Surgical Robots Help Females Break the Career Glass Ceiling: Evidence from da Vinci Adoption

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Abstract

We study whether skill-biased technology can reduce gender barriers within an elite high-skill occupation. Exploiting staggered adoption of the da Vinci surgical system across Chinese hospitals, we estimate its effects on the gender composition of surgical teams using an estimation window spanning two years before and after the first robotic surgery. Robot adoption raises the female share of surgeons by 4-5 percentage points and the probability of a female chief surgeon by 40 percentage points. Notably, overall representation effects emerge half a year following the first robotic surgery, preceding promotion effects which manifest after one year. The mechanism operates through a quality-and-complexity channel rather than workload reallocation: female surgeons' case shares remain unchanged, while they shift toward higher-grade procedures and their patients experience significant reductions in 30-day readmission rates following adoption. These results suggest that technology can reshape comparative advantage inside high-skill professions, not merely redirect workers across them.

Keywords: Technological change; Gender inequality; Robotic surgery; Career advancement

JEL Classifications: J16, J44, O33, I11, J62

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1 Introduction

Gender gaps in high-skill professions are large and persistent. Across corporate leadership, academia, law, and medicine, women now constitute roughly half of entry-level professionals, yet their presence declines sharply at senior and leadership roles.[1] Surgery is an extreme case. Women account for just 24.9% of general surgeons in the United States, falling to 6.5% in orthopedic surgery (Association of American Medical Colleges, 2024), and a mere 6% in China (Bai, 2021).[2] This gap reflects structural barriers rooted in the physical demands of surgery, the gendered nature of mentorship networks, and performance evaluation norms that have long favored male surgeons. Can technology dismantle these barriers? In this paper, we show that the answer is **yes**.

We study this question in the context of robotic surgery. The da Vinci surgical system transforms the surgical procedure in ways that specifically reduce barriers faced by women. It allows surgeons to operate seated at a console with three-dimensional high-definition vision, seven degrees of freedom, and built-in tremor filtration. These features reduce the premium on upper-body strength and ergonomic endurance, which disproportionately disadvantage female surgeons in traditional procedures (Kono et al., 2024; Piyadeoglu et al., 2025; Adams et al., 2004; Fenton et al., 2008; Sutton et al., 2014). Standardized simulation-based training also reduces reliance on the predominantly male senior surgeon as gatekeeper to skill acquisition (Soomro et al., 2019; Mwipatayi et al., 2020; Silver et al., 2024; Chen et al., 2025). By reducing performance variability, the system further attenuates the gender punishment gap documented in the literature: women face harsher penalties than men for equivalent mistakes (Egan, Matvos and Seru, 2022; Sarsons, 2025). Taken together, these

[1] See, for example, Wood, Corcoran and Courant (1993) on lawyers; Bertrand, Goldin and Katz (2010); Huang, Mayer and Miller (2024) on corporate managers; Sasser (2005); Reyes (2006) on physicians; Murciano-Goroff (2022) on software engineers; and Preston (2004); Ginther and Kahn (2009, 2004); Ginther (2006) on science and academic professionals.

[2] While female representation in medicine has reached a historic milestone—with women comprising over half of all doctors across OECD countries for the first time in 2023—a distinct gender gap persists across specialties. Female physicians remain concentrated in general medicine and pediatrics, and are largely absent from surgery (OECD, 2025).

channels suggest that women hold a comparative advantage in the robotic surgeries relative to traditional open surgeries.

To study this question, we exploit the staggered adoption of the da Vinci surgical system across China. Our data combine inpatient electronic medical records from 526 general surgery departments in 298 tier-3A hospitals over 2016–2023 with the universe of robotic procedure records in China.

We document three findings. First, da Vinci adoption substantially raises female representation: the female surgeon share increases by 4–5 percentage points, the share of female department heads rises by 6–8 percentage points, and the probability that a department has a female chief surgeon rises by about 40 percentage points. Promotion effects appear before overall representation effects, consistent with a female leadership pipeline mechanism. Second, the gains are concentrated among junior cohorts, with female residents becoming significantly more likely to enter adopting departments.

Our first contribution is to the literature on technology and gender gap in labor market performance.[3] Prior work shows that new technologies can reshape the task content of jobs and thereby alter the relative productivity of men and women, in settings ranging from agriculture to weaving to computer-based occupations. We extend this literature to a high-skill, elite profession. Rather than reallocating workers across occupations, we show that technology can reshape comparative advantage within surgery, enabling women to take on more complex procedures, improve performance, and advance in the career hierarchy.[4]

Our second contribution is to the economics of medical innovation (Cutler and Huckman, 2003; Skinner and Staiger, 2015). Existing work focuses on effects of medical innovation on patient health outcomes, healthcare costs, and social welfare (Drummond et al., 2005; Jay-

[3]See, for example, Goldin and Katz (2008); Acemoglu and Autor (2011); Boserup (1970); Alesina, Giuliano and Nunn (2013); Xue (2025); Juhn, Ujhelyi and Villegas-Sanchez (2014); Black and Spitz-Oener (2010); Autor and Dorn (2013); Goos, Manning and Salomons (2014); Michaels, Natraj and Van Reenen (2014).

[4]Tafti (2023) shows that surgical robot adoption narrows performance gaps across surgeons, consistent with our finding of a comparative advantage shift.

achandran, Lleras-Muney and Smith, 2010; Lazuka, 2023; Lakdawalla, Malani and Reif, 2017; Jones, 2016; Koijen, Philipson and Uhlig, 2016; Frankovic, Kuhn and Wrzaczek, 2020; Murphy and Topel, 2006). We highlight a distinct and understudied channel: medical innovation reshapes the physician labor market, determining who enters, how effort is allocated, and who advances within medical hierarchies.

Our third contribution is to the literature on female leadership and the gender pipeline (Beaman et al., 2012; Kunze and Miller, 2017; Carrell, Page and West, 2010; Neumark and Gardecki, 1998; Porter and Serra, 2020). Prior work documents that female leaders serve as role models and are more likely to promote female talent. We provide causal evidence of the dynamic through which this pipeline operates: robot adoption first promotes women into leadership, and leadership subsequently drives entry. This promotion-before-representation pattern identifies the direction of causality in the pipeline mechanism.

The remainder of the paper proceeds as follows. Section 2 describes the da Vinci system and discusses its implications for gender gap in surgical performance. Section 3 describes the data. Section 4 presents the empirical strategy. Section 5 reports the main results on female representation and promotion. Section 6 examines mechanisms. Section 7 concludes.

2 Background

2.1 The Rise of Surgical Robots

Surgical technique has passed through two major transitions over the past four decades. The first, beginning in the 1980s, replaced a substantial share of open procedures with minimally invasive laparoscopy, which reduced incision size and length of stay but imposed new ergonomic and visual constraints on the surgeon: two-dimensional monitors, long rigid instruments operating through fixed ports, and awkward standing postures that have been

linked to musculoskeletal strain (Sutton et al., 2014). The second transition, beginning with the FDA approval of the da Vinci system in 2000, introduced a robotic interface between the surgeon and the patient. Rather than replacing laparoscopy, the robot extends it, but it also alters several features of how surgical work is performed.

The da Vinci system, manufactured by Intuitive Surgical, is the globally dominant robotic surgical platform. It comprises three components: a surgeon console, a vision cart, and a patient-side cart with four robotic arms. The surgeon operates from a seated position at the console, controlling wristed instruments and a stereoscopic endoscope attached to the robotic arms. The vision system delivers a high-definition, three-dimensional view of the surgical field with up to ten-fold magnification; the instruments are tremor-filtered and offer seven degrees of freedom, compared with four in conventional laparoscopic instruments. These design features are intended to improve precision and reduce fatigue, and have been associated with smaller incisions, lower estimated blood loss, and shorter recovery times for a range of procedures. By the end of 2021, the cumulative number of surgeries performed globally using da Vinci systems had exceeded 10 million, with installations of 6,500 systems spanning 67 countries.[5] By 2024, more than 76,000 surgeons worldwide had been trained for da Vinci systems, and over 14 million surgeries have been performed using the platform.[6]

Diffusion in China has been rapid but uneven. The first da Vinci system was installed at the People's Liberation Army General Hospital in Beijing in 2006. Adoption was limited during the first several years and accelerated after 2013, following a combination of falling unit costs, expanded provincial approval for tier-3A hospital procurement, and a growing pool of certified robotic surgeons. Figure 1 plots cumulative installations and the annual volume of robotic procedures in China from 2006 to 2021. By 2021, approximately 89,500 procedures were performed using the system nationwide. The staggered rollout across hospitals is the source of variation we exploit in the empirical analysis.

[5] https://isrg.intuitive.com/news-releases/news-release-details/intuitive-reaches-10-million-procedures-performed-using-da-vinci/

[6] https://www.intuitive.com/en-us/patients/da-vinci-robotic-surgery

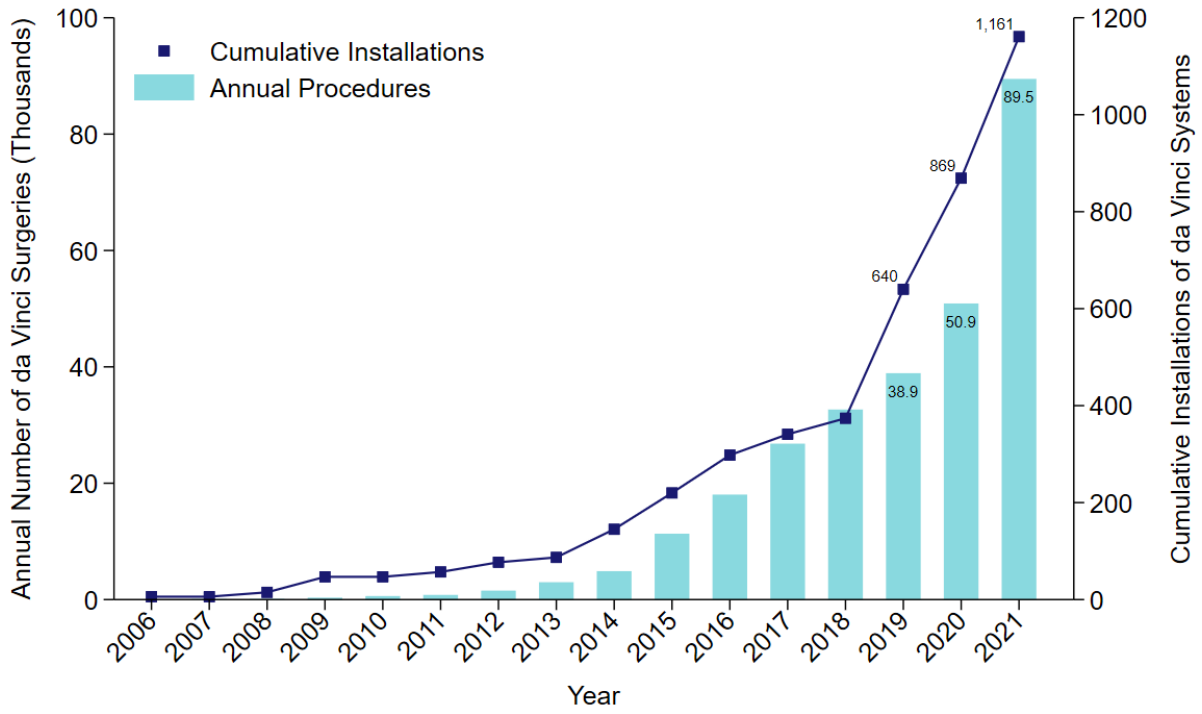


Figure 1: The Adoption of and Procedures Performed by da Vinci Surgical Systems in China

Notes: This figure illustrates the cumulative installations of the da Vinci surgical systems, along with the annual number of procedures performed by the system in China from 2006 to 2021.

2.2 Gender Gap in Surgical Performance

The da Vinci system alters the surgeon's job along five margins that the prior literature has linked, directly or indirectly, to the gender composition of surgical departments. Specifically, by standardizing skill acquisition, alleviating physical and visuospatial demands, augmenting fine motor control, and compressing the variance of errors, the system systematically diminishes the comparative advantage traditionally held by men in surgery. We summarize each in turn and return to them when we interpret our empirical results.

Training and mentorship. Surgical skill is traditionally transmitted through a hands-on apprenticeship in which residents learn intraoperatively under the supervision of senior surgeons. Senior surgeons are predominantly male, and evidence from both the United States

and China indicates that male-skewed mentorship networks can disadvantage female trainees: female medical students report preferring female mentors but being more frequently matched with male ones (Luc, Stamp and Antonoff, 2018); survey evidence suggests that some male academic surgeons perceive surgery as a less suitable career for women (Ahmadiyeh et al., 2010); and a majority of female medical students who opt out of surgery cite the anticipated absence of supportive mentorship as a factor (Zhou et al., 2022). Robotic training partially substitutes simulator-based instruction for mentor-dependent intraoperative learning. The standard da Vinci training pathway combines online didactics, dual-console observation, and virtual-reality simulation before live cases (Soomro et al., 2019; Mwipatayi et al., 2020); these components reduce, though do not eliminate, the dependence of skill acquisition on access to individual senior mentors.[7]

Physical demands. Traditional open and laparoscopic surgery place the surgeon in a standing posture for the duration of the procedure, with sustained static loading on the shoulders, lower back, and wrists. Sutton et al. (2014) document that female laparoscopic surgeons report higher rates of shoulder pain and work-related hand injury than their male colleagues, a pattern they attribute to the design of operating rooms and instruments around surgeons with larger hands and longer reach (Adams et al., 2004; Fenton et al., 2008). Survey evidence from Chinese hospitals suggests that female surgeons are more likely to report physical discomfort and inadequate fit of laparoscopic devices (Wong, Moore and Carey, 2022). The da Vinci console permits the surgeon to operate seated, with the arms supported and the field of view adjusted to individual ergonomics, and removes direct physical contact with the patient. These changes have been associated with lower self-reported physical strain across surgeons in general (Dalsgaard et al., 2020; Hislop et al., 2024), and may have disproportionate benefits for surgeons with smaller hands or shorter reach.

