Shut Down and Shut Out: Women Physicians in the Era of Medical Education Reform [*]

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April, 2019

Abstract

Women made tremendous inroads into the medical profession in the late nineteenth century. By 1900, women constituted more than 10 percent of practicing physicians in some cities. Progress, however, did not continue into the twentieth century, as the fraction female among American physicians actually declined after 1900. This reversal is often linked to the professionalization of medical practice and the associated changes in medical education that led to a wave of medical school closures. Using a newly constructed panel data set of medical colleges, we show that women's access to medical education was blocked not only by the closure of schools with traditionally high female enrollments, but also by the shrinking number of seats for women at the schools that survived. We find that female enrollment dropped when schools added requirements for pre-medical school college coursework. We also find that school rules and state regulations requiring hospital internships further decreased women's enrollment in medical schools.

JEL Classification Codes: K3, J2, J70, N3, N31, N32
Keywords: women physicians; occupational licensing; Flexner; discrimination

I Introduction

In 1900, women comprised 19 percent of practicing physicians in Minneapolis, 18 percent in Boston, and 15 percent in Los Angeles (Walsh, 1977, p.185-87). Nationwide, women accounted for 6 percent of doctors. But instead of increasing during the early twentieth century, the percentage of women in the medical profession declined. By 1920, women constituted only 10 percent of doctors in Boston and only 8 percent in Minneapolis. As shown in Figure 1, the share of women physicians fell to 4 percent nationwide by 1940, and did not regain its 1900 level until after 1960. Even more striking is that the *number* of women physicians in 1940 (7,708) was barely above its level in 1900 (7,387), despite the fact that the profession expanded its ranks by over 30,000 during the same period (Walsh, 1977, p.187).

[*]We thank Claudia Goldin, Jenna Bednar, John Ferejohn, and participants the World Economic History Conference, the economic history seminar at Northwestern University, and the Indiana University Political Institutions and Economic Policy workshop for their comments.

In this paper, we argue that medical education reforms that culminated in changes in licensing laws led to a decline in the share of women physicians during the early 20th century that persisted until the 1960s. Using a newly constructed dataset of all American medical schools, we investigate the relationship between women's enrollment and the share of women who were medical graduates, and the changes that occurred in medical education over the period. These changes began in the late nineteenth century when some of the more prestigious medical schools revised their curricula to include training in basic science and laboratory work. They also increased the length of their programs from two to four years, raised their standards of admission to require college coursework and added the completion of an internship at a hospital to their graduation requirements. Many medical schools did not have the resources to adapt to the new standards and were forced to close.

Our results confirm existing studies that show that medical school closures disproportionately affected women. Further, among schools that remained open, we demonstrate that declines in female enrollment can be attributed to changes in those schools' requirements that frequently preceded licensing laws (Ludmerer, 1985, p.248). Using a difference-in-differences framework with differential timing across medical schools, we find that the adoption of requirements for two years of college coursework reduced the proportion of female enrollment by 2.1 percentage points and the proportion of female graduates that by 2.7 percentage points, relative to a base-level of 5.7 percent for enrollment and 6.4 percent for graduates. Hospital internship requirements further adversely affected female enrollment and graduation from medical school.

In addition to documenting how changes in medical education requirements disproportionately affected women relative to men, we also investigate whether the differential impact can be attributed to underlying differences in the qualifications or ability of women, or to another cause. While our data are not rich enough to let us test this directly, additional data sources suggest it was not a lack of ability or preparedness that resulted in declining shares of women attending medical school.

Given recent work suggesting that women and minorities may benefit or at least are not differentially harmed from occupational licensing (Blair & Chung, 2018a,b), our results indicate the need to re-examine the impact of the Progressive Era physician professionalization movement on

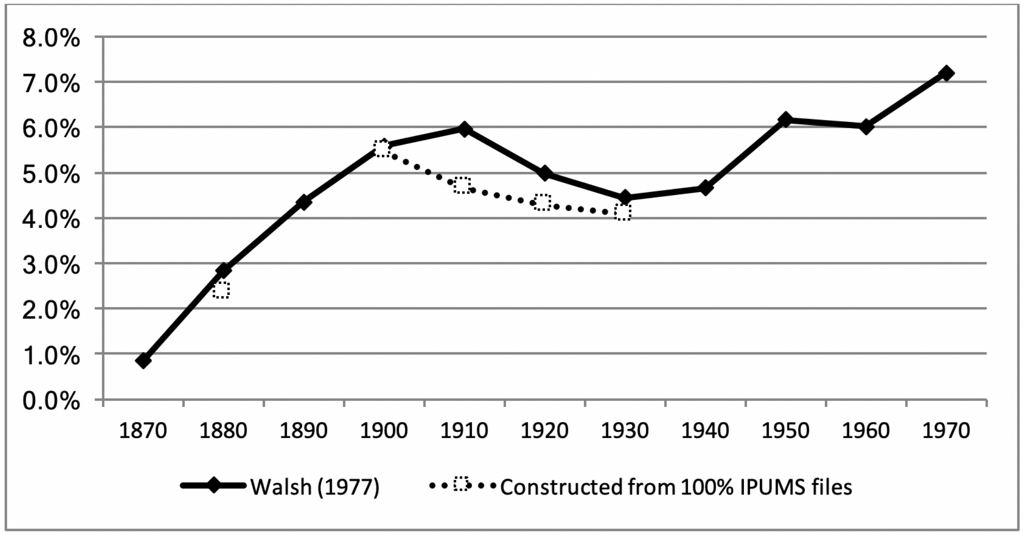

Figure 1: Supply of Women Physicians as Percentange of All Physicians, 1870-1970
Occupational Data from the U.S. Census of Population. *Sources:* Walsh (1977, p. 187); authors calculations from IPUMS datafiles (Ruggles *et al.* , 2018).

women and other underrepresented groups. Importantly, the requirements of the schools themselves often preceded the licensing regulations, so examining the dates of licensing regulations alone fails to capture the full effect of these changes. For example, Law & Marks (2009) find that licensing rules had no effect on the likelihood a woman reported herself a physician in the census. While they rely on variation in the timing of state licensing laws mandating certain requirements to measure the impact of licensure, we instead focus on the schools' decisions to adopt these requirements themselves and how the adoption affected women's enrollment in medical school. We choose to focus on the schools because many of them adopted the requirements earlier than the states. By 1940, all medical schools had adopted these requirements, even though several states still had not.

II Occupational Licensing and the Medical Profession

The majority of the literature on occupational licensing focuses on its effects on wages, employment, or average quality. Occupational licensing creates entry barriers to a profession and can increase wages for those who become licensed either by restricting supply (Friedman & Friedman, 1962; Kleiner & Krueger, 2013), or by improving the quality of labor supplied (Leland, 1979; Ronnen, 1991; Anderson *et al.* , 2016; Deming *et al.* , 2016). Research examining the effect of licensing on the medical professions suggests that each of these mechanisms may be at work. For example, Law & Kim (2005) show that early 20th-century state physician licensure laws decreased entry to the profession, increased physician incomes relative to other occupations, increased the average quality of physicians and reduced mortality from physician-treatable diseases.

