Dispensing Education: PharmD and Supply Side Responses in Higher Education

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Abstract

How do universities and labor markets respond when a policy shock dramatically expands the supply of workers in a profession? In 2000, the entry-level degree to become a pharmacist increased from an undergraduate degree to a graduate degree. This credential shift acted as a large shock to the supply of pharmacy education and led to unexpected outcomes: the number of new pharmacists nearly doubled over the following 15 years. We show that universities responded to this shock by opening new pharmacy schools and directing the resulting revenue toward investments in "quality"—increasing faculty, research, and institutional support—with no evidence of cross-subsidizing undergraduate enrollment or tuition. We also document that the resulting growth in pharmacy education depressed pharmacist wages by approximately 5 percent and, by some measures, reduced the quality of pharmacy graduates. We argue that the growth in pharmacy education arose because graduate students can borrow substantially more in federal student loans than undergraduates, meaning the shift to a graduate credential dramatically expanded students' access to federal credit and fueled a surge in demand for pharmacy education that institutions were quick to supply.

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1 Introduction

In 2000, the entry-level degree required to practice pharmacy in the United States shifted from a five-year undergraduate Bachelor of Science in Pharmacy (BSPharm) to a six-year graduate Doctor of Pharmacy (PharmD). Standard models of occupational licensing predict that raising educational requirements restricts supply and increases wages (Friedman and Kuznets, 1945). In pharmacy, these predictions failed. Over the next twenty years, the number of pharmacy programs nearly doubled, and the annual number of graduates rose by a similar magnitude. This paper studies how that expansion reshaped universities and the pharmacist labor market as well as why that expansion occurred.

We begin with the supply side of higher education. The opening of PharmD programs generated substantial new revenue for institutions of higher education. Using accreditation data and institution-level administrative records, we document that the post-2000 growth in pharmacy education was driven primarily by the entry of new PharmD programs at institutions that had not previously offered a BSPharm. These entrants were disproportionately private, non-profit institutions. Enrollment growth was concentrated in these new programs, accounting for the majority of the overall expansion.

Because pharmacy programs are quite profitable, we examine how universities responded to this new source of funds. Exploiting staggered program openings in a difference-in-differences framework, we compare institutions that opened PharmD programs to observationally similar institutions that did not. Institutions that opened PharmD programs experienced sizable increases in total revenues and expenditures. However, these funds were not used to expand undergraduate enrollment or to reduce undergraduate tuition. Instead, we find evidence of increased spending on faculty, research, and institutional support. Total instructional staff rose substantially, and the increase in faculty exceeds what can be accounted for by pharmacy-school hiring alone, indicating cross-subsidization to other academic units. These patterns are consistent with models in which universities behave as complex, multi-product firms that reinvest marginal revenue in measures of prestige and quality (Bowen, 1980; Ehrenberg, 2000).

We next turn to the downstream labor market. The expansion of PharmD programs led to a substantial increase in the flow of new pharmacists. Using Census and American Community Survey data, we show that states in which new PharmD programs began graduating students experienced increases in the number of young pharmacists. In those same states, median hourly wages for pharmacists declined by roughly five percent in the decade following program entry. We do not observe analogous wage changes for other college-educated workers, suggesting that the results are not driven by general equilibrium shifts in local skilled labor markets. Nor do we find strong evidence of adjustments along the hours margin. In contrast to the classic prediction that more stringent licensing requirements reduce supply and raise wages in exchange for improved service quality (Friedman and Kuznets, 1945), the pharmacy case features an expansion in supply, lower wages, and suggestive declines in measures of graduate quality, including lower licensing exam pass rates at new programs.

These institutional and labor market responses are puzzling if the PharmD requirement is viewed solely as an increase in training costs. We argue that the key to understanding this episode lies in the interaction between the increased degree requirement and federal student loan policy. Graduate and professional students have historically faced much higher annual and lifetime borrowing limits than undergraduates (Hegji, 2021), and the creation of the Grad PLUS program in 2006 effectively removed borrowing caps for graduate study (Black et al., 2023b). The shift from BSPharm (an undergraduate degree) to PharmD (a graduate degree) therefore mechanically increased students' access to federal credit. In the final years in which both degrees were offered, PharmD students were eligible to borrow several times more per year—and over a lifetime—than BSPharm students, and subsequent cohorts of PharmD graduates accumulated debt far in excess of undergraduate borrowing limits.

We document that PharmD students borrowed more than their BSPharm counterparts even when both degrees coexisted, and that borrowing rose sharply as the PharmD became mandatory. While rising pharmacist wages in the 1970s, 1980s, and 1990s may have increased demand for pharmacy education, there was no sharp break in wage growth that coincided with the influx of new enrollments and simple calibrations suggest that wage growth can account for only a modest share of the post-2000 enrollment surge. In contrast, the expansion of federal borrowing capacity directly relaxed credit constraints for prospective students and increased their ability to pay tuition (Denning, 2019; Denning and Jones, 2021; Black et al., 2023a; Black et al., 2023b). In a market with relatively low barriers to entry on the institutional side, this demand shock translated into program entry and enrollment growth.