[7] See https://www.intuitive.com/en-us/-/media/ISI/Intuitive/Pdf/davinci-resident-fellows-training-guide-1024650-.pdf for Intuitive Surgical's official training curriculum.

Visuospatial demands. Conventional laparoscopy requires the surgeon to reconstruct a three-dimensional operative field from a two-dimensional video display. The prior literature documents average gender differences in performance on conventional visuospatial tasks (Schueneman, Pickleman and Freeark, 1985; Donnon, DesCôteaux and Violato, 2005; Ali et al., 2015), which some studies have linked to performance on laparoscopic training tasks. The da Vinci console provides a stereoscopic, magnified view of the surgical field, and Byrn et al. (2007) find that the three-dimensional vision it provides improves performance time and reduces error rates for novice and experienced laparoscopic surgeons alike during simulated tasks. Chiu et al. (2020), in a controlled comparison of 39 male and 19 female medical students on a robotic suturing task, report that female students outperform male students on a virtual-reality component and achieve a higher number of stitches with comparable quality on the physical simulator. We read this as suggestive evidence that the design of the da Vinci interface may narrow, rather than widen, the gender performance gap that has been documented in earlier laparoscopic settings.

Ambidexterity and fine motor control. The adoption of the da Vinci surgical system may attenuate the gender gap in ambidexterity. Constrained by the four degrees of freedom in conventional laparoscopy, surgeons exhibit a pronounced right-hand advantage (Moorthy et al., 2004; Choussein et al., 2018), with right-handed males exhibiting greater ambidexterity than right-handed females on virtual-reality endoscopic manipulations (Elneel et al., 2008). By providing seven degrees of freedom and utilizing wristed end effectors that filter hand tremors, the da Vinci system augments the motor capabilities of both upper limbs and reduces the operational reliance on the non-dominant hand. Consequently, this technological advancement reshapes comparative advantage in favor of female surgeons.

Gender-asymmetric response to errors. A related strand of the literature documents that women in professional settings face harsher reputational penalties than men for com-

parable mistakes (Egan, Matvos and Seru, 2022; Sarsons, 2025). To the extent that surgical robots reduce intraoperative error rates and compresses the variance of surgical output across operators (Tafti, 2023), it narrows the space within which asymmetric punishment can operate, even if it does not change the underlying evaluation norms. We return to this channel when interpreting the promotion results in Section 5.

In sum, the technological advancement has changed both the training methods and skill requirements for surgeons. The adoption of surgical systems reduces the demand for physical strength, spatial reasoning, as well as ambidexterity in surgical procedures. Consequently, the traditional comparative advantage held by men may diminish, potentially paving the way for greater female participation in surgical fields. While our data do not allow us to empirically disentangle these mechanisms, they collectively yield a testable implication. Specifically, if more females choose to enter surgical specialties or perform a greater number of more complex procedures, this would suggest that the da Vinci surgical system has shifted the comparative advantage between male and female surgeons, thereby relaxing the constraints on females' specialty choice and career development.

Figure 2 documents the evolution of the average annual number of da Vinci surgeries performed per surgeon by gender, utilizing the full sample of adopting departments. Since the second year after the installation of the da Vinci surgical system in the department, female surgeons, on average, perform more da Vinci surgeries annually than their male counterparts.[8] After the adoption of the da Vinci surgical system, the average annual volume of da Vinci surgeries performed by female surgeons gradually surpasses that of male surgeons, likely driven by the impact of surgical system adoption on gender-based differences in comparative advantage.

[8]To ensure sample homogeneity, we replicate this analysis in Appendix Figure A1 by restricting the sample to a balanced panel of hospital departments and surgeons with at least seven years of continuous adoption; the findings remain consistent.

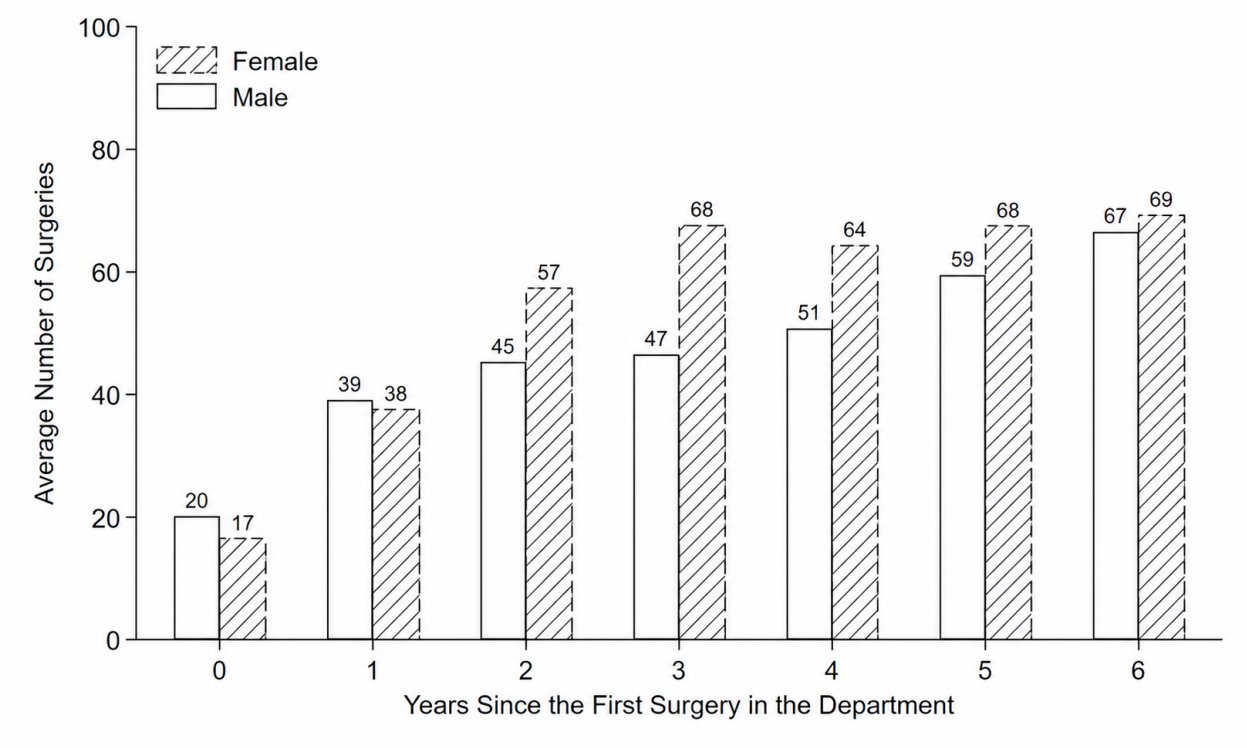


Figure 2: Number of da Vinci Surgeries per Surgeon by Gender

Notes: This figure depicts the evolution of per surgeon da Vinci surgical volume by gender over the years since the first procedure performed using the da Vinci surgical system in hospital departments. The sample consists of all da Vinci procedures in hospital departments that had adopted the da Vinci surgical system by 2021.

3 Data

We use three administrative datasets. The primary data are inpatient electronic medical records from tier-3, grade-A hospitals, the main adopters of the da Vinci system in China. For each inpatient admission, the data record the hierarchical composition of the surgical team, the complexity of the procedure, and patient health outcomes. The second dataset documents the exact adoption timing of the da Vinci system at the hospital-department level, establishing the treatment status for our empirical design. The third dataset provides granular, procedure-level records of all da Vinci surgeries, allowing us to track the robotic surgical volume of individual male and female surgeons. The large sample size, as well as the availability of detailed information, enable a comprehensive analysis of the surgical

performance and the career advancement of female and male surgeons.

3.1 Data Sources

To examine the effects of the adoption of da Vinci surgical systems on gender gap, we draw on three datasets. The first data records the months in which da Vinci systems are installed and first utilized at 284 hospitals in China from 2006 to 2023. The procurement of surgical robots in China is subject to strict regulations; hospitals must secure a specific allocation quota from the National Health Commission prior to purchase. Despite the stringent regulation, the diffusion of robotic surgery systems (RSS) has accelerated markedly over the past decade. The second data includes the universe of procedures performed using da Vinci surgical systems in China. It provides granular, procedure-level records, specifying the name of the surgeon, the operating hospital, and the date of the surgery. From 2007 to 2022, this dataset documents 314,138 da Vinci procedures conducted by 282 female surgeons and 2,349 male surgeons. The fact that female surgeons make up only 10.7% of robotic-assisted surgeons underscores their underrepresentation in this profession. The third dataset consists of the face sheets of inpatient electronic medical records (EMR) from 298 tier-3, grade-A hospitals across China. These records contain patient-level information, including demographics, ICD-10-CM disease classifications, surgical grades, and detailed breakdowns of medical expenditures.

This combined dataset offers three advantages for our study. First, it ensures reliability and uniformity, as the face sheet of the inpatient medical record is a standardized, mandatory reporting document required by the National Health Commission. Second, the standardized documentation perfectly mirrors the hierarchical career ladder within Chinese hospitals—sequentially listing the department head, chief surgeon, attending surgeon, and resident—allowing us to map organizational structures and track individual career trajectories. This also enables us to ascertain the surgeons' professional titles and predict their gender based on

their names using the "ngender" algorithm, which achieves an accuracy rate of approximately 82%.[9] Finally, our focus on tier-3, grade-A hospitals ensures a highly representative sample, as they are the primary adopters of the da Vinci system—the dominant surgical robot in China. Tier-3, grade-A hospitals represent the apex of China's hospital classification system. They are typically large and resource-abundant, managing the most complex and severe medical cases, which makes them the primary adopters of cutting-edge medical technologies like surgical robots.

3.2 Sample Definition

We construct the sample through the following steps. First, we begin with the universe of inpatient medical records from January 1, 2016, to December 31, 2023. Second, we exclude all records from January to April 2020 to net out the confounding shock of the initial COVID-19 pandemic outbreak. Third, we restrict the sample to general surgery departments. We focus on general surgery for two reasons. First, unlike highly specialized departments such as gynecology or urology—which often exhibit inherent gender-skewed sorting—general surgery is a gender-neutral department, established in nearly all hospitals. Second, general surgery is a major adopter of da Vinci surgical systems. Between 2006 and 2021, it accounts for 23.72% of all da Vinci surgeries in China, making it the second-largest adopting department after urology. Furthermore, The department encompasses a wide range of procedures, including gastrointestinal, hepatobiliary, and pancreatic surgeries, ensuring a large sample. Fourth, to construct our treatment variable, we merge the inpatient medical records with the da Vinci adoption data using hospital and department identifiers. This allows us to pinpoint the month of the initial da Vinci surgery for each department. Finally, the sample includes 42 hospitals that have adopted the da Vinci systems during our study period and 256 hospitals that have not. The sample of ever-treated hospital departments includes 121 departments,

[9] https://pypi.org/project/ngender/

3,288 surgeons, and 2,247,703 patients across 42 hospitals.

We aggregate the patient-level records to two distinct levels tailored to our empirical analysis. For the baseline analysis of female representation and promotion, we collapse the data to the hospital-department-by-half-year level. Specifically, we compute the head-counts of surgeons and their surgical volumes, both disaggregated by gender, within each department-period cell. To explore mechanisms regarding surgical complexity and expenses, we construct a finer panel at the surgeon-by-quarter level. At this level, we calculate the frequency and share of procedures across the four complexity grades for each surgeon, while also computing the average medical expenditures incurred by the patients they manage.

3.3 Variable Constructions

Female Representation and Promotion. We construct two types of indicators to measure gender composition across four career titles, namely department heads, chief surgeons, attending surgeons, and residents. Among these, department heads and chief surgeons are typically more seasoned surgeons, and changes in their gender composition can reflect shifts in promotion opportunities for females. In contrast, attending surgeons and residents are less experienced, primarily reflecting the gender composition of junior surgeons. As for the extensive margin, we define an indicator variable equal to one if there is at least one female in the corresponding title, and zero otherwise. As for the intensive margin, we calculate the share of female surgeons in the corresponding title.

Surgical Complexity and Medical Expenses. First, we rely on the official surgical grading system, which classifies procedures from Level I (least complex) to Level IV (most complex), to measure surgical complexity. Level I surgeries are classified as low-risk procedures that are relatively simple and involve minimal technical difficulty. Level II surgeries involve a moderate level of risk, average procedural complexity, and a moderate degree of

technical difficulty. Level III surgeries are considered high-risk operations that are more intricate and technically challenging. Level IV surgeries refer to major surgeries characterized by high risk, substantial procedural complexity, and significant technical difficulty. We compute the share of procedures at each complexity level as a fraction of a surgeon's total quarterly procedure volume. Second, we use disaggregated medical expenditures—specifically diagnostic, treatment, and medical service fees—to measure the medical expenses. For each surgeon-quarter, we compute the average expenditures incurred per patient across these categories, and subsequently apply a logarithmic transformation to these averages.

Healthcare Quality. We measure healthcare quality using two primary patient outcomes. The first is a binary indicator for 30-day inpatient readmission, which equals one if a patient is rehospitalized within 30 days of discharge, and zero otherwise. The second measure is an indicator for whether the patient is discharged per physician's orders. Discharge dispositions are classified into six categories: discharge per physician's order, transfer per physician's order to another hospital, transfer to a community healthcare center or township hospital, discharge against medical advice, death, and other. Discharge per physician's order is regarded as the expected discharge outcome.

Patient Controls. We include a set of demographic and baseline health status controls in the patient level analysis. As for patient demographics, we control for patient gender and nine discrete age groups: 0–14, 15–19, 20–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75 and over. As for baseline health status, we classify primary diagnoses into 20 distinct categories based on the first three digits of the International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) codes. Furthermore, we include the Charlson comorbidity index, calculated following the coding algorithm established by Quan et al. (2005), to capture the potential influence of pre-existing chronic conditions on surgical outcomes.[10] Additionally,

[10]See Appendix Table A1 for summary statistics.

each medical record documents the patient's age, gender, exact dates of admission and discharge, discharge disposition, and disease classification based on ICD-10-CM codes. It also records whether a surgery is performed and its specific grade. Furthermore, the records contain a granular breakdown of medical expenses, explicitly disaggregating total costs into diagnostic fees, treatment fees, and medical service fees, among others. These financial measures serve as proxies for the intensity of medical care and surgical complexity.