Our work contributes to the empirical literature on the differential effects by gender of occupational licensing and regulatory barriers to entering an occupation. Looking at the medical profession, Law & Marks (2009) find that women and minorities do not suffer negative impacts relative to men using state-level licensure changes across occupations from 1870-1960. Others show negative impacts on women from licensure. Jonathan Hall *et al.* (2018) find regulations on the Uber ride-sharing platform lead to reduced female participation as drivers. Kleiner & Park (2010) find that female nurses reduce labor supply in response to reduced prescribing privileges.

Recent work, however, has shown potentially positive effects of occupational licensing for women. Blair & Chung (2018b) finds that the license wage premium is larger for women than for men because a license provides a more important signal for women in reducing asymmetric information. Thus, licensing potentially contributes to a reduction in the gender wage gap. In a follow up paper, Blair & Chung (2018a) find that licensing reduces labor supply of men, but find no statistically significant impact on the labor supply of women. Together, the results are interpreted as licensure simultaneously increasing women's wages with no employment effects.

In contrast, we find that women were increasingly excluded from the physician labor market by the professionalization process that occurred in medicine over the first half of the 20th-century. Reforms in medical education that increased admission requirements to medical school, updated curricula to be more science and laboratory based, and the closure of "lower quality" medical schools reduced female enrollments and new women graduates relative to the reductions experienced by men.

III Educational Reforms and Medical Licensing in the Progressive Era

Prior to 1900, entry into the medical profession was relatively open and easy. After medical schools supplanted the apprenticeship system that used to train physicians during the colonial period, most states allowed anyone graduating from a chartered medical school to practice as a physician (Shyrock, 1967, 26). Charters were easy to obtain; beginning as early as 1812 in Maryland, states would grant charters even to proprietary colleges with no university or hospital affiliation. Often, schools were owned by the faculty who received income from student fees and had incentives to maximize revenues by increasing the number of students. As more institutions opened, competition with other schools caused standards to fall further (Shyrock, 1967, 27-28).[1] When Charles Eliot took over as President of Harvard in 1869, Harvard Medical School admitted any fee-paying student. Eighty percent of the students did not hold undergraduate degrees and one faculty member suggested that over half the students could not write.

Not only were students ill-prepared before entering medical school, but the quality of their medical education was also poor. Compared to schools in Germany, which brought medicine into the realm of mainstream science and focused on experimental research in laboratories, the quality of medical education in the United States was lacking (Ludmerer, 1985, pp. 30-1). Term lengths were short and curricula limited. Harvard required just two, four-month terms of lectures. Students were not required to perform laboratory work or gain clinical experience and needed to pass only five of nine five-minute oral quizzes to pass their studies (Ludmerer, 1985, pp. 49-50). Students were so poorly trained that when the United States required that physicians seeking to enter the army or navy medical service pass an exam, only 25 percent were able to do so (Ludmerer, 1985, pp. 15-16).

Americans who studied overseas came home and joined the faculties of U.S. universities, where they pressed for changes to improve the quality of medical education (Ludmerer, 1985, p. 33). In the 1870s, Harvard finally succeeded in implementing a series of reforms at the medical school; they lengthened their terms to nine-months, imposed a three-year program, and emphasized laboratory work and clinical instruction. To offset declining fee revenue as enrollment decreased in response to the changes, administrators took over the finances of the medical school and salaried professors instead of letting them divide fee income (Shyrock, 1967, p. 46). Other schools, including Penn and Michigan, followed Harvard's lead. In 1893, Johns Hopkins became the real game-changer

[1]Shyrock notes that in 1849, only New Jersey and the District of Columbia had meaningful licensure. Many states had no licensing laws whatsoever (either because they had not been enacted or had even been repealed) and most states still allowed graduates of chartered medical schools to practice (Shyrock, 1967, 30).

when it required all students to have a bachelors degree for admission, to receive rigorous training in the sciences and laboratory work, and to receive two years of clinical instruction (Ludmerer, 1985, pp. 50-1).

Efforts to diffuse this new model of medical education intensified with the major scientific discoveries of the period. A voluntary association of medical schools, the Association of American Medical Colleges (AAMC), formed in 1876 and then re-formed in 1889 to push for collaboration to increase standards (Rothstein, 1972, p. 288). These efforts at reform were accommodated by the states, who began to revive state examining and licensing boards. By 1900, Alaska remained the only state with no regulations, although only 22 states required diplomas and examinations. Six states allowed *any* diploma, while others accepted "approved" diplomas or examinations (Shyrock, 1967, 54-55). Often, state licensing boards used a list of approved schools published by the state of Illinois.

In 1904, the American Medical Association (AMA) established the Council on Medical Education (CME) in 1904 to promote change in a more systematic way. In 1905, the AMA recommended that all medical school students have a high school education and that medical education be completed over five years, including one year of study devoted to the basic sciences (American Medical Association, 1906). In 1906, the CME conducted a survey of medical schools and found that most fell far short of the meeting these standards. Based on these findings, the AMA developed a rating system for medical schools. Schools rated A were acceptable; schools rated B were in need of improvement, but redeemable; and schools rated C needed complete reorganization. By 1914, 31 states would not license physicians who had trained at schools receiving a C rating from the AMA (Ludmerer, 1985, p. 241).

In 1908, the CME suggested that the Carnegie Foundation for the Evaluation of Teaching study the state of medical education in the United States "to hasten the elimination of medical schools that failed to adopt the CME's standards" (Beck, 2004). The Carnegie Foundation engaged Abraham Flexner to conduct the study. Flexner collected data on entrance requirements, enrollment, faculty, physical and financial resources, and curricula. His final report, published in 1910, claimed that the vast majority of American medical schools were low quality; some schools he