Taken together, our results contribute to four strands of literature. First, we provide new evidence on supply-side responses to student aid. Much of the empirical literature has focused on the Bennett Hypothesis, that programs raise prices to capture increases in financial aid (Singell Jr and Stone, 2007; Cellini and Goldin, 2014; Lucca et al., 2019; Baird et al., 2022; Black et al., 2023b). Our setting highlights the importance of quantity adjustments and institutional entry which has largely gone unexplored.[1] Ignoring quantity responses may lead to an incomplete picture of the effects of additional financial aid. Second, we offer evidence on universities as multi-product organizations with objectives that extend beyond enrollment maximization.[2] The allocation of PharmD-generated revenue toward faculty hiring and research activity is consistent with revenue-driven investment in quality and prestige (Bowen, 1980; Ehrenberg, 2000). Third, we show how licensing changes can generate unintended consequences when they interact with credit markets. In pharmacy, raising formal educational requirements expanded supply and reduced wages, the opposite of the typical response (e.g. Acevado et al., 2024; Kleiner and Xu, 2025). Fourth, we show the labor market effects of a shock to the supply of a particular type of worker (Autor et al., 2013; Peri and Yasenov, 2019) in a field, healthcare, which is now the largest industry by employment in

[1] Related work has examined non-financial demand shocks, typically driven by labor market conditions (Gilpin et al., 2015; Conzelmann et al., 2023; Light, 2024), and finds universities to be relatively elastic along this margin.

[2] Related work has examined university costs and responses to student demand (Jacob et al., 2018; Hemelt et al., 2021).

the United States (Gottlieb et al., 2025).[3]

The rest of the paper proceeds as follows. Section 2 provides background on the transition from BSPharm to PharmD and documents the growth in pharmacy programs and enrollment. Section 3 analyzes institutional responses to the opening of PharmD programs. Section 4 studies the effects on pharmacists' wages, employment, and quality. Section 5 examines the role of student loan policy and alternative explanations for rising demand. Section 6 concludes.

2 Background and Facts

Transition to PharmD

Our summary of the history of pharmacists' education and practice relies heavily on Urick and Meggs (2019). Prior to 2000, students could become practicing pharmacists with either a PharmD or a BSPharm. A BSPharm was typically a five-year program consisting of two years of science prerequisites and three years of pharmacy-focused coursework. Some schools also offered a PharmD, which typically took six years.[4] The additional year of PharmD training focused on patient care and clinical skills (Kreling et al., 2010).

In 1946, the Pharmaceutical Survey, commissioned by the American Council on Education, recommended requiring six years of instruction for pharmacists. The question was debated frequently thereafter. In 1984, the American Pharmaceutical Association advocated for the PharmD as the standard degree. A vote on the matter by the American Association of Colleges of Pharmacy House of Delegates in 1985 was narrowly defeated. In 1989, the Accreditation Council for Pharmaceutical Education declared its intent to make the PharmD the standard degree by 2000. In 1997, the American Council for Pharmacy Education formally adopted this standard, and by 2005 BSPharm programs had been phased out entirely (Urick and Meggs, 2019; Kreling et al., 2010).

The decision was controversial. McLeod (1992) summarizes the arguments on both sides. Proponents held that five years of training was insufficient to develop the clinical and therapeutic skills pharmacists needed, and saw the transition as an opportunity to raise the profession's status and align it more closely with physician training. Opponents worried about the added costs to students and questioned whether the additional skills were necessary for many roles pharmacists actually filled in the labor market.

The CEO of the National Association of Chain Drug Stores argued against the transition, contending that the marketplace was functioning well and that eliminating the BSPharm would raise

[3] Other work in economics has used the pharmacy profession to shed light on broader labor market trends. In particular, Goldin and Katz (2016) highlight features of the occupation—most notably its standardized hours and limited returns to long workweeks—that help explain its unusually small gender pay gap. This insight has been highly influential in shaping subsequent work on gender differences in earnings and the organization of work (Goldin, 2014, 2024). While the hours structure of pharmacy is not central to our analysis, we examine wage effects separately by gender and do not find substantial differential impacts along this margin. More broadly, this literature demonstrates that pharmacy is a valuable laboratory for studying questions of general economic interest.