3.4 Summary Statistics

Appendix Table A1 presents summary statistics for these ever-treated hospital departments, including personnel composition, workload, surgical complexity, and healthcare quality before and after the adoption of the da Vinci surgical systems.

Panel A of Appendix Table A1 illustrates the personnel composition. Prior to adoption, female surgeons account for an average of only 15% of all surgeons. This underrepresentation intensifies sharply at the top of the professional hierarchy: females represent 8% of department heads, 10% of chief surgeons, 14% of attending surgeons, and 22% of residents. On average, only 28% of general surgery departments are headed by a female department head, and 44% have a female chief surgeon. Following the adoption of the system, we observe a shift in leadership representation: the share of female department heads modestly increases to 9%, while 32% and 45% of the departments feature a female department head and a female chief surgeon, respectively.

Panel B of Appendix Table A1 presents summary statistics on workloads and surgical complexity. We use the surgical grading system—ranging from Level I (least complex) to Level IV (most complex and high-risk)—to proxy the task allocation among surgeons. In terms of workload, prior to adoption, female surgeons treat 12% of patients and perform 13% of surgeries on average. For male surgeons, Level I through Level IV surgeries account for an average of 13%, 30%, 37%, and 20% of their quarterly surgical volume, respectively; for

female surgeons, the corresponding shares are 14%, 31%, 33%, and 22%. After adoption, the shares of Level I and Level II surgeries among male surgeons decline to 11% and 26%, while the share of Level IV surgeries increases to 26%. For female surgeons, the shares of Level I and Level II surgeries decrease to 10% and 30%, whereas Level III and Level IV surgeries rise to 38% and 23%, respectively. Concurrently, the average total medical expenditures increase for patients treated by both male (from 21,387.90 yuan to 23,308.80 yuan) and female surgeons (from 22,031.83 yuan to 22,728.34 yuan). The increases in both surgical levels and medical expenditures suggest that male and female surgeons have been handling more complex cases after the adoption of the da Vinci surgical systems.

Panel C of Appendix Table A1 presents summary statistics related to healthcare quality and patient characteristics. Importantly, the shift toward more complex procedures is accompanied by improvements in surgical outcomes. After the adoption of the da Vinci surgical systems, the 30-day readmission rates for patients treated by male and female surgeons decrease from 19% to 13% and from 19% to 14%, respectively, indicating an improvement in the quality of healthcare.

4 Empirical Strategy

We estimate the event-study model in equation (1) to identify the dynamic effects of da Vinci adoption on the gender composition of general surgery departments.

$$Y_{it} = \sum_{k=-4,\, k\neq -1}^{k=4} \beta_k daVinci_{it,\,k} + \delta_i + \eta_t + \varepsilon_{it}, \tag{1}$$

where Y_{it} is the outcome of interest for hospital-department i in period t. In the department-level analysis, a period refers to a half-year. We examine the presence of females and their shares across different titles—department head, chief surgeon, attending

surgeon, and resident. $daVinci_{it,k}$ is an indicator variable that equals 1 if, period t is k periods relative to the first da Vinci procedure in hospital-department i, and 0 otherwise. The estimation window spans from two years before the first surgery to two years after. We omit $k = -1$, the period immediately before the first da Vinci procedure, as the baseline period. In addition, we control for hospital-department fixed effects, δ_i, and period fixed effects, η_t. ϵ_{it} represents the idiosyncratic error term. Standard errors are clustered at the hospital-department level.

To interpret the coefficients β_k as ATT of da Vinci adoption, our event-study design requires three identifying assumptions: parallel trends, no anticipation, and homogeneous dynamic treatment effects across groups. We summarize institutional and empirical evidence supporting the validity of the identifying assumptions.

Parallel trends. Parallel trends require that, absent da Vinci adoption, adopting and comparison hospital-departments have the same time trends in female representation and promotion. The pre-adoption estimates provide suggestive evidence in favor of the parallel trends assumption.

No anticipation. No anticipation requires that departments do not adjust their gender composition in response to future da Vinci adoption before the first da Vinci procedure. The assumption is plausible because changes in department personnel are typically low-frequency organizational decisions governed by formal appointment, promotion, and recruitment procedures. To mitigate concerns regarding potential anticipatory personnel adjustments prior to the formal adoption of the da Vinci surgical system, we assess the robustness of our estimates using alternative definitions of treatment timing, notably the installation month.

Homogeneous treatment effects across groups.

In our setting, the assumption requires that, while ATT can change over event time, the magnitude of the effect at any given event time is invariant across hospital-departments regardless of their adoption timing. In robustness analysis, we replicate the baseline results

using heterogeneity-robust estimators.

5 Effects of Surgical Robots on Gender Gap

This section presents the main results on effects of da Vinci surgical system adoption on gender gap within surgical departments. We first examine changes in overall female representation and then turn to promotion outcomes in senior positions.

5.1 Female Representation in Surgical Departments

Panel A of Figure 3 presents event-study estimates of the impact of da Vinci surgical system adoption on female representation in surgical departments. Appendix Table A2 reports the corresponding coefficient estimates. Panel A reports the effect on the share of female surgeons. The pre-adoption coefficients are close to zero, indicating no differential trends prior to robot adoption. Following adoption, the female share rises gradually. The estimates become positive several half-years after adoption and reach roughly 4–5 percentage points by one or more years after adoption.

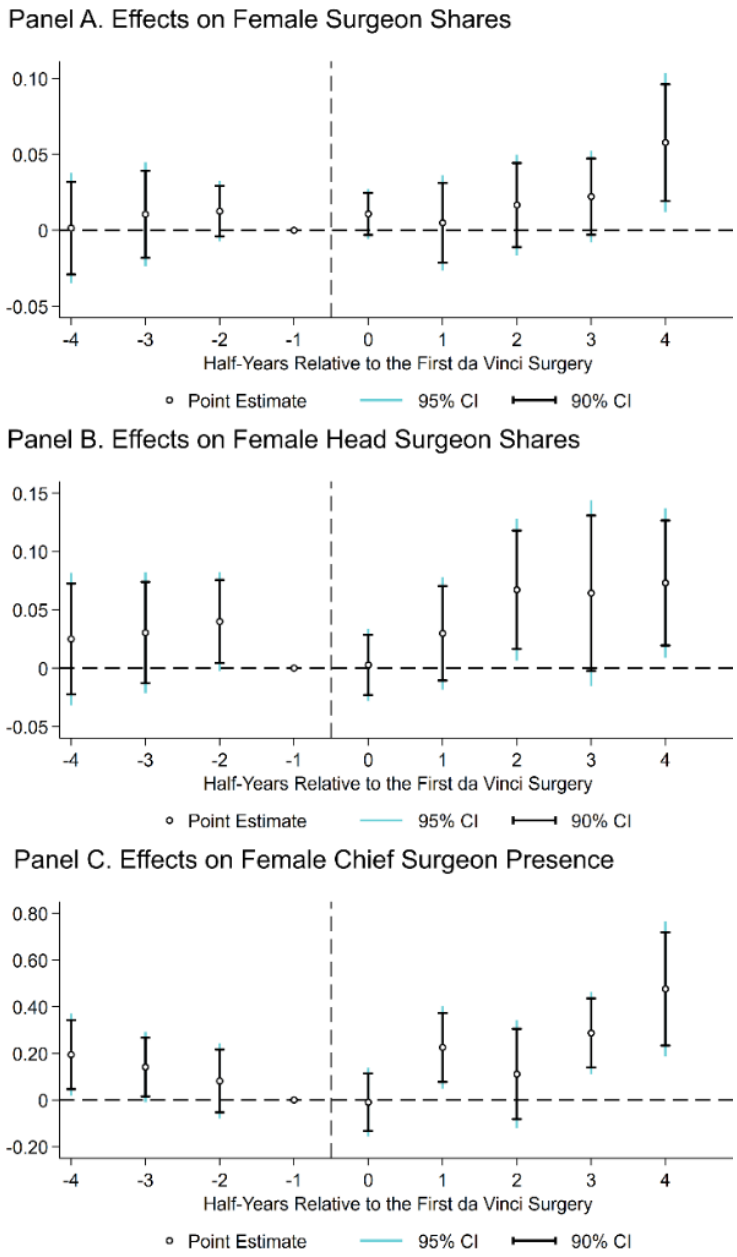


Figure 3: Impact of Robot Adoption on Female Representation

Notes: This figure illustrates the dynamic effects of robot adoption on the share of female surgeons. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while blue and pink bars indicate 95% and 90% confidence intervals, respectively. Standard errors are clustered at the hospital-department level. Corresponding results are reported in column (1) of Appendix Table A2.

5.2 Female Promotion into Senior Positions

Panels B and C of Figure 3 turn to senior positions within the surgical hierarchy. Appendix Table A3 reports the corresponding coefficient estimates. Panel B examines the share of female department heads. The pre-adoption coefficients are close to zero, indicating no systematic differences prior to robot adoption. Following adoption, the estimates increase gradually and reach roughly 6–8 percentage points in the later post-adoption periods. Panel C examines whether a department has at least one female chief surgeon. The pre-adoption coefficients again remain close to zero. After adoption, the coefficients rise steadily and reach about 0.4 in the later post-adoption periods, corresponding to roughly a 40-percentage-point increase in the probability that a department has at least one female chief surgeon.

Taken together, these results indicate that da Vinci surgical system adoption is associated not only with higher female representation in surgical departments, but also with increased female presence in senior leadership positions. An interesting feature of the dynamics is that improvements in female leadership appear earlier than changes in overall female representation. In particular, the increase in the share of female department heads and the probability of having a female chief surgeon occurs shortly after robot adoption, while the rise in the overall share of female surgeons becomes more pronounced only in later periods. One possible interpretation is that improvements in female leadership facilitate the recruitment or retention of additional female surgeons. This interpretation is consistent with evidence that female leaders can shape the aspirations and career choices of younger women through role-model effects and may also be more likely to identify and promote talented female workers within organizations (Beaman et al., 2012; Kunze and Miller, 2017; Lawson et al., 2022).

5.3 Robustness Checks

We conduct a series of robustness checks to verify that the main findings are not driven by specific variable definitions, sample selection, or model specifications.

First, we examine whether the results are sensitive to fixed-effect structures and control specifications. Appendix Figures 4 and 5, together with Appendix Tables A2 and A3, show that the dynamic effects remain similar across alternative fixed-effects. We also examine female presence using an indicator equal to one if the female share exceeds 5%. In addition, Appendix Figure A3 demonstrates that the baseline estimates remain stable after controlling for alternative sets of variables.

Second, since surgeon gender is inferred from names, we assess the sensitivity of the results to the confidence of the gender prediction procedure. Appendix Figure A2 plots the distribution of the predicted probability of correct gender classification. The distribution is concentrated near 1, suggesting that the algorithm classifies gender with high confidence for most surgeons. Appendix Table A5 estimates the effects on the female share after progressively restricting the sample to surgeons whose predicted gender probability exceeds increasing thresholds. Appendix Table A6 conducts the same exercise for the share of female department heads. The estimated post-adoption effects remain positive. This suggests that the main results are not driven by potential misclassification in the gender prediction algorithm. Appendix Figure A4 and Figure A5 plot the corresponding coefficient estimates.

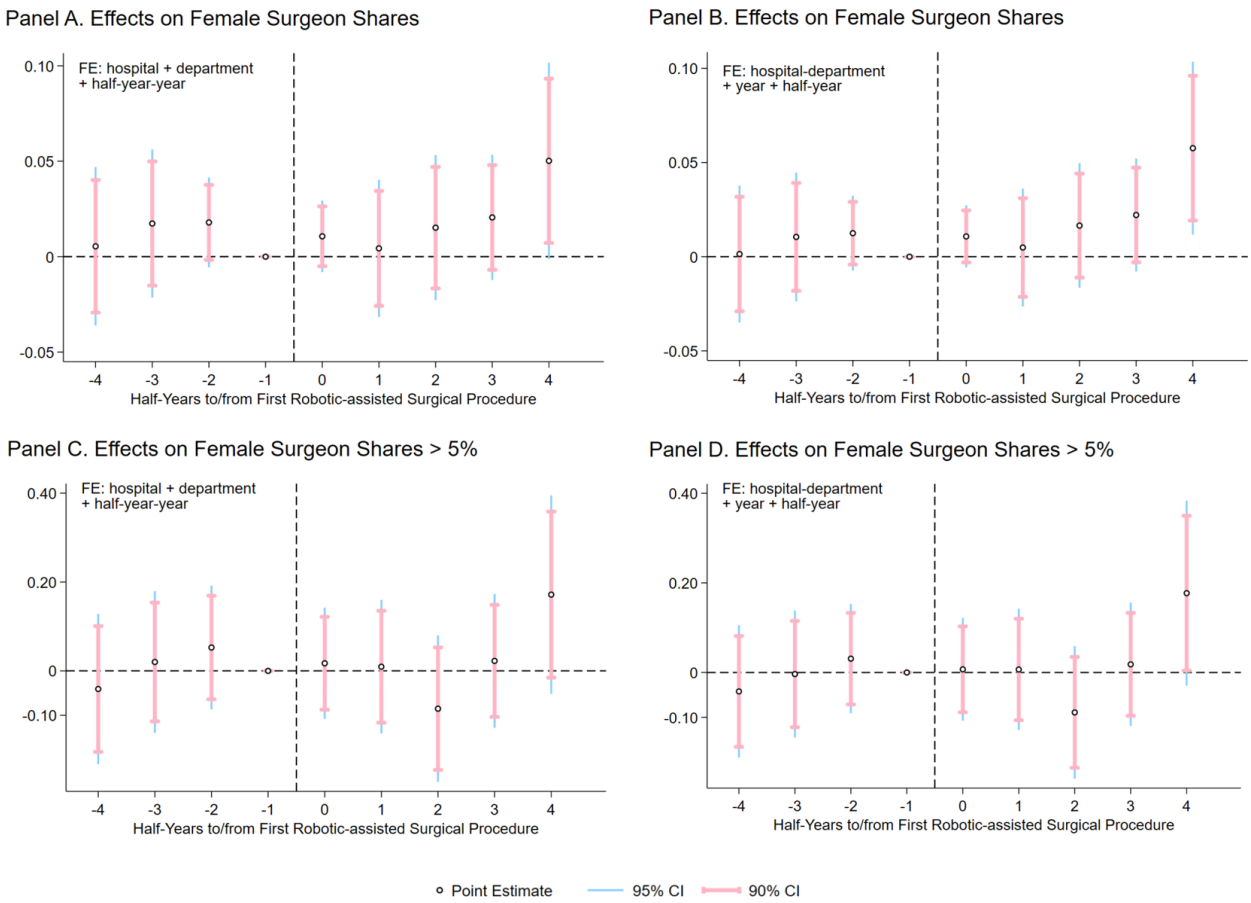


Figure 4: Impact of Robot Adoption on Female Representation

Notes: This figure illustrates the dynamic effects of robot adoption on female representation. Panels A and B plot the effects on the share of female surgeons. Panels C and D plot the effects on an indicator for whether the female share exceeds 5%. The estimates correspond to columns (2)–(3) and (5)–(6) of Appendix Table A2. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while blue and pink bars indicate 95% and 90% confidence intervals, respectively. Standard errors are clustered at the hospital-department level.