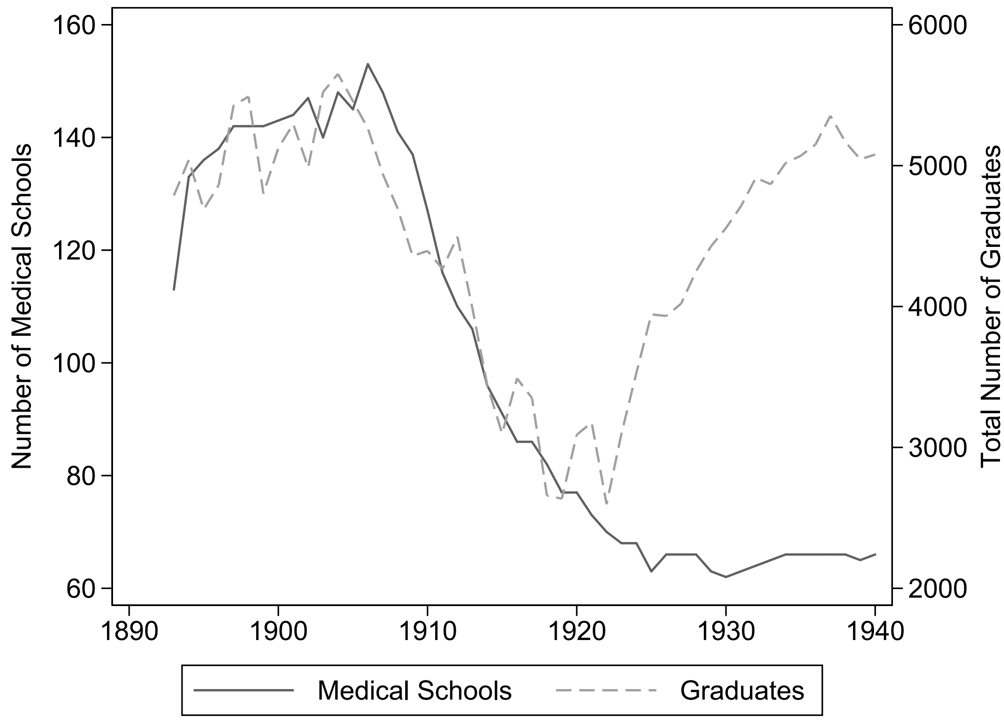

Figure 2: Trend in number of medical schools and graduates

labeled outright frauds. Flexner's report did not initiate the transformation of American medical education, but its publication likely prodded some state legislatures to act (Ludmerer 1985: 237). Many states went on to impose requirements for licensing that mirrored the requirements already adopted by the most rigorous medical programs, such as one or two years of college coursework prior to medical school and the completion of a hospital internship.

Medical schools were forced to respond quickly to these changes in order to maintain their enrollments. Schools that could not meet the cost of the new standards, which usually required expanding or enhancing a schools physical plant, allying with a hospital and hiring new full-time faculty, simply shut their doors.[2] The total number of medical schools in the U.S. fell from over 150 in 1900 to around 80 by 1923 (Mayers & Harrison, 1924, p. 16), as shown Figure 2. Closing schools meant falling total enrollments and a reduction in new physicians produced from a peak of 5,700 graduates in 1906 to a low of 2,700 in 1921.

[2]At Johns Hopkins in 1913, it cost $110,000 to maintain full-time departments of medicine, surgery and pediatrics, of which patient fees paid for $10,000 (The General Education Board, 1915, p. 22). Even more expensive was allying with a hospital and ensuring it met the standards suggested by Flexner. In 1919, the General Education Board estimated that $1 million would be the minimum amount necessary for a small, up-to-date medical school.

IV Examining the Differential Impact on Women

To examine how medical education and licensing reforms may have differentially impacted the ability of women relative to men to obtain a medical degree, we construct a panel dataset of all medical schools enrolling students between 1893 and 1940.[3] Data for the period 1893 to 1905 come from the annual reports of the U.S. Commissioner of Education; data for 1906 to 1940 come from the annual reports of the AMA's Council of Medical Education (CME). The data provided in the reports varies to some degree from year to year. However, for every year, we have data on female and male enrollment, the number of graduates, term length, and the number of faculty.

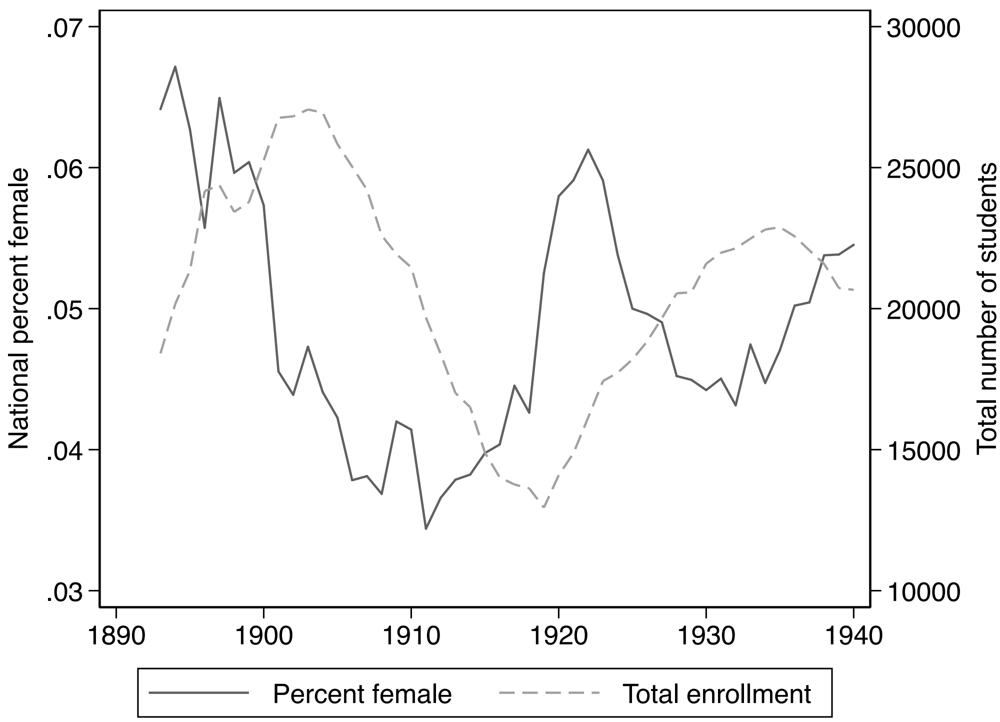

Figure 3: Trend in total enrollment and proportion female

The *prima facie* evidence linking medical education reforms to the decline of women in medicine is the dramatic changes over the first half of the 20th-century in the female proportion of medical school enrollments and graduates. Figure 3 presents data on total medical school enrollment and the percentage female enrolled in medical schools between 1893 and 1940. While total enrollment

[3]All of the data are reported for academic years, e.g. 1892-93, 1893-94, etc. We use the convention throughout the paper of referring to an academic year by the calendar year in which it ended (e.g., 1892-93 is referred to as 1893).

in medical school declines precipitously beginning in the first decade of the 20th century, the proportional decrease in the share of women enrolled begins to fall earlier and faster. We argue that the decline in the share of women enrolling in medical school operates through two channels. First, there may have been a "shut down" effect associated with school closures. As medical education requirements changed, women's only schools and schools with higher proportion of female students may have been more likely to close since many had fewer resources than schools that did not admit women. Second, even among schools that remained open, women may have been "shut out" of the opportunity to receive a medical degree if coeducational institutions admitted fewer women either from enacting gender-based quotas or becoming more selective in admissions decisions as competitor schools closed. Although the two effects overlap somewhat in time, as seen in Figure 3, the school closure period lasts from roughly 1900-1922, the "shut out" period lasts from 1915-1933, with dramatic temporary changes during WWI.