[4] A BSPharm typically had two years of prerequisites with 3 years of pharmacy instruction. A six-year program typically consists of four years of pharmacy instruction preceded by two years of science prerequisites, often completed as part of a bachelor's degree.

healthcare costs. He also characterized the transition as anti-competitive, since it removed a credential that was producing many well-prepared graduates (National Association of Chain Drug Stores, 1998). We searched quarterly earnings calls for CVS, Walgreens, and Rite Aid for mentions of the BSPharm-to-PharmD transition but found none—though our access to earnings calls begins in 2006, after the transition was complete.[5]

Pharmacy Programs: Profitability, Excess Demand, and the Accreditation Environment

Many professional programs at universities appear to be quite profitable (e.g. Harvard Business School, 2024; University of Colorado Boulder, Budget & Fiscal Planning, 2023). Using data from from the American Association of Colleges of Pharmacy's (AACP) office of Institutional Research and Effectiveness, we provide evidence that this is also the case for Pharmacy programs.

One question from this survey indicates that the pharmacy school is unambiguously"profitable," that is, that the program returns money to the university. If a pharmacy school chooses the answer, "Totally self-reliant on funds I generate but a portion of which are returned/given back to (or taxed by) the campus/university", we classify the pharmacy program as being profitable.[6] The answers to this question are reported separately by private and public schools and so we discuss these separately.

In 2011-12, 50% of the 30 private schools that participated in the survey stated that they were profitable while only 3.3% indicated that they received a subsidy from the university. By 2021, 57% of the 64 private schools that responded say they are profitable. Over that time period there were 34 more schools that reported, and the increase in the number of profitable schools was 22.

We conclude that most private pharmacy schools are unambiguously "profitable." The survey further reports the total income and revenues as well as expenditures across the sector. In 2012-13, private institutions' income and revenues are 72 percent higher than expenditures. At the school level, the median income and revenues less expenses was $4.7 million. In short, private pharmacy programs are quite profitable. The single biggest source of revenue is college tuition and fees which in aggregate was 67 percent of income and revenue.

It is less clear what fraction of public universities are profitable because they primarily choose the answer, "Reliant on funds I generate combined with a state (or private university) supplemental allocation some of which is returned/given to (or taxed by) the campus/university." This leaves open the possibility that they are profitable, but it is not definitive. That said, in aggregate, public schools have income and revenues that is 34 percent higher than expenditures and at the school level, median revenue less expenses was $4.7 million.

Overall, public pharmacy schools tend to receive money from the university or state and rely

[5]Specifically, we searched for the keywords "PharmD", "BSPharm", "education", "pharmacists", "shortage", and "staff."

[6]The other options are "Totally self-reliant on the funds which I am able to generate and all of which I keep", "Reliant on funds I generate combined with a state (or private university) supplemental allocation some of which is returned/given to (or taxed by) the campus/university", or "Other".

on research to fund their school.[7] Private pharmacy programs rely much more heavily on tuition. Hence, if the growth in pharmacy schools after the move to PharmD is driven by an increased ability to generate revenue from tuition, we would expect most of the entrants to be private schools.

Despite the profitability of pharmacy programs, until recently, there was a considerable amount of excess demand for pharmacy education. For example, for the 2003-2004 cohort, approximately 34 percent of applicants were admitted to a pharmacy school (American Association of Colleges of Pharmacy, 2024). This estimate comes from the Pharmacy College Application Service (PharmCAS), a centralized service for Pharmacy school admissions. PharmCAS began in 2003-2004 with 43 of the existing 89 pharmacy schools participating.[8] This suggests that there was sufficient demand for schools to expand the sizes of their incoming classes or new schools could have opened had they wanted to do so. Recent work (Blair and Smetters, 2021) suggests that selective schools face a tradeoff from expanding: although they gain larger revenues, they lose prestige and their costs rise. Intuitively, for a school to expand or to be created, the amount of revenue gained has to be large enough to justify the increased costs and also the cost to prestige. Models of this type predict that non-elite colleges expand enrollment the most in response to excess demand.

The accreditation environment that schools operate in is crucially important for understanding how firms (universities) respond. Over this time period, the attitude of the accrediting body in pharmacy was not to restrict supply by limiting the creation of new programs. Instead, they were interested in maintaining standards of instructional quality. We discuss this environment in more detail in Appendix B.

Growth in Pharmacy Schools

We document several facts about the growth in pharmacy education. First, the number of pharmacy degrees conferred increased markedly beginning around 2000. Second, this growth was driven primarily by the opening of PharmD programs at institutions that had not previously offered a BSPharm. Third, the new pharmacy schools were disproportionately private and nonprofit.

Using accreditation data collected from the Accreditation Council for Pharmacy Education (ACPE), Figure 1a shows the total number of pharmacy schools over time.[9] The number of schools grew from the 1940s through the 1960s before plateauing for roughly 30 years. After a modest uptick in the early 1990s, the count grew rapidly from 2000 onward. In 1999, there were 75 accredited pharmacy programs in the United States; by 2023, that number had nearly doubled to

[7] The primary sources of revenue for public pharmacy programs are research revenue (23.6 percent of total revenue) and state or campus allocations (22.4 percent). Tuition only represents 14 percent of total revenue.