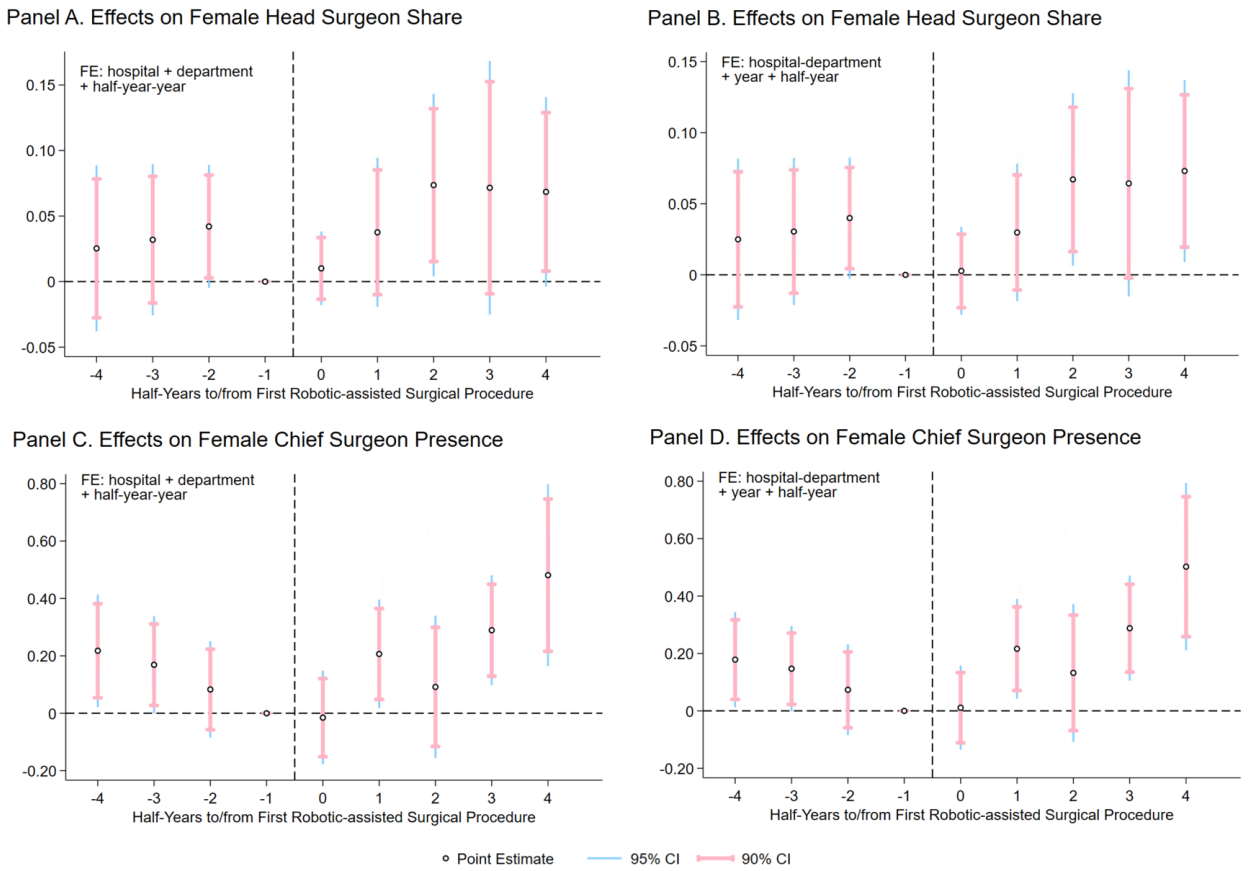


Figure 5: Impact of Robot Adoption on Female Promotion

Notes: This figure illustrates the dynamic effects of robot adoption on females' promotion opportunities. Panels A and B plot the effects on the share of female head surgeons. Panels C and D plot the effects on an indicator for whether a department has at least one female chief surgeon. The estimates correspond to columns (2)–(3) and (5)–(6) of Appendix Table A3. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the first use of the da Vinci surgical system. Dots denote point estimates, while blue and pink bars indicate 95% and 90% confidence intervals, respectively. Standard errors are clustered at the hospital-department level.

6 Mechanisms

How does the adoption of the da Vinci surgical system disproportionately benefit female surgeons, thereby narrowing the gender gap in both entry and career advancement within the general surgery department? To address this question, we investigate how robot adoption affects surgeons' workloads, the complexity of surgeries, and surgical quality. We also explore

how these factors are associated with the promotion outcomes.

6.1 Workloads

To examine whether the workload of female surgeons changes following the adoption of the da Vinci surgical system, we use hospital-department-by-half-year level data constructed as described in Section 4 and estimate the event-study specification outlined in equation (1). The dependent variables measure female surgeons' workloads, captured by the share of medical records managed by female surgeons and the share of surgical procedures performed by female surgeons.

Figure 6 and Appendix Table A7 report the effects of robot adoption on these workload measures. The estimated treatment effects are small and close to zero, indicating that the relative workload between female and male surgeons remains largely unchanged following robot adoption. These results suggest that changes in workload are unlikely to be the primary channel through which da Vinci surgical system affects gender gap in general surgery departments.

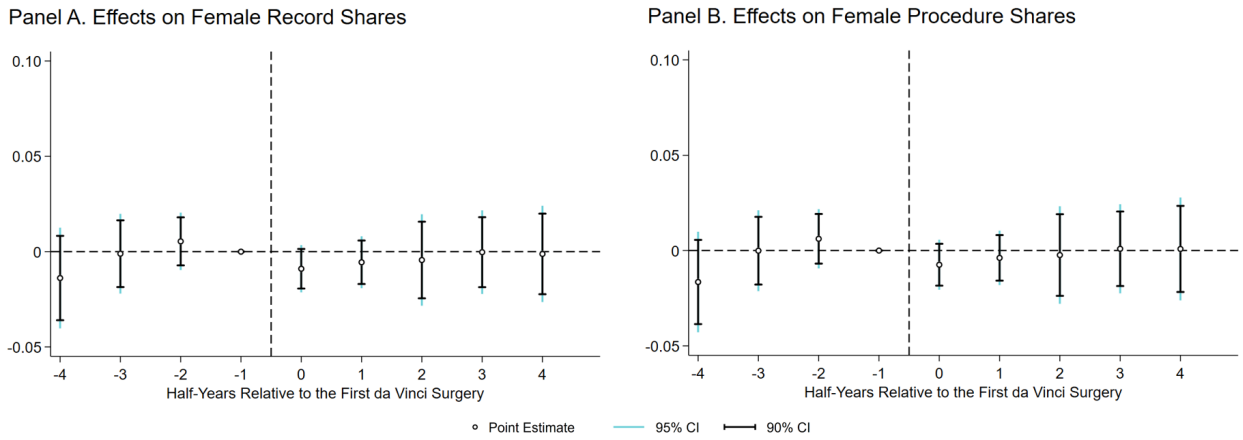


Figure 6: Impacts of Robot Adoption on Females' Workloads

Notes: This figure illustrates the dynamic effects of robot adoption on share of cases managed and surgeries performed by female surgeons. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while blue and pink bars indicate

95% and 90% confidence intervals, respectively. Standard errors are clustered at the hospital-department level. Corresponding results are reported in Appendix Table A7.

6.2 Complexity

We then examine potential changes of gender differences in surgical complexity induced by the adoption of the da Vinci surgical system. Specifically, we aggregate medical records at the surgeon-by-quarter level and estimate the following ordinary least squares (OLS) specification:

$$Y_{ijt} = \beta_1 daVinci_{it} + \delta_j + \eta_t + \varepsilon_{ijt} \tag{2}$$

where the dependent variables comprise two sets of measures capturing the complexity of surgeries and medical records. The first set consists of the proportion of surgeries at each complexity level among all procedures performed by surgeon j in quarter-year t in hospital-department i. The second set includes the natural logarithm of average medical expenditures incurred by the patients treated by surgeon j in quarter-year t. The key independent variable, $daVinci_{it}$, is an indicator equal to 1 if hospital-department i has adopted the da Vinci surgical system in quarter-year t, and 0 otherwise. Surgeon and quarter-year fixed effects are captured by δ_j and η_t, respectively. ε_{ijt} denotes the idiosyncratic error term. Standard errors are clustered at the hospital-department level.

Figure 7 and Appendix Table A8 present the gender-specific effects of robot adoption on the distribution of surgeries across different complexity levels. Each bar in Figure 7 corresponds to the estimated coefficient β_1 in equation (2). Among male surgeons, the adoption of the da Vinci surgical system significantly reduces the share of Level I (the least complex) surgeries by 3.3%, while increasing the shares of Level III and Level IV (the most complex) surgeries by 2.4% and 1.9%, respectively. For female surgeons, robot

adoption leads to declines in the shares of Level I through Level III surgeries, though these changes are not statistically significant. In contrast, the share of Level IV surgeries rises significantly by 5.2%. To evaluate whether these changes differ systematically by gender, we conduct permutation tests. The results show that gender differences in treatment effects are statistically significant for Level III and Level IV surgeries, suggesting a gendered impact on complex surgeries. Robot adoption substantially increases the volume of Level IV surgeries, the most complex and high-risk procedures, performed by female surgeons, while increasing the volume of Level III surgeries performed by male surgeons.

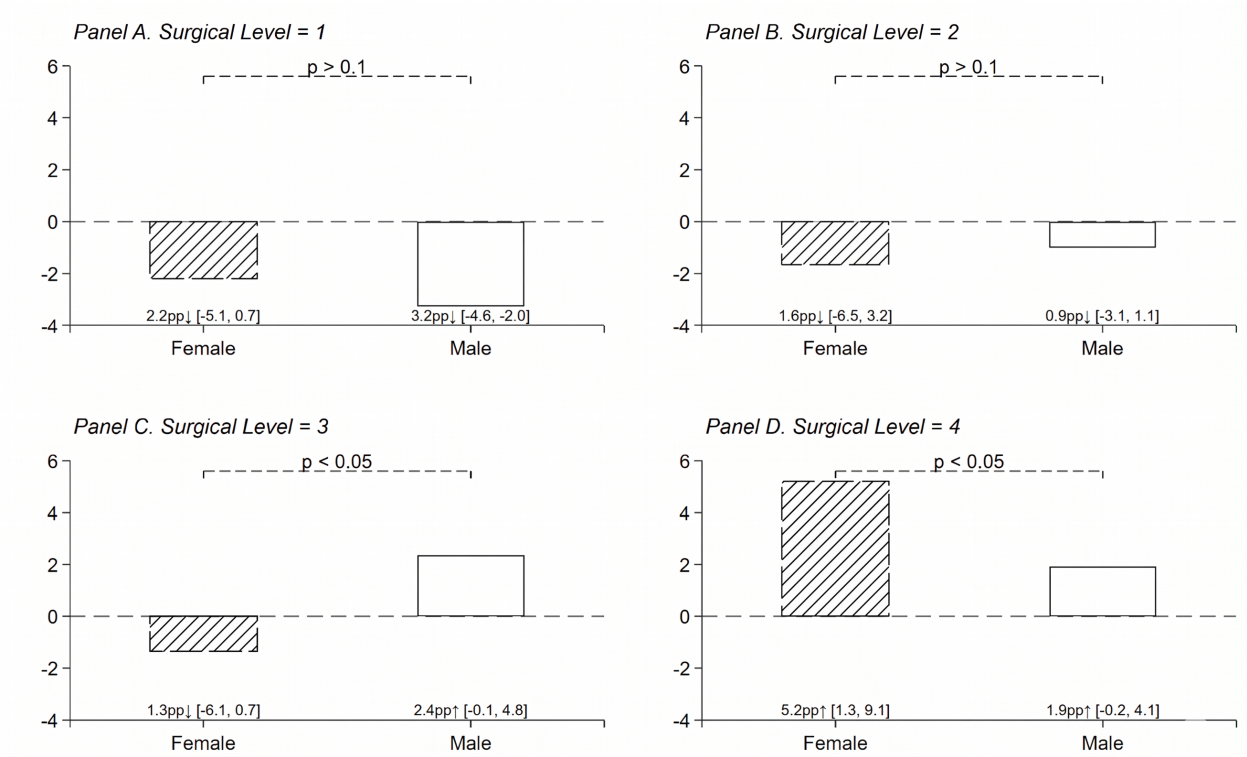


Figure 7: Impacts of Robot Adoption on Share of Surgeries by Surgical Level and Gender

Notes: This figure presents the impact of adopting da Vinci surgical robot on share of surgeries with different surgical levels, by the gender of the surgeon. Estimations are based on equation (2). Panels A through D correspond to Level I through Level IV surgeries, respectively. Level I surgeries are classified as low-risk procedures that are relatively simple and involve minimal technical difficulty. Level II surgeries involve a moderate level of risk, average procedural complexity, and a moderate degree of technical difficulty. Level III surgeries are considered high-risk operations that are more intricate and technically challenging. Level IV surgeries refer to major surgeries characterized by high risk, substantial procedural complexity, and significant technical difficulty. Each bar corresponds to a separate regression. Values on y axes denote percentage point (pp) changes. Values on x axes represent point estimates along with 95% confidence intervals. P-values are from permutation tests. The corresponding results are reported in Appendix Table A8.