V Shutdown: Impact of School Closures on Female Physicians

An important component of the fall in female enrollment between 1893 and 1920 were closures of women's-only schools. The dramatic rise in women in medicine in the late nineteenth century was facilitated by the establishment of these schools. A few women, like Elizabeth Blackwell and her sister Emily, were able to gain admittance to existing male-only medical schools, but the resistance to coeducation was strong. Blackwell's success in gaining entry to an American medical school could hardly be attributed to progressive attitudes towards womens abilities and opportunities (Walsh, 1977, p.1). Despite her strong background, Blackwell received rejection upon rejection after she began applying to medical schools in 1847, with some rejection letters suggesting that she might be able to attend if she were willing to disguise herself as a male (Lopate, 1968, p.3). The Geneva Medical School in New York accepted Blackwell, but through a very unusual course of events. The faculty at Geneva, not willing to take responsibility for rejecting a candidate with such strong credentials, decided to leave her fate to a vote of the student body. In a raucous assembly, the students unanimously voted yes – apparently as a joke (Lopate, 1968, p.4). The students responded in shock a few weeks later when Blackwell entered the classroom (Morantz-Sanchez, 1985a, p.48).

Over time, women's medical schools continued to play an important role in women's entry into the medical profession through the 1890s. In 1895, eight women's only schools enrolled 546 students, accounting for 41 percent of all female enrollment in medical schools. Seven of the eight schools operating in 1895 closed by 1920, and the one that remained enrolled only 89 students.

However, women also lost ground because the coeducational schools that enrolled the most women also had high closure rates. Among schools operating in 1893-94, Table 1 shows that schools with at least 20 percent female students were more likely to close than schools with fewer women in their student bodies. By 1910, 67 percent of the schools with higher female enrollments shut down, compared to only 39 percent of schools enrolling fewer women. Similarly, by 1920, 78 percent of the schools with higher proportions of female students closed, compared to 58 percent of schools with a lower ratio of women in their classes.

Why were women's-only schools and schools enrolling higher shares of female students more likely to close? The most likely explanation is that they lacked the resources to remain open in the face of reforms in medical education. Appendix Table A1 provides a list of summary statistics for the sample of medical schools operating in 1893-94. We consider characteristics that are associated with level of rigor – such as having a four-year course of study and the length of the annual term, and resources – total enrollment, tuition, and the value of buildings owned by the school. A sizable fraction of schools (26 percent) did not provide data on the value of buildings owned. Most of these schools were affiliated with universities and likely did not independently own the buildings they used for instruction. We therefore include an indicator variable for missing data on value of buildings.[4] We also include indicator variables for whether a school affiliated with a non-regular sect of medicine, eclectic/Thomsonian or homeopathy.

In Table 2, we present results from linear probability models of whether these schools closed by 1910 or 1920 using characteristics measured in 1894 as predictors. Overall, we find that the more rigorous and better resourced schools were less likely to close. The probability of closure was lower for schools that adopted four year terms by 1894 and that had longer annual terms and

[4]For a small number of schools, a value of buildings was reported for 1892-93 but not 1893-94. In those cases, we used the value reported in 1892-93. It is important to note, that for several schools, the value of buildings was reported as zero. For these schools, we treated this as a value not a missing report.

higher enrollments. For the longer time horizon, closure by 1920, we find suggestive evidence that schools with better financial positions, as proxied by the value of buildings, were also less likely to close; the coefficient on the natural log of the value of buildings (plus 1 dollar) is negative and the p-value is 0.11.

In columns (3) and (4), we include measures of school's openness to women students to see if these had additional effects on closure probabilities. Column (3) includes an indicator if the proportion of enrollment that was female is above 20 percent, and column (4) includes an indicator for whether the medical school enrolled only women. The estimated effect of having a student body that was 20 percent or more female had no effect on the likelihood a school had closed by 1920. The higher observed closure rates of such schools shown in Table 1 can be attributed to the other characteristics of these schools. The estimated effect of being an all-women's college is negative and has a p-value of 0.12. Even this result, however, is indicative of the likelihood of closure be driven by the level of rigor and resources rather than openness to women. As noted above, of the seven all-women's schools open in 1893-94, six had closed by 1920. The fact that the effect of being a women's college does not meet standard levels of significance implies that these schools had other characteristics associated with closure.

To explore further the school characteristics associated with being more open to women, we estimate analogous regressions using measures of female enrollment as the dependent variables. In the final four columns of Table 2 we show that the predictors of closure are correlated with measures of female intensity at medical schools. Column (5) regresses the female proportion of enrollment and column (7) regresses an indicator for greater than 20 percent female on the same characteristics discussed previously. We find evidence that women were more likely to attend smaller schools with more limited financial resources. Additionally, schools of homeopathic medicine had much larger proportions of enrollment made up of women than schools of regular medicine. The same general story remains when we drop the all-women's schools in column (6). Co-educational schools with lower financial resources, smaller enrollments and teaching sectarian medicine had higher female enrollment proportions on average.

We do not have quantitative evidence to interpret these results as demonstrating that the market, the AMA, or state licensing boards purposefully targeted women's-only and schools with a high proportion of female students for closure. However, we can also not rule out such gender-based discrimination. Instead, at this point, we interpret our results as suggesting that women tended to attend schools with characteristics predictive of closure. The differential impact on women of the school closures is a *potentially* unintended consequence of increasing admission requirements for medical education and the licensing changes imposed to bring intransigent medical schools in line with the desires of professional bodies. We return to the existence of gender-based discrimination later in the paper.

It is important to note that, at the time, the closure of women's medical schools was viewed by some to be a step forward for women in the medical profession. Many prominent women physicians had long argued that women could only compete on an equal footing with men if they were trained in the same institutions. Women's colleges were viewed as a measure of temporary expedience, necessary only to demonstrate that women could handle the rigors of medical education (Morantz-Sanchez, 1985b, p.85). With the opening of Johns Hopkins as a coeducational medical school in 1893, many believed that the tide had turned and that coeducational opportunities would expand.[5] The closures of the all women's schools may have been driven by the increasing financial burden of providing a curriculum that kept pace with the scientific advances of the period, but they were not generally viewed as limiting the opportunities for women to pursue medical education. The Blackwells' school, the Woman's Medical College of the New York Infirmary for Women and Children, closed in 1899. Writing in 1900, Emily Blackwell reflected on her own experiences and those of others associated with women's medical schools, writing, "We had held open the doors for women until broader gates had swung wide for their admission" (as quoted in Walsh (1977, p. 180).