[8] Unfortunately, we have not found data on the fraction of applicants admitted to schools that do not use the PharmCAS. However, we can create a rough upper bound by assuming that all of those schools admitted one hundred percent of applicants. In that case, the acceptance rate would be no more than 68 percent.

[9] New pharmacy programs are accredited by the ACPE, which requires applicants to demonstrate legal authority to grant degrees, propose a curriculum, and submit a financial plan. The ACPE grants precandidate status that progresses to candidate status upon meeting certain milestones. Importantly, the ACPE focuses on instructional quality rather than restricting the number of pharmacists entering the market. See Appendix B for more detail. Table A1 lists all schools that opened.

145.

Because all pharmacy schools switched exclusively to PharmD enrollment after 2000, the growth in programs must reflect expansion of PharmD rather than BSPharm offerings. Figure 1b shows the cumulative number of new PharmD programs opened at institutions that had not previously offered a BSPharm—isolating new entry from conversions of existing programs. Virtually none existed before 2000; by 2023, 71 had opened.

Growth in Pharmacy Enrollments

Growth in the number of schools does not necessarily imply growth in total enrollment—new schools could simply draw students away from existing programs. As the blue line in Figure 2 shows, however, this was not the case.[10] Total enrollment in BSPharm and PharmD programs combined grew from approximately 34,000 in 2000 to more than 57,000 by 2020.

This expansion had two sources: enrollment at newly created schools and enrollment growth at existing BSPharm institutions. The red line in Figure 2 shows that new schools—those without a prior BSPharm program—grew to enroll more than 20,000 students by the late 2010s before declining somewhat. New schools account for 73 percent of overall enrollment growth. The remaining 27 percent reflects expansion at existing institutions, which added approximately 6,200 students over this period.

Figure 3 breaks down enrollment trends further by school type: public, private non-profit, and private for-profit. Among existing schools, both public and private institutions expanded enrollment through the early 2010s, after which private non-profit enrollment declined. Among new schools, private non-profits account for the majority of growth. Figure 3b shows that enrollment per school grew modestly at new public and for-profit institutions, but much more substantially at existing public and non-profit schools. This means that growth at new non-profit and public schools was driven primarily by the proliferation of schools rather than by increases in school size after opening.

3 Effects on Institutions

We turn our attention to how universities were affected by the opening of a new pharmacy program. Given that many pharmacy schools are profitable, we ask how the university spends the additional, marginal dollars. This gives insight into what a university's objective function is and yields some insight into a policy relevant parameter: if universities are able to raise revenue, how will they spend it? Further, it is related to work on the Bennett Hypothesis which states that universities raise tuition in response to additional financial aid. However, that literature has typically not focused on how universities use the money they raise.

[10] Authors' calculations using data from the American Association of Colleges of Pharmacy (AACP) and the ACPE. Data are available from 1990 onward. See https://public.tableau.com/app/profile/aacpdata/viz/FirstProfessionalPharm_D_andGraduateEnrollmentTrends/Final.

To date, in higher education, we know very little about the supply side responses to new resources due to a lack of natural experiments. There are numerous ways institutions could use the increased funds. A few examples include cross-subsidizing undergraduates by increasing undergraduate enrollment, reducing tuition/increasing institutional aid, investing in measures of "quality" such as research or additional faculty, paying down debt, investing in infrastructure, etc.

We provide evidence on these possibilities using a differences-in-differences approach. We use data from the Integrated Postsecondary Education Data System (IPEDS) which is a set of surveys that all colleges and universities that received federal financial aid are required to complete. IPEDS includes information on enrollment, financial aid disbursed, staffing, and spending in broad categories.[11]

To fix ideas, consider the following two-way fixed effects specification

$$Y_{jt} = \beta_0 + \beta_1 PharmDOpen_{jt} + \gamma_j + \alpha_t + \varepsilon_{jt} \tag{1}$$

where $PharmDOpen_{jt}$ is an indicator for whether school j had opened a new PharmD program by year t, γ_j are university fixed effects, and α_t are cohort fixed effects. To avoid confusing a new PharmD program with a BSPharm converting to a PharmD program, we set $PharmDOpen_{jt} = 0$ for schools that had a BSPharm program prior to the switch to PharmD. We also require that new schools have IPEDS data for two years prior to opening their program. This results in 45 PharmD programs that we can use as treatments. We typically use data from the 2001 academic year through the 2017 academic year, though not all outcomes we examine are available in all years.