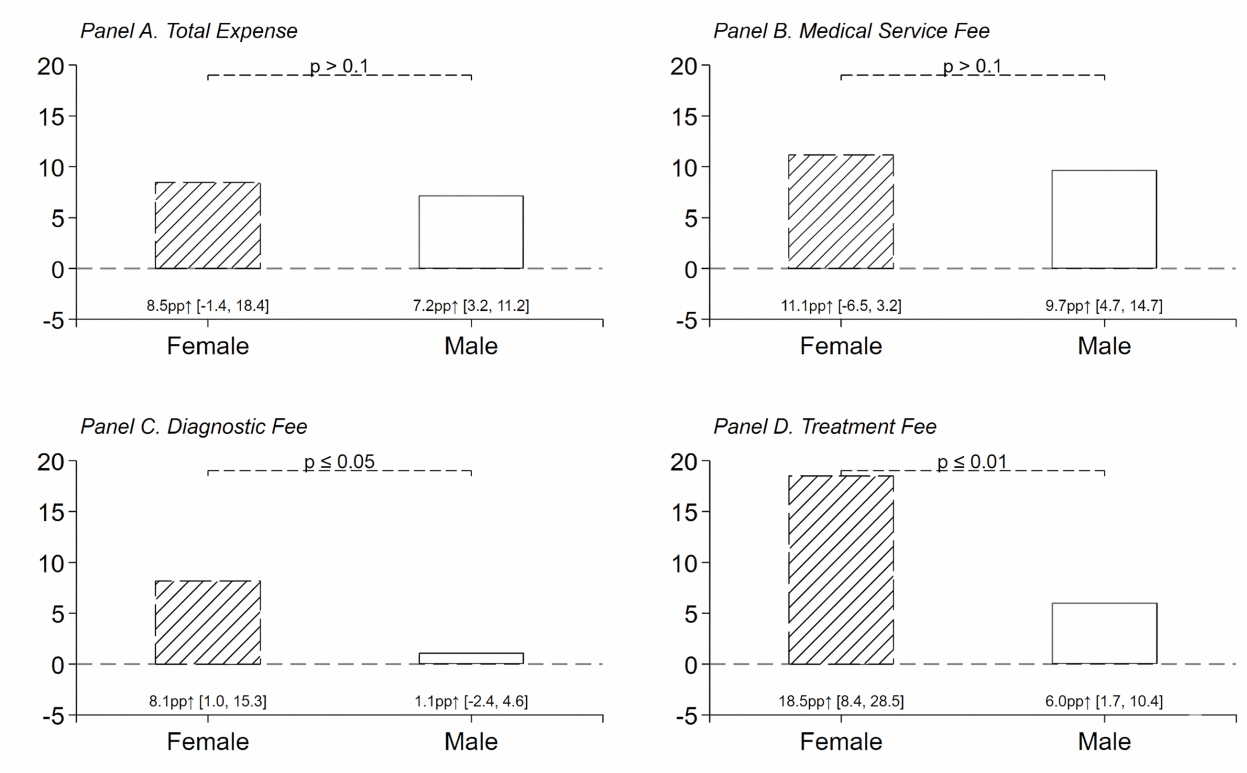


Figure 8: Impacts of Robot Adoption on Medical Expenditures by Gender

Notes: This figure presents the impact of adopting da Vinci surgical robot on medical expenditures, by the gender of the surgeon. Estimations are based on equation (2). Panels A through D correspond to total expenses, medical service fees, diagnostic fees, and treatment fees, respectively. Each bar corresponds to a separate regression. Values on y axes denote percentage point (pp) changes. Values on x axes represent point estimates along with 95% confidence intervals. P-values are from permutation tests. The corresponding results are reported in Appendix Table A11.

Figure 8 and Appendix Table A11 present the effects of robot adoption on various categories of medical expenditures incurred by patients treated by male and female surgeons. With the exception of diagnostic fees for patients of male surgeons, all expenditure categories increase significantly following robot adoption for both male and female surgeons' patients. In terms of total expenses and medical service fees, we find no statistically significant difference between male and female surgeons. However, diagnostic and treatment fees rise significantly more for patients treated by female surgeons. Specifically, diagnostic fees increase by 1.1% for patients of male surgeons and 8.1% for those of female surgeons; treatment fees rise by 6.0% and 18.5%, respectively. Diagnostic fees encompass charges for pathology, laboratory tests, imaging, and clinical evaluations, while treatment fees include

both surgical and non-surgical procedures. These two categories are the major components of overall medical expenses. The disproportionate increases in these fees for patients treated by female surgeons may reflect a higher volume of da Vinci surgeries—typically more expensive and complex than traditional open surgeries—performed by female surgeons. This aligns with our earlier finding that female surgeons perform a greater share of Level IV surgeries.

6.3 Quality

This subsection evaluates the effects of the da Vinci surgical system on surgical quality by surgeon gender. Our empirical specification is a event study model at the patient level that takes the following form:

$$Y_{pit} = \sum_{k=-4,\, k\neq -1}^{k=8} \beta_k daVinci_{it,\,k} + X_p + \delta_i + \eta_y + \eta_q + \varepsilon_{pt} \tag{3}$$

where p denotes a patient and i denotes a hospital-department. Y_{pit} is the outcome of interest, and we consider two measures of patient outcomes. The first is 30-day inpatient readmission, defined as a binary indicator equal to 1 if the patient is rehospitalized within 30 days of discharge, and 0 otherwise. The second is a dummy variable indicating whether the patient is discharged per physician's order[11].

The definition of $daVinci_{it,\,k}$ remains the same as before. Patient demographics X_p

[11]Discharge dispositions are classified into six categories: discharge per physician's order, transfer per physician's order to another hospital, transfer to a community healthcare center or township hospital, discharge against medical advice, death, and other. Discharge per physician's order is regarded as the expected discharge outcome.

include gender, age group[12], diagnostic category[13], and the Charlson comorbidity index[14]. We also control for hospital-department fixed effects δ_i, year fixed effects η_y, and quarter fixed effects η_q. ε_{pt} is the idiosyncratic error term. Standard errors clustered at the hospital-department level.

Figure 9 and Appendix Table A14 illustrate the gender-specific dynamics in healthcare quality before and after the adoption of the da Vinci surgical system. Prior to adoption, the 30-day inpatient readmission for patients treated by male and female surgeons evolves in an almost parallel pattern. After the adoption, however, a divergence emerges. Patients treated by female surgeons experience a sharp and sustained decline in the probability of 30-day inpatient readmission. On average, their readmission rate drops by 0.15 in the first two years following robot adoption.In contrast, there is no discernible change in 30-day readmission rates among patients treated by male surgeons, as shown in Appendix Figure A6. Additionally, the rate of discharge per physician's order remains unaffected for both male and female surgeons' patients.

[12]Patients are categorized into nine age groups: 0–14, 15–19, 20–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75 and over.

[13]We classify patients' primary diagnoses into 20 categories based on the first three digits of International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM): Diseases are classified into 20 categories: infectious and parasitic diseases, neoplasms, endocrine-nutritional-metabolic diseases, diseases of the blood, mental disorders, diseases of the nervous system, diseases of the sense organs, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system, diseases of the genitourinary system, complications of pregnancy, childbirth, diseases of the skin and subcutaneous tissue, diseases of the musculoskeletal system, congenital anomalies, disorders originating in the perinatal period, signs-symptoms, injury-poisoning, external causes of injury, and supplementary classification.

[14]Following Quan et al. (2005), we calculate patients' comorbidity index based on their diagnosis codes.

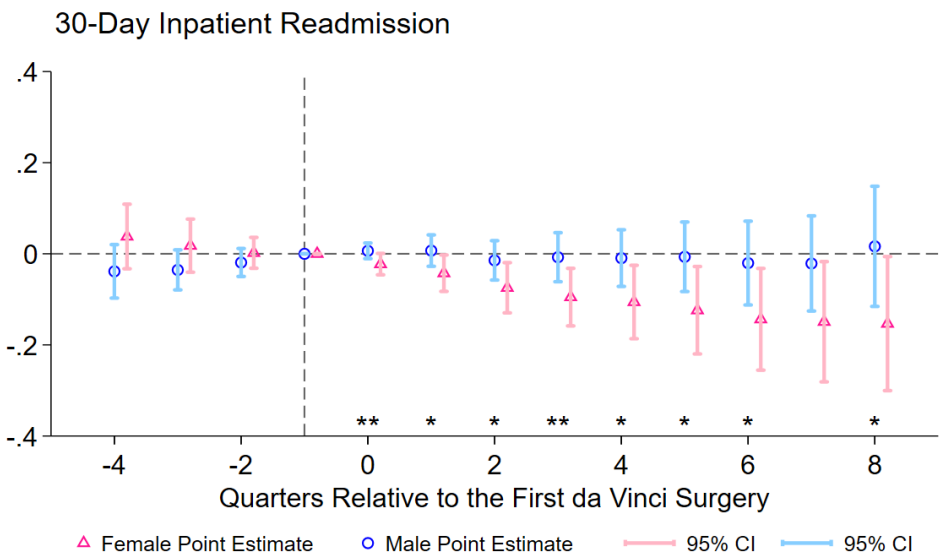


Figure 9: Impacts of Robot Adoption on Healthcare Quality by Gender

Notes: This figure illustrates the dynamic effects of robot adoption on healthcare quality, by the gender of the surgeon. Estimations are based on equation (3). The reference group is defined as the difference between patients in treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. The red and blue lines denote 95% confidence intervals, which are constructed using standard errors clustered at the hospital-department level. Corresponding results are reported in Appendix Table A14.

The aforementioned results broadly support the interpretation that changes in surgery complexity and surgical quality among female surgeons—rather than shifts in workload—are the primary drivers of the impact of robot adoption on female entry into and promotion within general surgery.

7 Conclusion

This paper studies how the adoption of surgical robots affects gender gap within surgical departments. Using detailed administrative data and exploiting the staggered adoption of the da Vinci surgical system across hospital departments, we examine how the introduction of da Vinci surgical systems changes female participation and career advancement in general surgery.

We document three main findings. First, the adoption of surgical robots is associated with a gradual increase in female representation in surgical departments. Both the share of female surgeons and the likelihood that a department has a non-trivial female presence rise following robot adoption. Second, we find evidence that female surgeons experience improved promotion outcomes after the introduction of surgical robots. In particular, the share of female department heads increases and departments become substantially more likely to have at least one female chief surgeon. Third, we show that these changes do not appear to be driven by shifts in workload allocation across surgeons. Instead, we find evidence that surgical outcomes improve for patients treated by female surgeons after robot adoption, suggesting that technological change may alter the skill requirements or comparative advantages within surgical practice.

Taken together, these findings highlight an important channel through which technological change can influence gender gap in high-skill professions. By altering the physical and procedural demands of surgical work, robotic technology may reduce barriers that have historically limited female participation in surgery. More broadly, our results suggest that the diffusion of new technologies can reshape comparative advantage across workers and thereby influence the composition of the workforce.

Understanding how technological change interacts with gender differences in skills, career choices, and workplace institutions remains an important direction for future research. As new technologies continue to transform professional tasks in medicine and other high-skill sectors, their implications for workforce diversity and career mobility are likely to become increasingly important.

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Appendix

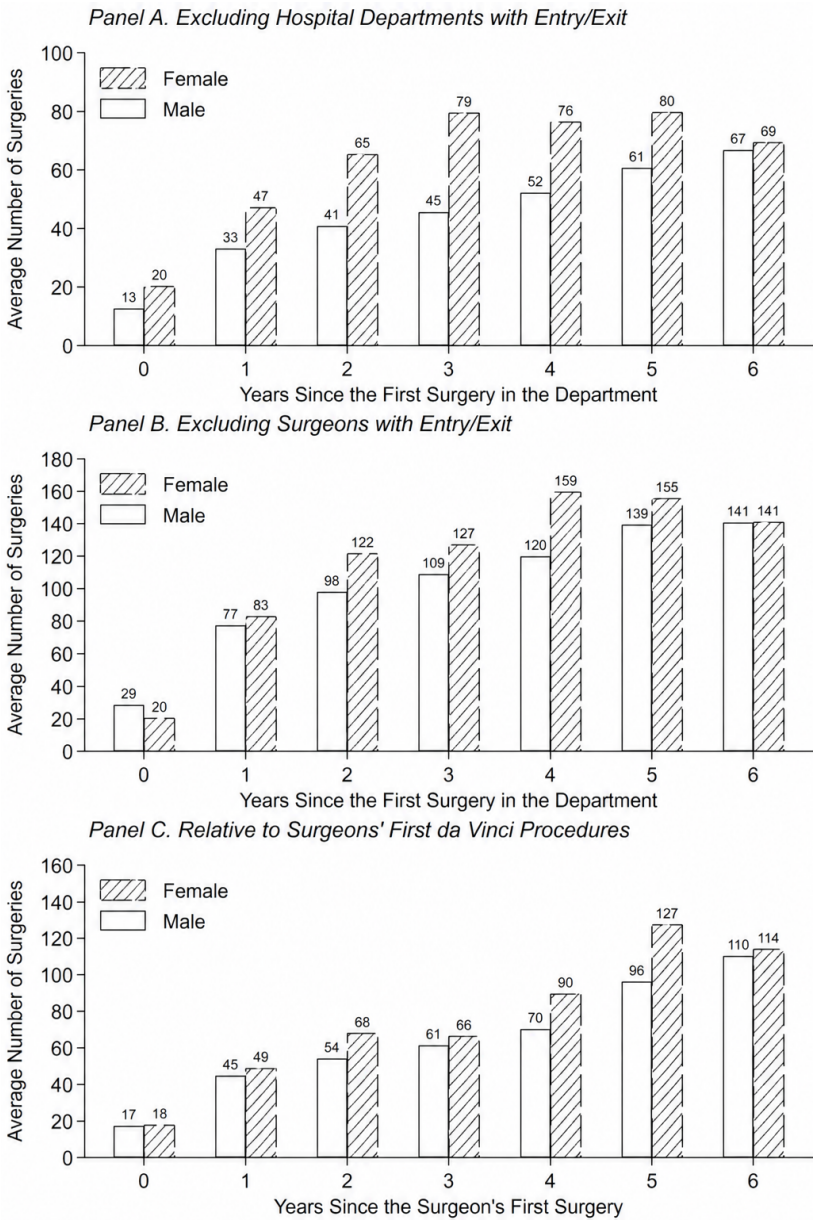


Figure A1: Number of da Vinci Surgeries per Surgeon by Gender

Notes: This figure illustrates the evolution of per surgeon surgical volume by gender over the years. Panels A and B are relative to the year in which each hospital department performed its first da Vinci procedure. Panel C is based on the year of each surgeon's initial use of the da Vinci surgical system. Sample in Panel A consists of da Vinci procedures performed in hospital departments that have been using the system for seven years since the first da Vinci procedure. Sample in Panel B consists of da Vinci procedures performed by surgeons that have been using the system for seven years since their first da Vinci procedures. Sample in Panel C consists of all da Vinci procedures in hospital departments that had adopted the system by 2021.