[5]Note that Johns Hopkins only became coeducational because of financial needs. While the hospital affiliated with the medical school opened in 1889, a lack of funding stalled the establishment of the school itself, since the funds intended for the school were tied up in stocks of the Baltimore and Ohio Railroad, which had stopped playing dividends in 1889. Four young women, all daughters of trustees of the University, came to the rescue by establishing the Womans Fund Committee and soliciting funds from women around the country. In 1890, the Woman's Committee offered Johns Hopkins $100,000 for its medical school, under the condition that the school would admit women on the same terms as men. The trustees voted to accept the funds and the condition of providing coeducation. Without this financial backing, it is unclear whether Johns Hopkins would have admitted women.

VI Shutout: Impact of Pre-Medical College Requirements on Female Physicians

Unfortunately, as demonstrated in Figure 3, the gates had not swung as wide as Blackwell had hoped. Women were shut out of many of the schools that remained open through the period of change. For example, Harvard Medical School did not admit women until 1945, and did so then only because of the pressures on enrollment due to World War II. Other schools were nominally coeducational, but admitted only a few women a year. More notable are the schools that significantly reduced their shares of female students in the early decades of the twentieth century. In this section, we further explore how changes in the technology of medicine and medical education, in combination with occupational licensing, affected women's access to medical training in the surviving schools. To capture the transformation of medical education, we use the timing of when a school adopted a two-year college requirement for admission. Law & Kim (2005) found that of the state licensing rules put into effect between 1880 and 1930, the only two that affected the stock of doctors were those requiring a four-year course of study and those requiring two years of college coursework prior to starting medical school. The impact of the four-year course of study, however, was small relative to that of the college coursework, and by 1900, almost all medical schools still open had four-year courses even though most states did not have such requirements for obtaining a license.[6]

The pre-medical education requirement may have reduced female enrollment in two ways. First, it may have had a direct effect. If the increased education requirements differentially reduced the supply of qualified women relative to men, then the proportion female for both enrollment and graduation may have decreased. Alternatively, these requirements may have opened the door for discrimination against women in medical school admissions. The raising of entrance requirements captures one of the mechanisms used by the AMA and AAMC, in conjunction with state licensing boards, to reduce the number of medical schools and the supply of (unqualified) physicians. In the presence of a taste for discrimination against women on the part of medical schools or fellow medical students, the less competitive environment faced by the surviving schools

[6] All surviving schools eventually imposed pre-medical education requirements for admission. The last school to impose a pre-med requirement was the New York Homeopathic Medical College and Flower Hospital in 1923. Of the 181 closed schools, only 15 adopted pre-med requirements for admission.

after the shutdown period would have reduced the cost of acting on that discrimination (Becker, 1957). The desire to discriminate against women could have taken the form of Goldin's "pollution" theory (Goldin, 2014). One of the goals of the AMA in its professionalization of medicine was to increase the prestige of the physician. Increased educational standards and the reliance on laboratory science was one method. However, given prevailing views of women in the workforce at the turn of the century, the entry of women to science-based medicine might "pollute" society's view of the physician, and reduce *his* prestige.

VI.A Empirical strategy

To quantify the shutout effect on access to medical education for women, we estimate the following baseline regression on the sample of surviving schools:

$$\%Female_{it} = \beta_0 + \beta_1(\text{Pre-med Requirements})_{it} + \mathbf{X}_{it}\beta_2 + \lambda_i + \lambda_t + \varepsilon_{it} \quad , \tag{1}$$

where i indexes the medical school, t indexes the year. We estimate equation 1 at the school-level for two dependent variables: the proportion of enrollment that is female, and the proportion of graduates that are female. The variable of interest, Pre-Med Requirements, is equal to one in a given year if the school required two years of baccalaureate education to enter medical school (year of enrollment for enrollment regressions, and year of graduation for the graduates regressions). The coefficient β_1 is the parameter of interest, capturing the association between a school's decision to require pre-medical undergraduate education and women's share of enrollment and graduation. It includes both the effect of increased entry requirements on directly limiting women's access to medical education, as well as the indirect effects through reductions in competitive pressures felt by medical schools.

The terms λ_i and λ_t represent school and year fixed effects. The school fixed effects control for unobserved school-level determinants of the proportion female that are constant over time, such as school reputation or prestige. The time fixed effects control for economy-wide shocks to enrollment and graduates that affected all schools (e.g. the reduction in demand for medical education by men during the years leading up to and immediately following World War I). The controls, X_{it}, include the log of total enrollment, an indicator for whether school i required an internship to graduate for classes enrolling (graduating) in year t, and an indicator for whether the state in which the medical school was located required an internship for licensure applicable to enrollees or graduates in year t. The log of total enrollment captures heterogeneity in the proportion female based on the size of the medical school. The internship and state-law-internship indicators allow us to control for important time-varying school-specific admission requirements and state licensing requirements that may have had an independent effect on the proportion female and that were also correlated with the school's choice to impose a two-year pre-medical education requirement.

Identification of β_1 comes from the variation in timing of the adoption of pre-med requirements across schools because all schools eventually adopt the requirements. The estimate is a weighted average of two-by-two difference-in-difference estimates of treatment timing groups (Goodman-Bacon, 2018). The weights are determined by the variance in treatment timing (time spent treated and time spent untreated) and the size of the timing group (the number of schools in a treatment timing group). Panel B of Figure 4 plots the variation in treatment timing across schools. The 1922 treatment timing group will have large weight for two reasons. First, the treatment variance is large. The groups spends half the sample in treatment and half as a control. Second, the sample size of the 1922 group is large; many schools adopted requirements in that year. In contrast, the 1909 timing group will have lower weight in the β_1 estimate. The sample size is small containing a single school, which spent the majority of the sample period in treatment (24 of the 27 years).

Baseline regression results correct the standard errors for clustering at the school-level (Bertrand *et al.* , 2004) and weight observations by enrollment (or the number of graduates) to capture the presence of heteroskedasticity with respect to school size (Solon *et al.* , 2015). Because the shutdown period ended in the late 1920s with the last medical school closing in 1926 (Kansas City University of Physicians and Surgeons), we limit the sample to 1906-1932. For the proportion female regressions, the sample is further limited to medical schools that admitted and graduated at least one female over the sample period. This restriction removes seven all-male and one all-female medical schools. We do not include school-specific linear time trends in the base models. *A priori*, we might expect there to be time-varying treatment effects in the models and the inclusion of linear trends would bias estimates toward zero by soaking up part of the true treatment effect (Meer & West, 2016; Goodman-Bacon, 2018). In the appendix, we provide a set of estimates showing the robustness of our main results to the inclusion of school-specific linear time trends, unweighted regressions, and extending the sample period to 1940.