Given the issues inherent in staggered timing differences-in-differences, we use the approach in Callaway and Sant'Anna (2021) to estimate the average treatment on the treated for these schools. In our preferred specification we use logged outcomes and weight the regressions by the size of total full-time enrollment in 1997, prior to any new PharmD program openings. We report the difference-in-differences coefficient based on the data from seven years before and after a PharmD program opens. Note that when we discuss our results, we will apply the standard transformation to the estimated coefficients to convert them to percent changes, $(e^{\hat{\beta}} - 1) * 100$. Additionally, we restrict the "control" schools to be those most similar to schools that opened PharmD programs during this period. We do this by restricting the sample to schools with graduate programs, we remove institutions that are primarily theological schools, and we require that institutions have an average of at least 500 students.[12] With the remaining schools, we use data from 1997 to predict whether a school would open a PharmD program using a logistic regression and institutional characteristics.[13] Last, we choose control schools as those that are in the 75th percentile or higher

[11] There are several well-known issues with the IPEDS data. We provide related details in Appendix C.

[12] We identify schools as primarily theological if any of the words theology, seminary, biblical, rabbinical, theological, ministry, talmudical, Buddhist, divinity, rabbi, yeshiva, bible, or Torah are in their title.

[13] Our predictors include indicators institutional affiliation, revenues, total expenditures, hospital expenditures, salary expenditures, benefit expenditures, academic support expenditures, student services expenditures, research expenditures, instruction expenditures, institutional grant expenditures, pell grant expenditures, state grant expenditures, full-time undergraduate enrollment, full-time graduate enrollment, full-time female enrollment, full-time non-white enrollment, average undergraduate and graduate tuition, and all indicators for missing variable imputation. The

of predicted probability of opening a pharmacy school, but we later show robustness to different cutoffs for selecting control schools.

We first check how universities' overall financial situation changed. As seen in Table 1, we find that total revenue increased for these schools by a statistically significant 12 percent and assets increased by 7 percent. We do not find statistically significant changes in liabilities. This can be thought of as a check on our earlier discussion about profitability.

We next check whether there is evidence of a cross subsidy to undergraduates by considering enrollment and the price that undergraduates pay. These results are presented in Table 2 and corresponding event study plots appear in Figure A1. We estimate that the number of students enrolled increased by a statistically significant 18 percent. This was driven by graduate enrollment which grew by approximately 107 percent. We do not see large changes in undergraduate enrollment; our point estimate suggests a small, 2 percent, increase, though we note that our standard errors are somewhat large. Minority enrollment increased by a slightly larger percentage than total enrollment, but we can not reject that fraction of students who are minorities remained the same.

Undergraduates might be cross-subsidized with lower prices. There are multiple ways to achieve this goal including lowering tuition and fees or increasing institutional grants. As seen in Table 2, we do not find strong evidence of either of these possibilities.[14] If anything, institutional grants appear to have fallen, though our standard errors are large enough that we can not rule out very large increases or decreases. The point estimates are not always precise, but they paint a consistent picture in which the increased revenue did not clearly lead to reductions in the price undergraduates paid for college.[15]

Having concluded that the additional revenue was likely not spent increasing undergraduate enrollment or reducing tuition, we next turn our attention to investments in "quality." This is what Bowen (1980) would predict revenues would be spent on. In Table 3, we see that total expenditures went up by 12 percent. Salaries and instructional spending went up by approximately 10 percent and 12 percent, respectively. Research spending increased markedly by almost 91 percent, and academic and institutional supports spending increased by 13 and 23 percent respectively.

We are also able to measure salaries in different categories including instruction, research, academic support, student services, and institutional support. Table 4 presents results for these outcomes. Expenditures on instruction salaries grew by 11 percent and research salaries by 71 percent. The point estimates suggest that there might have been smaller increases in salaries for academic supports, students services, and institution supports, but we can not reject a null of no effect because our standard errors are quite large. Event study figures for these outcomes appear in Figure A2. In principle, these additional expenditures on salaries, instruction, research, and other categories could simply reflect increases related to the opening of the pharmacy program.

regressions are weighted by total full-time enrollment.

[14] Institutional grants are measured for first-time full-time undergraduate students. The grants were originally reported in IPEDS only for those who received them. We have scaled the estimates to be per first-time full-time undergraduate student.

[15] We also have measures of total grants, federal grants, state grants, and loans. As with institutional grants, our standard errors are very large. As a result, unfortunately, we are not able to learn much from those outcomes.

To determine whether this is the case, we turn to data on faculty counts.

We present results for the impact of a PharmD program on the number and rank of faculty at the institution in Table 5. Our estimates suggest that total faculty increased by 21 percent with Lecturers increasing by 31 percent and Assistant Professors increasing by 21 percent. Our estimates for Associate and Full Professors are smaller and not statistically significant. While we cannot directly measure which department hired these faculty, our point estimate, combined with the average number of faculty at the PharmD institutions, suggests that total faculty increased by 99 individuals. As a basis for comparison, we collected data from historical websites of all of the pharmacy schools that opened and the average number of faculty was 30.1.[16] Using the lower bound on the 95-percent confidence interval implied by our estimate, we can reject that total faculty grew by less than 60. Given that, and the average number of faculty at the new PharmD programs, we can rule out that the increase in faculty was driven solely by Pharmacy faculty hiring. Rather, it appears that the additional revenue was used to hire non-Pharmacy faculty.