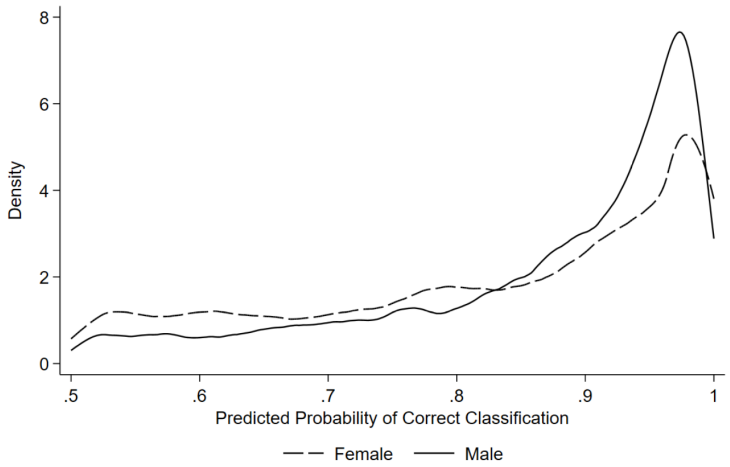


Figure A2: Gender Prediction Accuracy

Notes: This figure plots the distribution of the predicted probability of correct gender classification from the name-based gender prediction algorithm, "ngender", separately for female and male surgeons.

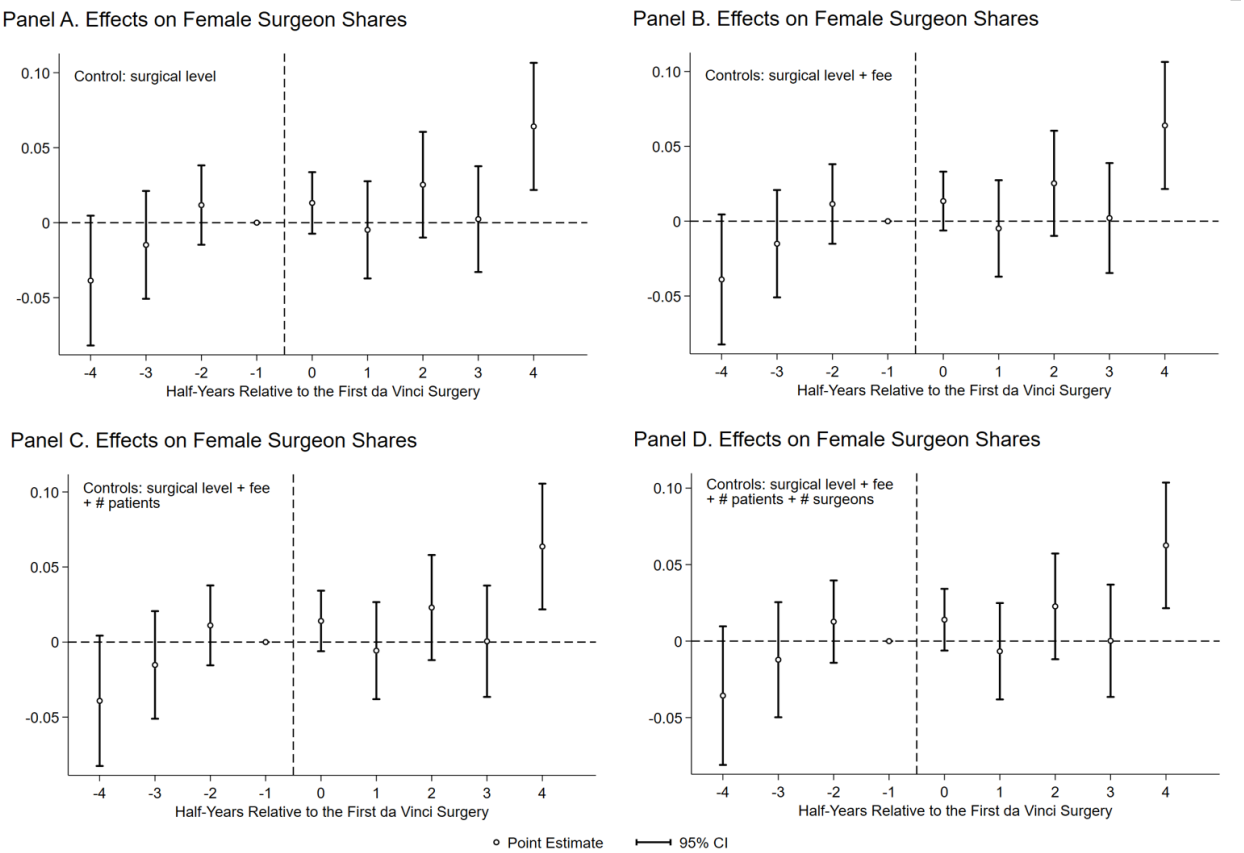


Figure A3: Impacts of Robot Adoption on Share of Female Surgeons: Alternative Controls

Notes: This figure illustrates the dynamic effects of robot adoption on female representation. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while pink bars indicate 95% confidence intervals. Standard errors are clustered at the hospital-department level. Corresponding results are reported in Appendix Table A4.

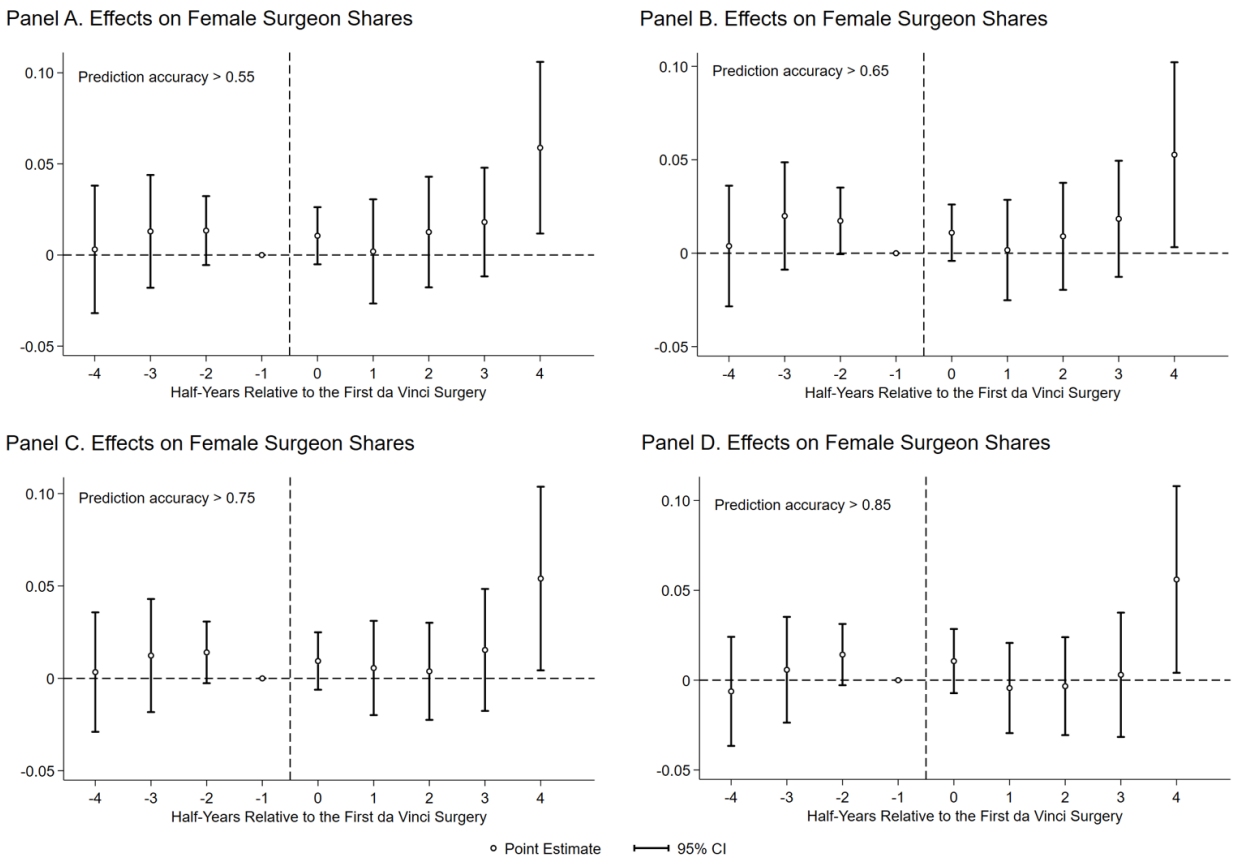


Figure A4: Impacts of Robot Adoption on Share of Female Surgeons: Gender Prediction Accuracy

Notes: This figure illustrates the dynamic effects of robot adoption on female representation. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while pink bars indicate 95% confidence intervals. Standard errors are clustered at the hospital-department level. Corresponding results are reported in Appendix Table A5.

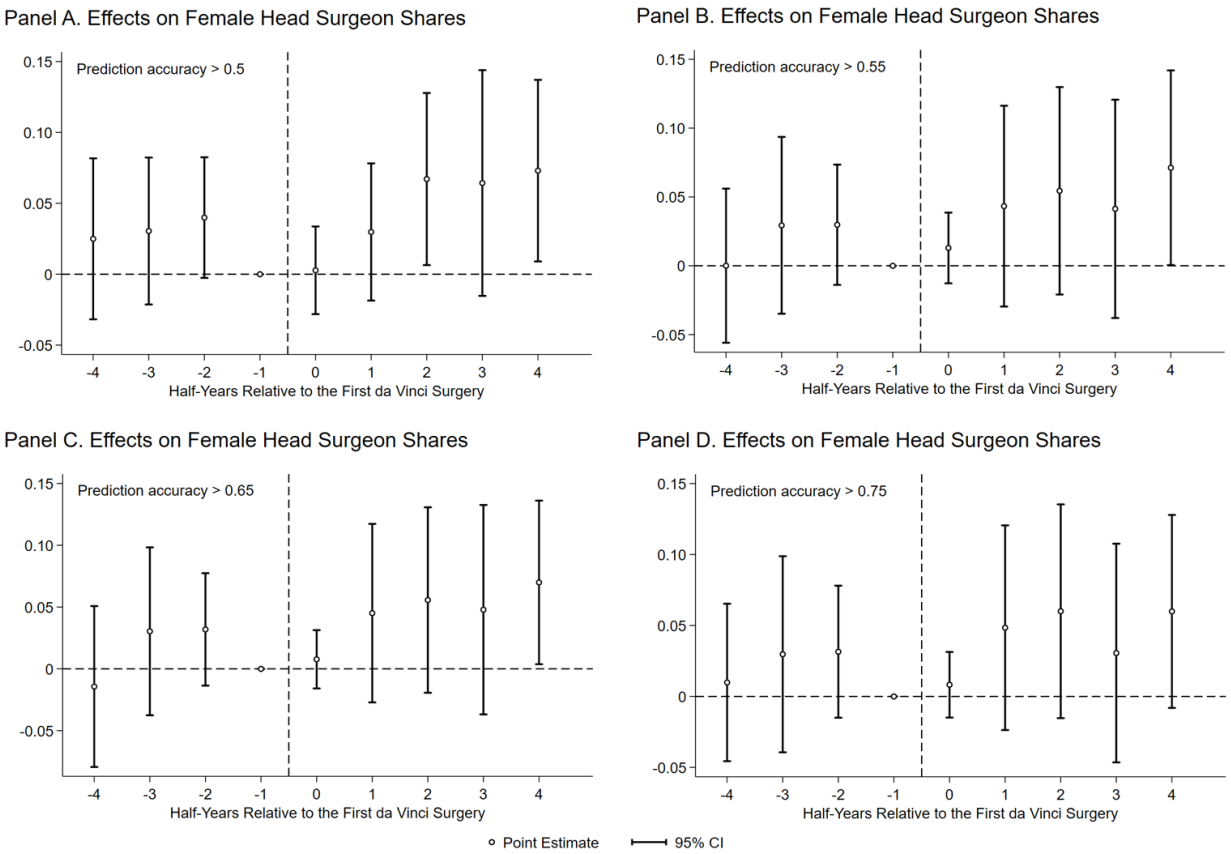


Figure A5: Impacts of Robot Adoption on Share of Female Head Surgeons: Gender Prediction Accuracy

Notes: This figure illustrates the dynamic effects of robot adoption on females' promotion opportunities. Estimations are based on equation (1). The reference group is defined as the difference between treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. Dots denote point estimates, while pink bars indicate 95% confidence intervals. Standard errors are clustered at the hospital-department level. Corresponding results are reported in Appendix Table A5.