Appendix Table A2 presents summary statistics for the samples used in the shutout regressions. The mean across school-years of the proportion female for enrollments was 4.58 percent, with a large range from 0 to 31.14 percent. For graduates, the mean proportion female across schools was similar at 5.44 percent, with an even larger range from 0 to 100.

VI.B School-level results on shutout

Base estimates of β_1 with annual data for the period 1906-1933 are presented in Table 3. Panel (A) presents results for the proportion female. Column (1) and column (4) suggest that for surviving schools the adoption of pre-med requirements leads to an 2.077 percentage point reduction in the proportion female for enrollment and a 2.688 percentage point reduction for graduates. The estimated effect sizes are meaningfully large. Limiting the sample to the years prior to the adoption of a two-year pre-med college requirement, the average proportion female is 4.58 percent for enrollment and 5.44 percent for graduates, implying estimated effect sizes of 45 percent and 49 percent, respectively. The estimated effect size for graduates is slightly larger than for enrollments, but this difference is not statistically significant. Even if the difference was meaningful and precisely estimated, we would hesitate to interpret it as evidence of two separate leakage points from the pipeline of female physicians: the first upon admission to med school, and the second at graduation. The estimated effect on enrollment is likely attenuated because of measurement error. Ideally, we would like to use class-specific enrollment by gender, but the AMA did not publish data at this level. Instead, we have total enrollment across all four classes at a school in a given year, giving a four-year rolling average. The full effect of an increase in admission requirements is not felt until a full four years after its introduction.

Columns (1) and (4) report results for schools that remained open for the entire sample period. We prefer these specifications as our base results because few closed schools actually implemented pre-med college requirements. For completeness, we include Columns (2) and (5), which present results for the full sample (surviving and closed schools combined), and columns (3) and (6) for the sample of closed schools. Estimates of β_1 are slightly smaller for the full sample of schools. Closed schools experienced relatively small, but imprecisely estimated declines in the proportion female of both enrollments and graduates.

Conditional on holding pre-med requirements constant, we find suggestive evidence that internship requirements imposed by the medical schools reduced the proportion female by 2.179 percentage points for enrollment, and a 1.625 reduction for graduates. However, only 7 of the 62 schools in the sample required internships for graduation, and thus we do not emphasize the results on internships. State licensure requirements for internships are never statistically significant across any specification, and relatively small in magnitude.

The adoption of pre-med requirements by medical schools decreased total enrollment and the number of graduates at the same time as decreasing the proportion female. Panel B of Table 3 presents estimates of β_1 from equation 1 using the natural log of enrollment and graduates as dependent variables. Estimates suggest that the adoption of pre-med requirements lead to a 33.3 percent reduction in enrollments and a 21.1 percent reduction in the number of graduates. Clearly, the number of potential male and female students interested in and qualified to enroll in medical school decreased in response to medical schools increasing admission requirements. Combined with the concurrent reductions in the proportion female, we interpret these findings as evidence of a differentially negative impact on the production of female physicians relative to male physicians.

VII Discussion

Our results show that medical education reforms impacted women more than men. Women's colleges closed and coeducational institutions experienced a decline in the the percentage of women enrolled, so that the percentage of women practicing as physicians actually declined in the early part of the twentieth century. In this section, we explore competing theories about *why* women may have been differentially affected.

First, it may have been the case that women were less able to meet the one- and two-year premedical education requirements implemented by the schools. 1890-1930. Data show that while more men than women received degrees throughout the period, the gap between men and women did not change with the exception of World War I, when the number of degrees awarded to men sharply declined.[7] Moreover, as the number of undergraduate degrees earned by men fell during WWI, the percentage of women enrolled in medical school increased even as total enrollment across all schools continued to decline as schools closed down.Taken together, these data suggest that that the supply of qualified women entering medical school was not a limiting factor in determining the share of women who enrolled. Rush, Johns Hopkins, Cornell, and University of Pennsylvania greatly increased their enrollments of women students between 1915 and 1922 only to cut them back sharply by 1930. Pressures on enrollments during the war years were so great that even Harvard Medical School contemplated admitting female students. The male students at Harvard circulated a petition in opposition, stating as a primary objection that whenever a woman proved herself capable of intellectual achievement, the area in question ceases to constitute an honor to the men who had previously prized it (as quoted in Walsh (1977, p.210). In the end, Harvard did not admit any women, claiming that it had not received any qualified applicants. (Ibid: 210). Harvard, in fact, did not admit women until 1945.

The response of the medical schools and students during the war years is consistent with another theory: that of discrimination. If medical schools harbored a taste for discrimination against women, the less competitive environment faced by the surviving schools after weaker institutions closed would have lowered the cost of acting on that discrimination (Becker, 1957). The Harvard students' objection to enrolling women is suggestive of Goldin's "pollution theory," in which schools and students reduced admissions of women because the prevailing view of women in the labor force in the early twentieth century may have reduced the perceived prestige of the field (Goldin, 2014).

Unfortunately, we have no way of formally testing whether medical schools discriminated against women in the admissions process, as we do not know the pool of all students who applied for admission. Nevertheless, qualitative evidence supports the theory that medical schools discriminated against women. Both Johns Hopkins and Northwestern became coeducational because of financial necessity. In the case of Johns Hopkins, it could not open until it received

[7] In the series on undergraduate enrollment, there is a decline in the number of women attending college, but this may be a data error since the decline is not later reflected in a declining number of graduates.

more funding. Several daughters of the school's Trustees formed a group called the "Women's Committee" and offered the medical school the funding it needed if it agreed to admit women. In Chicago, the Medical College of Chicago graduated 350 women doctors by 1892, when it became part of Northwestern, which operated the women's division as a separate unit. Ten years later, the university closed the women's division with no notice. The medical school did not again accept women until 1926, after Elizabeth Ward (the wife of the late tycoon Montgomery Ward) casually asked about women being admitted to the school when she was in the process of making a donation. Immediately, women started being accepted (Walsh, 1977, pp. 204-205). Nevertheless, the school set a quota: only four women could be allowed to attend per year, with their 100 male classmates. The reason: students worked on dissection in teams of four, and it would have been "unseemly" to have mixed dissecting teams (Thielking, 2015).

Nor do the declines in female enrollments at coeducational medical schools seem to have been due to women's failure to succeed in coeducational environments. Qualitative evidence suggests the opposite - again consistent with a model of discrimination where the few women who were admitted were of top quality. Women accounted for six percent of medical school graduates from the University of Michigan between 1916 and 1926. Between 1923 and 1926, 84.8 percent of women had bachelor's degrees upon admission, compared to only 44.1 percent of men. The women did better while at medical school as well, with a grade point average of 3.87 compare to men's 3.46 (Walsh, 1977, p. 205-206). At Tufts College Medical School, women accounted for 26 percent of all graduates in 1902, but 60 percent of the students receiving honors. One of the school's trustees remarked that the objection to coeducation was that female students had performed too well. Although this could have been an argument to maintain or even expand the enrollment of women, the number of female students instead declined. In 1900, Tufts enrolled 62 women, accounting for 25 percent of its total enrollment. By 1910, the number of female students had fallen to 33, only 8 percent of total enrollment.[8]

[8] Walsh (1977, p. 210) argues that this dramatic change was due to the imposition of limits on the numbers of females admitted to the school to appease male students.