In summary, we see that revenue and expenditures increased. We do not see evidence of the new graduate program cross-subsidizing the number of undergraduates or the tuition they pay. However, we find increases in research and the number and salaries for faculty; broadly, these look like investments in school "quality." Interestingly, the increase in faculty went beyond those working directly in Pharmacy, suggesting that the new PharmD programs cross-subsidized other parts of the universities.

The near-doubling of PharmD programs and universities' reactions raise questions about the welfare effects in the market for pharmacy education. We explore this in Appendix D and summarize our conclusions briefly here. Assuming schools open programs only if they expect to break even in the long run, that PharmD programs have pricing power, and that there are no barriers to entry beyond potentially large fixed costs, we estimate that a program with average profits, tuition, and enrollment among post-2000 entrants generates approximately $7.6 million in social welfare per year, despite the higher prices and debt it imposes on students. This simple approach has numerous limitations, and a fuller welfare analysis is beyond the scope of this paper.

Robustness

We have two main robustness exercises for these analyses. First, we check how sensitive the results are to changes in how we construct our control group. And second, we collect data on other programs that the schools open and include those as controls in our regressions.

Recall that we constructed the control group for our analyses by running a logistic regression with 1997 data to predict which schools would eventually open a new pharmacy program. Our control group thus far has been schools that were predicted to be in the 75th percentile or higher. In this first set of robustness results, we will set the threshold at different levels, rerun our analyses, and compare the results.

[16] We used the wayback machine to view new PharmD programs' webpages five years after they opened. We chose five years after opening because that gives new programs time to stabilize.

The results are presented in Appendix Tables A2 - A6, corresponding to our results in Tables 1-5. While the point estimates (and standard errors) vary slightly from one threshold value to another, the results tend to be very similar and imply the same takeaways. Universities' revenues, graduate enrollments, minority enrollments, expenditures, and faculty all consistently increase after the PharmD program opens. We continue to see no strong effects on undergraduate students' enrollment, tuition, or institutional grants. For each of the cutoffs used, the implied increase in faculty is still too large to be accounted for purely by hiring faculty to the pharmacy school, suggesting that at least some of the PharmD program's profits go towards hiring professors in other disciplines.

We might also worry that universities open up other academic programs when they create their PharmD program, and that our previous estimates were capturing the effects of those programs. To address this concern, we first collected data from the Department of Education's Database of Accredited Postsecondary Institutions and Programs for universities that opened PharmD programs. After identifying the five most common programs that opened within a three-year window around a PharmD program opening, we collected data on openings of those programs in our control schools.[17] From there, we reran our analyses with an additional control variable that indicates whether the school had opened one of these programs by a given date.

As seen in Appendix Tables A7-A11, including this control does not materially affect our results. For instance, the point estimate for the change in total enrollment moves from 0.165 to 0.168 with the addition of the controls; the estimate for total faculty moves from 0.187 to 0.185; and the point estimate on salary expenditures for instruction remained the same at 0.102. Across all of the regressions, the average change in the point estimate is 0.3 percent while the average change in magnitude is 5.3 percent.[18] So while universities open other programs, our estimates for the impacts of PharmD programs do not appear to be heavily influenced by those other new programs.

4 Labor Market Impacts

The increase in new pharmacists, seen in Figure 2, is large enough that the opening of new PharmD programs could have had non-trivial impacts on market outcomes for new and existing pharmacists. In this section, we will explore how PharmD programs affected labor market outcomes and

[17] More specifically, we look up each institution that created a PharmD program in 1998 or later. The database contains the accreditation date for every post-baccalaureate program that has been accredited at the institution. Since full accreditation is typically achieved in the year that the first cohort graduates, we subtract the program's length (number of years) from that date to obtain the year the program began. Because we are most concerned with time-varying omitted variables in our difference-in-differences analysis, we identified programs that began within a three year window of the PharmD program. Because there are many programs that institutions have opened in the relevant time period, we selected the most common programs meeting this criterion. They were Doctor of Physical Therapy, Masters in Teaching/Education, Masters in Nursing, Nursing Doctorates, and Advanced Practice Registered Nursing. These five programs comprise more than sixty percent of program openings that were within a three year window of a PharmD program beginning and the majority of new programs opened at our control schools.

[18] For the former calculation, increases in point estimates offset decreases in point estimates; for the latter, we average the absolute values of the percentage changes in the point estimates.

provide suggestive evidence on whether quality fell as quantity increased.

How Have Wages and Hours Responded?