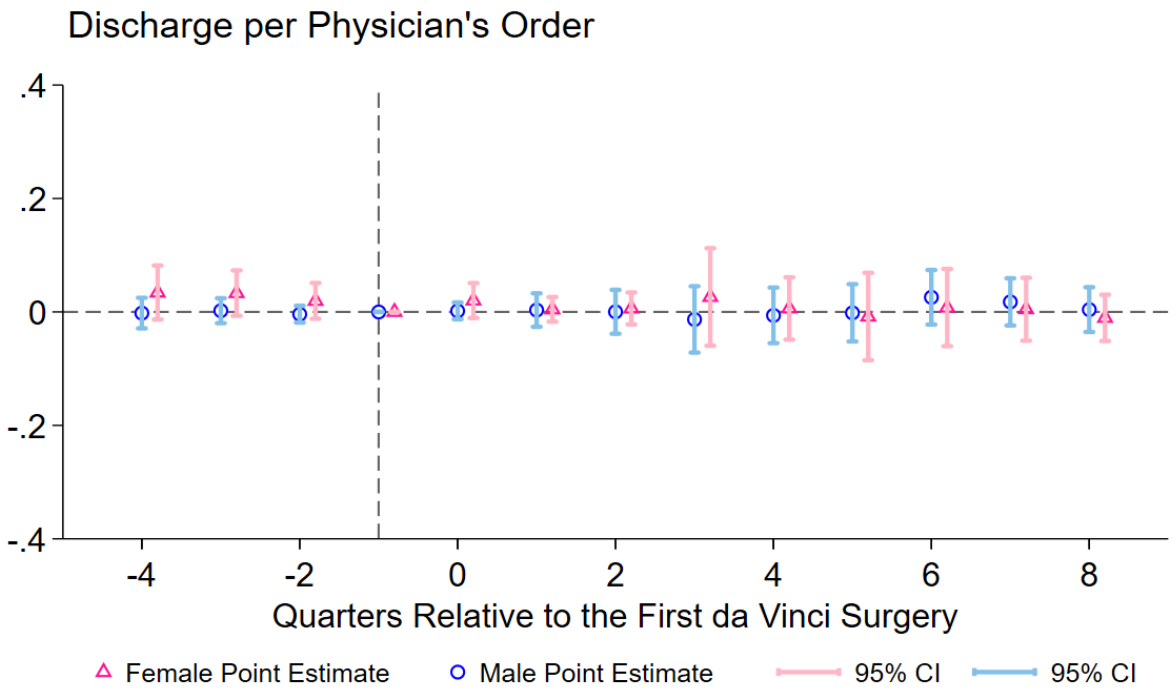


Figure A6: Impacts of Robot Adoption on Discharge Disposition by Gender

Notes: This figure illustrates the dynamic effects of robot adoption on discharge disposition, by the gender of the surgeon. Estimations are based on equation (3). The reference group is defined as the difference between patients in treated and control hospital departments in the half-year immediately prior to the adoption of the da Vinci surgical system. The red and blue lines denote 95% confidence intervals, which are constructed using standard errors clustered at the hospital-department level. Corresponding results are reported in Appendix Table A14.

Table A1: Summary Statistics

	Mean	SD
Panel A. Personnel		
Female Surgeon Share	0.15	0.11
Female Surgeon Presence	0.87	0.34
Female Head Share	0.09	0.19
Female Head Presence	0.30	0.46
Female Chief Share	0.10	0.16
Female Chief Presence	0.44	0.50
Female Attending Share	0.14	0.16
Female Resident Share	0.21	0.23
Panel B. Workload		
Female Record Share	0.12	0.11
Female Procedure Share	0.12	0.11
Male: Surgical Level and Expenditures		
% Level I Surgeries	11	17
% Level II Surgeries	28	26
% Level III Surgeries	37	26
% Level IV Surgeries	24	24
Total Expense (RMB)	22598.96	18329.35
Medical Service Fee (RMB)	2578.09	2574.53
Diagnostic Fee (RMB)	6044.29	3707.86
Treatment Fee (RMB)	5354.29	2531.88
Female: Surgical Level and Expenditures		
% Level I Surgeries	11	19
% Level II Surgeries	30	30
% Level III Surgeries	36	32
% Level IV Surgeries	23	29
Total Expense (RMB)	22450.71	19695.78
Medical Service Fee (RMB)	2238.55	2199.64
Diagnostic Fee (RMB)	6176.37	4193.52
Treatment Fee (RMB)	5026.45	3193.60
Panel C: Healthcare Quality		
Male		
30-day Readmission	0.15	0.36
Discharge per Physician's Order	0.88	0.33
Patient Age	51.28	17.75
Male Patient	0.42	0.49
Charlson Comorbidity Index	1.57	2.37
Female		
30-day Readmission	0.16	0.36
Discharge per Physician's Order	0.92	0.27
Patient Age	50.63	17.13
Male Patient	0.38	0.49
Charlson Comorbidity Index	1.53	2.37

Notes: This table presents summary statistics for the ever treated hospital departments. Panel A and the first two rows of Panel B report summary statistics at the hospital-department level, while the remainder of Panel B provides surgeon-level characteristics. Panel C presents summary statistics at the medical record level. We include patients admitted after January 1, 2016 and discharged before December 31, 2023. The sample in Sections 5 and 6.1 includes both ever treated and never treated hospital departments, covering 526 departments across 298 tier-3, grade A hospitals in China. The sample in Sections 6.2 and 6.3 is restricted to 42 ever treated hospitals only, comprising 121 departments, 3,288 surgeons and 2,247,703 patients. Note that the general surgery department within some ever treated hospitals may be never treated, thereby ensuring that the sample includes hospital departments that have never been treated.

Table A2: Impacts of Robot Adoption on Share of Female Surgeons

	Female Share			Female Share > 5%		
	(1)	(2)	(3)	(4)	(5)	(6)
2 Years Before	0.001	0.005	0.001	-0.045	-0.041	-0.042
	[0.018]	[0.021]	[0.018]	[0.077]	[0.086]	[0.075]
1.5 Years Before	0.011	0.017	0.008	0.002	0.020	-0.004
	[0.017]	[0.020]	[0.017]	[0.073]	[0.081]	[0.072]
1 Year Before	0.012	0.018	0.012	0.032	0.053	0.031
	[0.010]	[0.012]	[0.010]	[0.063]	[0.071]	[0.062]
The Half-Year of Adoption	0.011	0.011	0.009	0.014	0.017	0.007
	[0.008]	[0.010]	[0.008]	[0.058]	[0.064]	[0.058]
0.5 Years Later	0.005	0.004	0.003	0.010	0.009	0.007
	[0.016]	[0.018]	[0.016]	[0.070]	[0.077]	[0.069]
1 Year Later	0.017	0.015	0.016	-0.084	-0.085	-0.089
	[0.017]	[0.019]	[0.017]	[0.075]	[0.084]	[0.075]
1.5 Years Later	0.022	0.021	0.021	0.023	0.023	0.018
	[0.015]	[0.017]	[0.015]	[0.071]	[0.077]	[0.070]
2 Years Later	0.058**	0.050*	0.058**	0.180*	0.172	0.177*
	[0.023]	[0.026]	[0.023]	[0.105]	[0.114]	[0.105]
Hospital-Department Fixed Effects	Yes	No	Yes	Yes	No	Yes
Hospital Fixed Effects	No	Yes	No	No	Yes	No
Department Fixed Effects	No	Yes	No	No	Yes	No
Half-Year-Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
Year Fixed Effects	No	No	Yes	No	No	Yes
Half-Year Fixed Effects	No	No	Yes	No	No	Yes
Adjusted R-Squared	0.700	0.477	0.698	0.589	0.401	0.587
Number of Hospital-Departments	470	516	470	470	516	470
Observations	2201	2247	2205	2201	2247	2205

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female share refers to the proportion of female surgeons among all surgeons. Female share > 5% is an indicator variable that take the value of 1 if the female share exceeds 5% and 0 otherwise. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The indicator for the half-year immediately prior to adoption is omitted. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A3: Impacts of Robot Adoption on Females' Promotion Opportunities

	Female Head Share			Female Chief Presence		
	(1)	(2)	(3)	(4)	(5)	(6)
2 Years Before	0.025	0.025	0.024	0.194**	0.218**	0.178**
	[0.029]	[0.032]	[0.027]	[0.090]	[0.100]	[0.084]
1.5 Years Before	0.030	0.032	0.028	0.141*	0.169*	0.147*
	[0.026]	[0.029]	[0.026]	[0.077]	[0.086]	[0.076]
1 Year Before	0.040*	0.042*	0.041*	0.081	0.083	0.074
	[0.022]	[0.024]	[0.021]	[0.082]	[0.085]	[0.080]
The Half-Year of Adoption	0.003	0.010	0.001	-0.010	-0.015	0.011
	[0.016]	[0.014]	[0.016]	[0.075]	[0.083]	[0.074]
0.5 Years Later	0.030	0.038	0.029	0.225**	0.207**	0.217**
	[0.025]	[0.029]	[0.024]	[0.090]	[0.096]	[0.089]
1 Year Later	0.067**	0.074**	0.065**	0.111	0.092	0.132
	[0.031]	[0.035]	[0.031]	[0.118]	[0.126]	[0.122]
1.5 Years Later	0.064	0.072	0.063	0.287***	0.289***	0.288***
	[0.041]	[0.049]	[0.041]	[0.090]	[0.097]	[0.093]
2 Years Later	0.073**	0.068*	0.071**	0.476***	0.481***	0.502***
	[0.033]	[0.037]	[0.032]	[0.148]	[0.161]	[0.148]
Hospital-Department Fixed Effects	Yes	No	Yes	Yes	No	Yes
Hospital Fixed Effects	No	Yes	No	No	Yes	No
Department Fixed Effects	No	Yes	No	No	Yes	No
Half-Year-Year Fixed Effects	Yes	Yes	No	Yes	Yes	No
Year Fixed Effects	No	No	Yes	No	No	Yes
Half-Year Fixed Effects	No	No	Yes	No	No	Yes
Adjusted R-Squared	0.670	0.342	0.671	0.469	0.344	0.468
Number of Hospital-Departments	462	502	462	415	463	415
Observations	2151	2191	2155	1862	1910	1866

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female head share refers to the proportion of female surgeons among all department heads. Female chief presence is an indicator for the presence of a female chief. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The dummy variable indicating one quarter prior to adoption is excluded. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A4: Impacts of Robot Adoption on Share of Female Surgeons: Alternative Controls

	Female Share				
	(1)	(2)	(3)	(4)	(5)
2 Years Before	0.0014	-0.0386*	-0.0389*	-0.0391*	-0.0356
	[0.0185]	[0.0220]	[0.0221]	[0.0221]	[0.0230]
1.5 Years Before	0.0105	-0.0148	-0.0150	-0.0152	-0.0122
	[0.0174]	[0.0183]	[0.0182]	[0.0182]	[0.0191]
1 Year Before	0.0125	0.0117	0.0115	0.0111	0.0127
	[0.0101]	[0.0134]	[0.0135]	[0.0135]	[0.0137]
The Half-Year of Adoption	0.0108	0.0132	0.0134	0.0141	0.0140
	[0.0084]	[0.0104]	[0.0100]	[0.0102]	[0.0102]
0.5 Years Later	0.0049	-0.0048	-0.0048	-0.0057	-0.0066
	[0.0159]	[0.0165]	[0.0164]	[0.0164]	[0.0160]
1 Year Later	0.0165	0.0253	0.0253	0.0230	0.0227
	[0.0168]	[0.0179]	[0.0179]	[0.0178]	[0.0176]
1.5 Years Later	0.0221	0.0024	0.0021	0.0006	0.0002
	[0.0153]	[0.0179]	[0.0187]	[0.0188]	[0.0187]
2 Years Later	0.0576**	0.0642***	0.0640***	0.0636***	0.0626***
	[0.0233]	[0.0215]	[0.0216]	[0.0213]	[0.0209]
Average Surgical Level (Lagged)		0.0011	0.0016	0.0020	0.0024
		[0.0103]	[0.0099]	[0.0098]	[0.0098]
log(Average Fee) (Lagged)			-0.0032	-0.0002	-0.0006
			[0.0175]	[0.0179]	[0.0180]
log(# Patients) (Lagged)				0.0045	0.0037
				[0.0044]	[0.0047]
# Surgeons (Lagged)					0.0002
					[0.0002]
Hospital-Department Fixed Effects	Yes	Yes	Yes	Yes	Yes
Half-Year-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-Squared	0.700	0.686	0.685	0.686	0.685
Number of Hospital-Departments	470	293	293	293	293
Observations	2201	1375	1374	1374	1374

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female share refers to the proportion of female surgeons among all surgeons. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The indicator for the half-year immediately prior to adoption is omitted. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A5: Impacts of Robot Adoption on Share of Female Surgeons: Gender Prediction Accuracy

	Female Share				
	(1)	(2)	(3)	(4)	(5)
Gender Prediction Accuracy	> 0.5	> 0.55	> 0.65	> 0.75	> 0.85
2 Years Before	0.001	0.003	0.004	0.003	-0.006
	[0.018]	[0.018]	[0.016]	[0.016]	[0.015]
1.5 Years Before	0.011	0.013	0.020	0.012	0.006
	[0.017]	[0.016]	[0.015]	[0.016]	[0.015]
1 Year Before	0.012	0.013	0.017*	0.014*	0.014
	[0.010]	[0.010]	[0.009]	[0.008]	[0.009]
The Half-Year of Adoption	0.011	0.011	0.011	0.009	0.011
	[0.008]	[0.008]	[0.008]	[0.008]	[0.009]
0.5 Years Later	0.005	0.002	0.002	0.006	-0.004
	[0.016]	[0.015]	[0.014]	[0.013]	[0.013]
1 Year Later	0.017	0.013	0.009	0.004	-0.003
	[0.017]	[0.015]	[0.015]	[0.013]	[0.014]
1.5 Years Later	0.022	0.018	0.018	0.015	0.003
	[0.015]	[0.015]	[0.016]	[0.017]	[0.018]
2 Years Later	0.058**	0.059**	0.053**	0.054**	0.056**
	[0.023]	[0.024]	[0.025]	[0.025]	[0.026]
Hospital-Department Fixed Effects	Yes	Yes	Yes	Yes	Yes
Half-Year-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-Squared	0.700	0.705	0.692	0.712	0.715
Number of Hospital-Departments	470	470	470	470	470
Observations	2201	2201	2201	2201	2201