VIII Conclusions

The share of women enrolled in medical school and practicing as physicians declined during the first half of the twentieth century and did not return to its 1900 level until after 1960. Counter to the findings of previous work in the occupational licensing literature, we find that that medical education reforms culminating in state licensing changes contributed to a decline in the share of women physicians during the early 20th century. We attribute the effect to two mechanisms: shutdown and shut out. At the turn of the century, most women were educated in women's only colleges. We show that these institutions were much more likely to close than male-only or coeducational institutions because they lacked financial resources. Yet, the closure of women's schools cannot account for the entire decline in the number of women trained as physicians. Even as the women's colleges shut down, coeducational institutions enrolled fewer women. Moreover, the percentage of female students declined more in schools that implemented stricter standards.

Theory suggests that fewer women may have been admitted either because women were unprepared to meet the higher standards, or because schools and male medical students had a taste for discrimination. Qualitative evidence suggests the latter. Two prominent universities accepted women only to attract prominent donors. Others admitted few women, except when male applicants declined during WWI. Women admitted to these schools frequently were more prepared and performed more strongly than their male counterparts. Harvard refused to admit women until 1945, when enrollments were under pressure during WWII. And finally, the share of women medical students, having fallen after its peak around 1900, did not again meet that peak until after 1960. It was not until after 1970 when women made real ground in medical school admissions, when the Women's Equity Action League, alleging discrimination against women in admission, filed a class-action lawsuit against all medical schools. Two years later, the federal government passed Title IX of the Education Amendments Act of 1972, prohibiting discrimination on the basis of gender (Nilsson & Warren, 2016). Subsequently, the number of women enrolled tripled from 9 percent in 1970 to 21 percent in 1976, a number 300 percent above the 1960 figure (Walsh, 1977, p. 268). Today, about half of medical school students are female. These results suggest the need to re-evaluate the effect of Progressive-era medical education and licensing reforms on women.

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Table 1: Schools with higher proportion female more likely to close

Panel A: Closure by 1910			
	Med Schools with Proportion Female		
	$< 20\%$	$\geq 20\%$	All Schools
Open	69	9	78
	(61)	(33)	(58)
Closed	44	18	62
	(39)	(67)	(44)
Total	113	27	140
	(100)	(100)	(100)

Panel B: Closure by 1920			
	Med Schools with Proportion Female		
	$< 20\%$	$\geq 20\%$	All Schools
Open	47	6	53
	(42)	(22)	(38)
Closed	66	21	87
	(58)	(78)	(62)
Total	113	27	140
	(100)	(100)	(100)

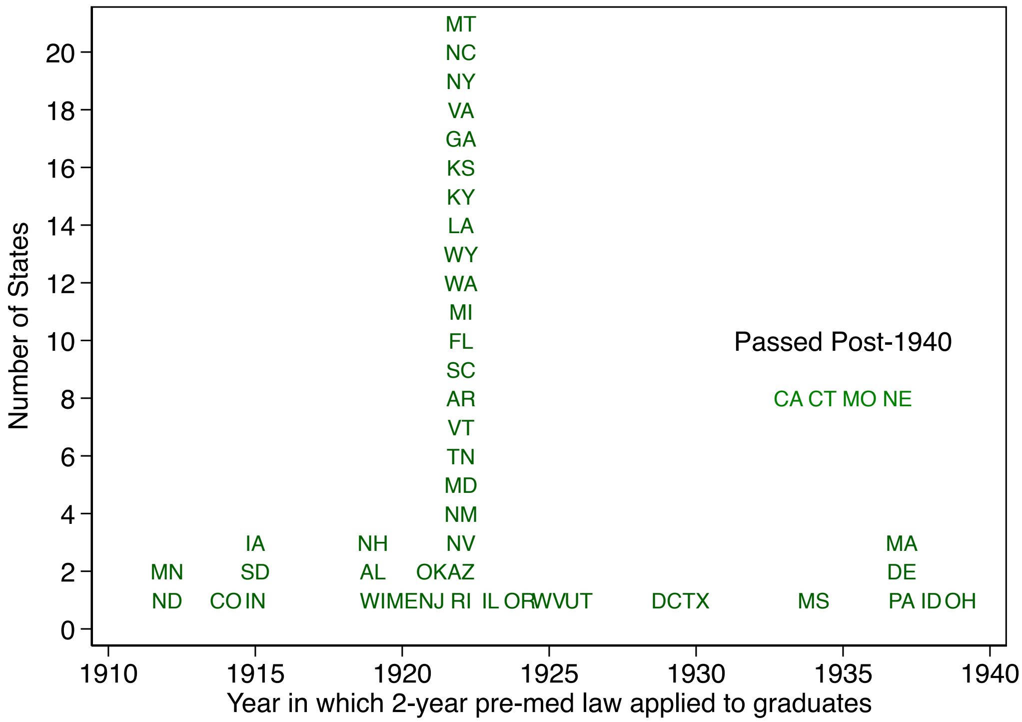
Panel C: Closure by 1920 - Limited to Women's Colleges			
	Womens Medical School		
	No	Yes	All Schools
Open	52	1	53
	(39)	(14)	(38)
Closed	81	6	87
	(61)	(86)	(62)
Total	133	7	140
	(100)	(100)	(100)

Notes: Entries are number of medical schools operating in 1893-94 that fit a closure and female proportion category, with column percentages in parentheses.
Sources: United States Commissioner of Education (1894); American Medical Association Council on Medical Education (1906-1940).