We use data from the American Community Survey from 2001 through 2022 in conjunction with the 5 percent sample of the 2000 census.[19] We limit the sample to individuals who mark their occupation as pharmacist and use the accreditation data discussed in Section 2 to determine the first year that a new pharmacy program began graduating students in a given state during our sample time period. The timing of treatment is based on the program's first graduating cohort rather than the year it opened because we are concerned with the flow of pharmacists into the market rather than the existence of the school itself.

Again, to fix ideas, consider the following two-way fixed effects model

$$y_{st} = \beta_0 + \sum_{i \neq -1} \theta_i T_s \, \mathbf{1}\left[openyear_t = t - i\right] + \beta_1 age_{st} + \beta_2 age_{st}^2 + \beta_3 female_{st} + \varepsilon_{st} \tag{2}$$

where y_{st} is the outcome for state s in year t, T_s is an indicator for whether the state will have a new PharmD program open up during the sample period, $\mathbf{1}\left[gradyear_t = t - i\right]$ is an indicator for whether the year the program will first graduate students is i periods from the observation's current year, age_{st} is the average age in the state and year, age_{st}^2 is the square of age in the state and year, $female_{st}$ is the fraction of the pharmacist population that is female, and ε_{st} is a residual term. In practice, we estimate the difference-in-differences coefficient using the Callaway and Sant'Anna estimator (Callaway and Sant'Anna, 2021) and we summarize the results with the difference of the pre- and post-periods using ten years on either side of the first program opening in the state. Unlike our previous analyses that analyzed seven years on each side of the opening of a new PharmD program, we use a longer time period in these analyses to increase power because we have fewer treated units (states instead of individual PharmD programs). The regressions are weighted by population and the standard errors are cluster-bootstrapped at the state level.

First, Figure 4 presents event-study results to confirm that there is an increase in the number of pharmacists in the state after a new PharmD program begins graduating students. Because total pharmacists is a slow moving stock and we are trying to confirm a flow into the market, we focus on the number of pharmacists who are 35 years old or younger.[20] While this is closer to what we would ideally measure, it comes with the tradeoff of greater sampling variation since the ACS is a small sample of the entire population. The estimates are understandably noisy, but there is an apparent increase in the number of pharmacists younger than 35 in the years following the first graduating cohort from a new PharmD program in the state. The corresponding difference-in-differences estimate, found in the first column of Table 6, suggests that there were an average of approximately 288 additional young pharmacists per year after the treatment occurred. This is a

[19] We use the IPUMS processing of these data.

[20] We also exclude the controls for age and gender in this one regression.

19 percent increase.[21]

Figure 5 presents the event-study estimates for median wages and salary per hour. The point estimates suggest that shortly after the first cohort of students graduates from the new PharmD program, hourly wages and salary fall and remain depressed for the next ten years. We observe a similar pattern for median income per hour as well (Figure A3).[22] The corresponding difference-in-differences results for the ten periods on each side of the event are presented in Table 6. The estimated reduction in median hourly wages and salary is $2.73. Relative to the average of the median hourly wage and salary for the treated group prior to treatment, $57.20, this is a little less than a five percent reduction. Our estimates for median hourly income again provide a very similar figure.

As a robustness check on these results, we re-estimate our model where the dependent variable is the median hourly wages for non-pharmacists with at least a BA degree. If our previous results were capturing broader, negative changes in the skilled labor market that coincided with the opening of a new pharmacy program, then we would expect to find results similar to those we presented for pharmacists. Appendix Table A12 presents these results. The first two columns provide our original estimates for pharmacists for comparison. Columns (3) and (4) show that the association between the opening of a new pharmacy program and wages or income for non-pharmacists with at least a BA degree is an order of magnitude smaller than our estimates for pharmacists and is not statistically distinguishable from zero. This suggests that there were not broader changes in the labor markets where pharmacy programs opened that are driving our results. The final two columns present results where the dependent variable is the difference between the outcome variable for pharmacists and non-pharmacists with at least a BA. Again, we see that pharmacists' wages and income appear to have fallen when a new pharmacy program opened.

Another dimension along which labor markets could react to the influx of new pharmacists is hours worked. We estimate whether the number of hours worked by pharmacists changes and whether the fraction of pharmacists working full time changes.[23] Figure A4 plots the event-study results for the average number of hours worked per week by pharmacists and Figure A5 plots the event-study results for the fraction of pharmacists who are working full time. In each case, there is no obvious, discernible change. The corresponding difference-in-differences estimates shown in columns (4) and (5) of Table 6 confirm this general takeaway. The lack of strong effects is consistent with the literature on physicians' labor supply (Nicholson and Propper, 2011).

Unlike many professions, the gender earnings gap in pharmacy is quite small after accounting for differences in hours of work (Goldin and Katz, 2016). We conduct the same analyses reported in

[21] As an alternative way to gauge the magnitude, we can estimate the number of students who would have graduated from the newly opened schools in the ten years after the first school opens. We estimate that in the ten years following the first cohort from a new program, there is an average of 1.59 additional pharmacy programs (including the first new program) and that the average graduating class is 60 students. Over a ten year period, this would imply an additional 954 PharmD graduates.