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female share refers to the proportion of female surgeons among all surgeons. Columns (1)–(5) vary the sample according to the accuracy of the gender prediction procedure. Specifically, for each threshold, we retain only those surgeons whose predicted gender probability exceeds that threshold, and then recompute the female share. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The indicator for the half-year immediately prior to adoption is omitted. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A6: Impacts of Robot Adoption on Share of Female Head Surgeons: Gender Prediction Accuracy

	Female Head Share			
	(1)	(2)	(3)	(4)
Gender Prediction Accuracy	> 0.5	> 0.55	> 0.65	> 0.75
2 Years Before	0.025	0.000	-0.014	0.010
	[0.029]	[0.028]	[0.033]	[0.028]
1.5 Years Before	0.030	0.029	0.030	0.030
	[0.026]	[0.033]	[0.035]	[0.035]
1 Year Before	0.040*	0.030	0.032	0.032
	[0.022]	[0.022]	[0.023]	[0.024]
The Half-Year of Adoption	0.003	0.013	0.008	0.008
	[0.016]	[0.013]	[0.012]	[0.012]
0.5 Years Later	0.030	0.043	0.045	0.048
	[0.025]	[0.037]	[0.037]	[0.037]
1 Year Later	0.067**	0.054	0.056	0.060
	[0.031]	[0.038]	[0.038]	[0.038]
1.5 Years Later	0.064	0.041	0.048	0.031
	[0.041]	[0.040]	[0.043]	[0.039]
2 Years Later	0.073**	0.071**	0.070**	0.060*
	[0.033]	[0.036]	[0.034]	[0.035]
Hospital-Department Fixed Effects	Yes	Yes	Yes	Yes
Half-Year-Year Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-Squared	0.670	0.666	0.658	0.639
Number of Hospital-Departments	462	460	455	440
Observations	2151	2138	2106	2040

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female head share refers to the proportion of female surgeons among all department heads. Columns (1)–(4) vary the sample according to the accuracy of the gender prediction procedure. Specifically, for each threshold, we retain only those surgeons whose predicted gender probability exceeds that threshold, and then recompute the female head share. We do not consider a threshold of 0.85, since imposing this cutoff would exclude more than half of female surgeons whose predicted probability of correct classification falls below that level. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The indicator for the half-year immediately prior to adoption is omitted. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A7: Impacts of Robot Adoption on Females' Workloads

	Female Record Share	Female Procedure Share
	(1)	(2)
2 Years Before	-0.022*	-0.025**
	[0.012]	[0.012]
1.5 Years Before	-0.013	-0.016
	[0.014]	[0.014]
1 Year Before	-0.008	-0.010
	[0.009]	[0.009]
The Half-Year of Adoption	-0.011	-0.011
	[0.008]	[0.008]
0.5 Years Later	-0.004	-0.003
	[0.013]	[0.013]
1 Year Later	-0.006	-0.006
	[0.014]	[0.015]
1.5 Years Later	0.003	0.002
	[0.020]	[0.021]
2 Years Later	0.025	0.025
	[0.030]	[0.031]
Hospital-Department Fixed Effects	Yes	Yes
Half-Year Fixed Effects	Yes	Yes
Adjusted R-Squared	0.771	0.765
Number of Hospital-Departments	475	475
Observations	2348	2343

Notes: This table presents estimates from the event study model based on equation (1). Each column in the table corresponds to a separate regression. Female record share represents the proportion of medical cases managed by female surgeons relative to the total number of cases. Female procedure share denotes the proportion of surgeries performed by female surgeons relative to the total number of surgeries. We include leads and lags of the da Vinci surgical system adoption to test the parallel pre-trend assumption and examine both medium- and long-term impacts. The indicator for the half-year immediately prior to adoption is omitted. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A8: Impacts of Robot Adoption on Share of Surgeries by Surgical Level and Gender

	% Level I	% Level II	% Level III	% Level IV
	(1)	(2)	(3)	(4)
β_m Robot Adoption (Male)	-0.033***	-0.010	0.024*	0.019*
	[0.007]	[0.011]	[0.013]	[0.011]
β_f Robot Adoption (Female)	-0.022	-0.017	-0.013	0.052***
	[0.015]	[0.025]	[0.025]	[0.020]
$\beta_m - \beta_f$	-0.011	0.007	0.037**	-0.033**
p-value	0.237	0.405	0.032	0.038
Mean before Adoption (Male)	0.146	0.303	0.366	0.185
Mean before Adoption (Female)	0.147	0.314	0.338	0.201
Adjusted R-Squared (Male)	0.566	0.645	0.605	0.619
Adjusted R-Squared (Female)	0.565	0.630	0.573	0.572
# Male Surgeons			1575	
# Female Surgeons			292	
Observations (Male)			9443	
Observations (Female)			1515	
Surgeon Fixed Effects			Yes	
Quarter-Year Fixed Effects			Yes	

Notes: This table presents the impact of robot adoption on surgical levels, differentiated by surgeon gender. β_m and β_f are estimated based on equation (2). P-values are calculated from 3000 permutations. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A9: Impacts of Robot Adoption on Share of Surgeries by Surgical Level and Gender: Previously Employed Surgeons

	% Level I	% Level II	% Level III	% Level IV
	(1)	(2)	(3)	(4)
β_m Robot Adoption (Male)	-0.021***	-0.019*	0.032***	0.008
	[0.007]	[0.010]	[0.011]	[0.011]
β_f Robot Adoption (Female)	-0.018	-0.030	0.009	0.040**
	[0.014]	[0.025]	[0.025]	[0.019]
$\beta_m - \beta_f$	-0.003	0.011	0.023	-0.031*
p-value	0.423	0.413	0.109	0.071
Mean before Adoption (Male)	0.128	0.303	0.367	0.202
Mean before Adoption (Female)	0.136	0.315	0.329	0.220
Adjusted R-Squared (Male)	0.466	0.658	0.637	0.552
Adjusted R-Squared (Female)	0.569	0.659	0.627	0.601
# Male Surgeons			1058	
# Female Surgeons			196	
Observations (Male)			7070	
Observations (Female)			1126	
Surgeon Fixed Effects			Yes	
Quarter-Year Fixed Effects			Yes	

Notes: This table presents the impact of robot adoption on the surgical levels of surgeons who are already employed at the hospital in the quarter prior to the first da Vinci procedure, differentiated by surgeon gender. β_m and β_f are estimated based on equation (2). P-values are calculated from 3000 permutations. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A10: Impacts of Robot Adoption on Share of Surgeries by Surgical Level and Gender: Newly Recruited Surgeons

	% Level I	% Level II	% Level III	% Level IV
	(1)	(2)	(3)	(4)
Female = 1	-0.017	0.004	0.040	-0.028
	[0.020]	[0.030]	[0.034]	[0.030]
Adjusted R-Squared	0.473	0.212	0.191	0.127
# Surgeons			388	
Observations			980	
Surgeon Fixed Effects			Yes	
Quarter-Year Fixed Effects			Yes	

Notes: This table presents the gender difference in surgical levels among newly recruited surgeons in the quarter of the first da Vinci procedure and thereafter. The dependent variable is the share of surgeries with different surgical levels performed by the surgeon in each quarter. The independent variable is a dummy indicating whether the surgeon is a female. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A11: Impacts of Robot Adoption on Medical Expenditures by Gender

	Total Expense (1)	Medical Service Fee (2)	Diagnostic Fee (3)	Treatment Fee (4)
β_m Robot Adoption (Male)	0.072***	0.097***	0.011	0.060***
	[0.020]	[0.025]	[0.018]	[0.022]
β_f Robot Adoption (Female)	0.085*	0.111*	0.081**	0.185***
	[0.050]	[0.059]	[0.036]	[0.051]
$\beta_m - \beta_f$	-0.013	-0.015	-0.070**	-0.124***
p-value	0.496	0.438	0.014	0.002
Mean before Adoption (Male)	9.799	7.542	8.531	8.402
Mean before Adoption (Female)	9.720	7.502	8.500	8.264
Adjusted R-Squared (Male)	0.692	0.618	0.777	0.587
Adjusted R-Squared (Female)	0.683	0.608	0.794	0.526
# Male Surgeons	1873	1037	1619	1666
# Female Surgeons	346	195	285	277
Observations (Male)	10854	5831	9812	9548
Observations (Female)	1700	950	1491	1402
Surgeon Fixed Effects	Yes	Yes	Yes	Yes
Quarter-Year Fixed Effects	Yes	Yes	Yes	Yes

Notes: This table presents the impact of robot adoption on medical expenditures, differentiated by surgeon gender. β_m and β_f are estimated based on equation (2). P-values are calculated from 3000 permutations. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A12: Impacts of Robot Adoption on Medical Expenditures by Gender: Previously Employed Surgeons

	Total Expense (1)	Medical Service Fee (2)	Diagnostic Fee (3)	Treatment Fee (4)
β_m Robot Adoption (Male)	0.067***	0.024	-0.004	0.026
	[0.024]	[0.026]	[0.021]	[0.024]
β_f Robot Adoption (Female)	0.047	0.080	0.067*	0.085*
	[0.051]	[0.063]	[0.038]	[0.048]
$\beta_m - \beta_f$	0.020	-0.056	-0.071**	-0.059
p-value	0.230	0.159	0.035	0.191
Mean before Adoption (Male)	9.797	7.557	8.577	8.487
Mean before Adoption (Female)	9.746	7.529	8.571	8.361
Adjusted R-Squared (Male)	0.678	0.568	0.793	0.520
Adjusted R-Squared (Female)	0.724	0.603	0.809	0.493
# Male Surgeons	1206	741	1013	1088
# Female Surgeons	220	160	183	186
Observations (Male)	7645	4581	6900	6852
Observations (Female)	1203	823	1076	1039
Surgeon Fixed Effects	Yes	Yes	Yes	Yes
Quarter-Year Fixed Effects	Yes	Yes	Yes	Yes

Notes: This table presents the impact of robot adoption on patients' medical expenditures of surgeons who are already employed in the hospital in the quarter prior to the first da Vinci procedure, differentiated by surgeon gender. β_m and β_f are estimated based on equation (2). P-values are calculated from 3000 permutations. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A13: Impacts of Robot Adoption on Medical Expenditures by Gender: Newly Recruited Surgeons

	Total Expense (1)	Medical Service Fee (2)	Diagnostic Fee (3)	Treatment Fee (4)
Female = 1	-0.096	-0.107	0.034	-0.052
	[0.088]	[0.108]	[0.069]	[0.076]
Adjusted R-Squared	0.139	0.153	0.317	0.164
# Surgeons	461	174	365	348
Observations	1087	445	940	870
Surgeon Fixed Effects	Yes	Yes	Yes	Yes
Quarter-Year Fixed Effects	Yes	Yes	Yes	Yes

Notes: This table presents the gender difference in patients' medical expenditures among newly recruited surgeons in the quarter of the first da Vinci procedure and thereafter. The dependent variable is the logarithm of the average medical expenditures per patient treated by the surgeon in the quarter. The independent variable is a dummy indicating whether the surgeon is a female. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table A14: Impacts of Robot Adoption on Healthcare Quality by Gender

	30-day Inpatient Readmission		Discharge per Physician's Order	
	Male	Female	Male	Female
	(1)	(2)	(3)	(4)
4 Quarters Before	-0.039	0.038	-0.002	0.034
	[0.029]	[0.035]	[0.014]	[0.024]
3 Quarters Before	-0.035	0.018	0.002	0.033
	[0.022]	[0.029]	[0.011]	[0.020]
2 Quarters Before	-0.019	0.002	-0.004	0.019
	[0.015]	[0.017]	[0.007]	[0.016]
Quarter of the Adoption	0.007	-0.023*	0.002	0.020
	[0.009]	[0.012]	[0.007]	[0.016]
1 Quarter Later	0.007	-0.043**	0.003	0.005
	[0.017]	[0.020]	[0.015]	[0.011]
2 Quarters Later	-0.014	-0.075***	0.000	0.006
	[0.022]	[0.028]	[0.019]	[0.014]
3 Quarters Later	-0.007	-0.095***	-0.013	0.026
	[0.027]	[0.032]	[0.029]	[0.043]
4 Quarters Later	-0.009	-0.106**	-0.006	0.006
	[0.031]	[0.040]	[0.025]	[0.028]
5 Quarters Later	-0.007	-0.124**	-0.002	-0.008
	[0.038]	[0.048]	[0.025]	[0.039]
6 Quarters Later	-0.020	-0.144**	0.026	0.008
	[0.046]	[0.056]	[0.024]	[0.034]
7 Quarters Later	-0.021	-0.149**	0.018	0.005
	[0.052]	[0.066]	[0.021]	[0.028]
8 Quarters Later	0.016	-0.153**	0.004	-0.010
	[0.066]	[0.073]	[0.020]	[0.021]
Hospital-Department Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Quarter Fixed Effects	Yes	Yes	Yes	Yes
Adjusted R-Squared	0.334	0.399	0.343	0.280
Number of Hospital-Departments	65	59	102	90
Observations	1542703	205715	1913559	248886

Notes: This table presents estimates from the event study model based on equation (3). Each column in the table corresponds to a separate regression. 30-day inpatient readmission is an indicator of whether the patient is readmitted within 30 days. There are six types of patient discharge methods: 1.discharge per physician's order; 2.transfer per physician's order; 3.transfer to community health service center per physician's order; 4.discharge against medical advice; 5.in-hospital death; 6.other. Discharge per physician's order is an indicator of whether the patient is discharged upon the physician's recommendation after completing their current course of treatment. Standard errors, clustered at the hospital-department level, are reported in brackets. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.