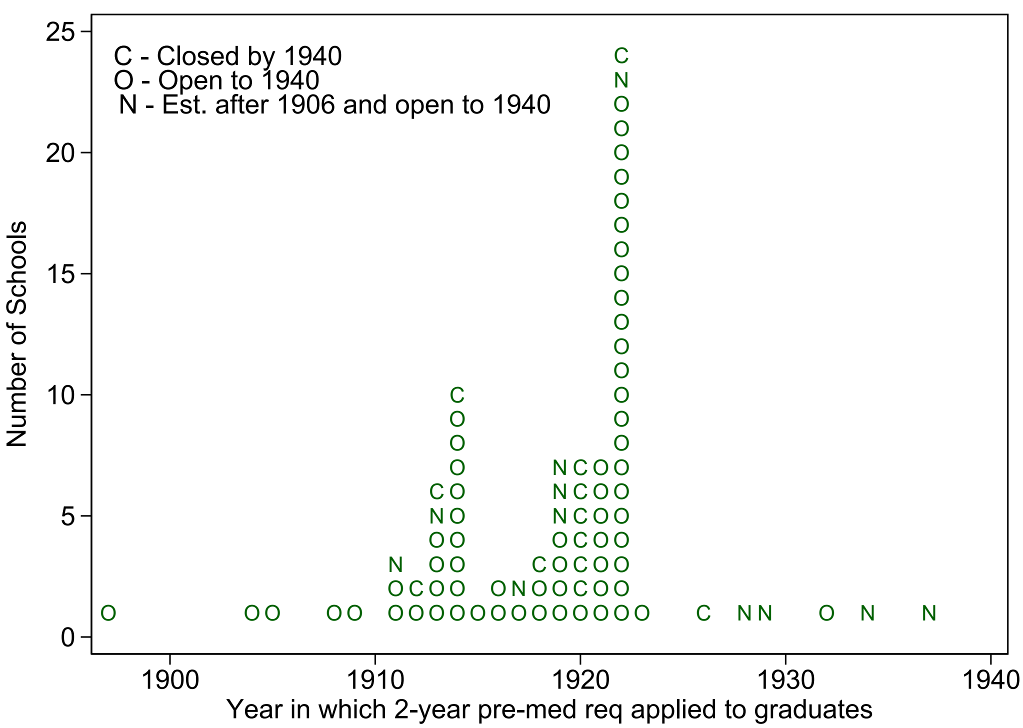
Table 2: School Characteristics, School Closure, and Proportion Female

	Medical school closed by				Proportion female			
	1910	1920	1920	1920	Continuous	Continuous	≥ 20	≥ 20
Four-year terms	-0.311**	-0.314***	-0.313***	-0.330***	3.154	-3.520	-0.030	-0.105
	(0.121)	(0.107)	(0.107)	(0.107)	(5.519)	(2.608)	(0.086)	(0.078)
Term length (weeks)	-0.016	-0.028***	-0.028***	-0.030***	1.009**	0.362*	0.009	0.003
	(0.010)	(0.009)	(0.009)	(0.009)	(0.466)	(0.213)	(0.007)	(0.006)
Ln(Total enrollment)	-0.137**	-0.165***	-0.163***	-0.156***	-7.194***	-4.070***	-0.112***	-0.080**
	(0.053)	(0.047)	(0.048)	(0.047)	(2.414)	(1.113)	(0.038)	(0.033)
Eclectic	-0.184	0.089	0.090	0.107	2.491	8.368***	-0.010	0.040
	(0.149)	(0.132)	(0.132)	(0.131)	(6.817)	(3.084)	(0.106)	(0.092)
Homeopathic	0.129	0.039	0.028	0.046	15.895***	19.551***	0.507***	0.566***
	(0.121)	(0.107)	(0.120)	(0.106)	(5.517)	(2.557)	(0.086)	(0.076)
Ln(Tuition)	0.027	0.026	0.024	0.018	2.848	0.154	0.065	0.037
	(0.076)	(0.067)	(0.068)	(0.067)	(3.481)	(1.582)	(0.054)	(0.047)
Ln(Value of buildings)	-0.009	-0.023	-0.023	-0.019	-1.741**	-0.517	-0.019	-0.013
	(0.016)	(0.014)	(0.014)	(0.014)	(0.740)	(0.371)	(0.012)	(0.011)
Missing value of buildings	-0.043	-0.183	-0.179	-0.124	-21.940***	-4.452	-0.189	-0.084
	(0.182)	(0.161)	(0.163)	(0.164)	(8.315)	(4.158)	(0.129)	(0.124)
Proportion female ≥ 20			0.021					
			(0.109)					
Woman's college				0.262				
				(0.168)				
Constant	1.514***	2.282***	2.275***	2.263***	21.524	18.559**	0.303	0.333
	(0.428)	(0.377)	(0.380)	(0.375)	(19.534)	(9.015)	(0.304)	(0.269)
Observations	139	139	139	139	139	132	139	132
R-squared	0.170	0.319	0.319	0.331	0.234	0.477	0.339	0.403

Notes: Entries are coefficient estimates and standard errors in parentheses from linear probability models of school closure (columns 1-4), or measures of proportion female (columns 5-8) on school characteristics measured in 1893-94. The sample includes all medical schools open in 1893-94. Columns 6 and 8 drop women's only schools from the sample.
Sources: United States Commissioner of Education (1900); American Medical Association Council on Medical Education (1910-1940).



(a) State licensure



(b) Medical school admission requirements

Figure 4: Timing of adoption of 2-year pre-med requirements

Table 3: The effect of pre-med and internship requirements

Panel A: Proportion female						
	(1) Enrollment Open	(2) Enrollment All	(3) Enrollment Closed	(4) Grads Open	(5) Grads All	(6) Grads Closed
School pre-req	-2.077***	-1.645**	-0.965	-2.688***	-2.044***	-2.226
	(0.668)	(0.650)	(1.464)	(0.762)	(0.666)	(1.495)
School intern req	-2.179**	-2.053**		-1.625	-1.208	
	(0.966)	(1.015)		(1.058)	(1.029)	
State intern req	-0.536	-0.537	0.109	-0.787	-0.561	-0.256
	(0.631)	(0.586)	(0.875)	(0.777)	(0.784)	(0.930)
Observations	1636	2556	841	1427	2275	821

Panel B: Log Enrollment and Log Graduates						
	(1) Enrollment Open	(2) Enrollment All	(3) Enrollment Closed	(4) Grads Open	(5) Grads All	(6) Grads Closed
School pre-req	-0.333***	-0.294***	0.110	-0.211**	-0.174**	0.298**
	(0.0761)	(0.0736)	(0.218)	(0.0854)	(0.0768)	(0.140)
School intern req	0.0580	0.0723		-0.159	-0.177	
	(0.108)	(0.105)		(0.158)	(0.166)	
State intern req	-0.0544	-0.0436	0.0628	-0.0821	-0.0656	0.255
	(0.0948)	(0.0864)	(0.133)	(0.0867)	(0.0829)	(0.159)
Observations	1839	2759	841	1612	2461	822

Notes: Each column represents a separate regression where the observation is at the school-year level. The dependent variable is the proportion of the class (or graduates) that are female, measured from 0 to 100. All regressions include school fixed effects, year fixed effects, and the natural log of total student enrollment. Observations are weighted by total student enrollment or total number of graduates. The sample period covers 1906-1932. Female only and male only medical schools are dropped from the sample. The open schools sample includes all medical schools that survived to 1933. The closed schools sample includes only schools that closed by 1933.
Sources: Various years of the annual report by the Committee on Medical Education of the American Medical Association published in the *Journal of the American Medical Association.*