anesthesia of skin (corresponding to ICD-9 codes 787.0, 339.3, 349.0, 995.89, and 782.0). Major complications included adverse events from anesthesia, malignant hyperhtemria or hyperprexia due to anesthesia, shock due ot anesthesia, poisoning by anesthestics, complications of administrating anesthetics, anoxic brain damage, and failure in dosage (corresponding to ICD-9 codes 995.22, 995.86, 995.4, 968, 668, 348.1, and E873). Other complications included throat pain, backache, or hematoma as a complication (748.1, 724.6, and 998.11). For each beneficiary visit with an anesthesia claim, we examined whether these diagnoses for complications were additionally listed.