[22] The Census and ACS contain two variables about income that we use. The first asks for all wage and salary income that the person has; the second asks for income from all sources.

[23] Following Goldin and Katz (2016), we record a pharmacist as full time if they are working at least 30 hours in a usual week.

Table 6 separately for male and for female pharmacists. Broadly speaking, the reductions in median hourly wages and income appear to affect female pharmacists more than male pharmacists, though we lack the statistical power needed to reject the null that the effects are the same. The results can be seen in Appendix Table A13.

We might be concerned that the labor market outcomes we observe are being driven by changes in the retail pharmacy market. Since the start of the 1980s, the retail pharmacy market has shifted toward large chain pharmacies (e.g. CVS, Walgreens), mass merchandisers (e.g. Wal-Mart), and supermarkets (e.g. Kroger), and away from small chain and independent pharmacies. For ease of exposition, we will refer to large chain pharmacies, but will include mass merchandise and supermarket pharmacies in that group. Large chain pharmacies were roughly forty percent of all pharmacies during the 2000s and 2010s (Qato et al., 2017). If wages at large chains are lower, then our results could simply reflect a change in the type of employment that pharmacists receive. We turn to data from the National Pharmacist Workforce Surveys (NPWS) to answer this question. The NPWS is a set of nationally representative surveys of licensed pharmacists in the United States and is sponsored by the Pharmacy Workforce Center. Using the 2000, 2004, and 2009 NPWS, we test whether pharmacists working at large chains earn a different amount than pharmacists working at other retail outlets.[24] Column (1) of Appendix Table A15 shows that on average, staff pharmacists at large chain pharmacies had hourly wages approximately 13 percent higher than staff pharmacists at small chain and independent pharmacies. Including year fixed effects, year of licensure fixed effects, state fixed effects, and an indicator for gender does not materially affect this average difference in wages (see column (2)). Columns (3) and (4) show that the same qualitative finding holds for pharmacists who are managers and owners. Taken together, if anything, shifting the pharmacist workforce towards large chains would have mechanically increased wages rather than decreased them.[25]

The results on pharmacist quantity and wages have similarities to cobweb models or hog cycles (Ezekiel, 1928; Kaldor, 1934; Rosen et al., 1994). If that is the correct model here, wages may eventually rise and the cycle may repeat.

How Has Quality Responded?

Historically, licensing requirements, often taking the form of specialized training, were thought to increase service quality (Friedman and Kuznets, 1945). In our setting, the switch from a BSPharm to a PharmD is an increase in the requirements needed to be eligible to obtain the license rather than a change from no license to requiring a license. The extra year of training required for the PharmD could increase the quality of pharmacy graduates, but the large influx of pharmacy programs and

[24] Starting with the 2014 NPWS, the survey began asking about changes in earnings from the previous year rather than earnings. Because of that change, we are not able to use the later data for this analysis.

[25] We have not found state by year counts of the number of pharmacies, by type of pharmacy, that we could include as a control in our analysis presented in Table 6. We have two noisy measures of the number of pharmacies in each state and year, one from the Bureau of Labor Statistics and one from the County Business Patterns data. Neither series matches totals from industry groups over the entire time frame of our sample (Qato et al., 2017). Our findings are qualitatively similar, though somewhat attenuated, when these controls are included. See Appendix Table A16.

students might mean that the marginal graduate is less well prepared to practice pharmacy. Once past the pharmacy licensing exam, the large expansion in the number of pharmacists might actually mean fewer tasks for each individual pharmacist, and as a result, higher quality output. Given these opposing forces, it is not clear what the net effect of the switch to PharmD will be on the quality of pharmacy graduates and services.

We provide evidence on quality in three different ways. First, we explore how acceptance rates at pharmacy programs have evolved over time. Second, we show data on the rates at which pharmacy students pass the licensing exam. Third, we use data from the NPWS to examine whether practicing pharmacists' workloads have changed over time.

Figure 6 plots acceptance rate data from pharmacy programs from 2003 through 2022.[26] The blue line is the number of unique individuals who were accepted into a pharmacy program divided by the number of unique individuals who applied to pharmacy programs. Because the data are derived from an application portal that was being rolled out to pharmacy schools, the PharmCAS, not all schools are represented in every year. In 2003-2004, the data cover 48 percent of schools. Coverage reached approximately 90 percent by 2012-2013 and has remained high since then. Because the composition of schools included in the data is changing so much over time, it is not clear whether the large upward trend in the blue line is a true representation of changes in acceptance rates or simply changes in the set of schools reporting. To speak to this issue, we also plot two gray lines which bound the true acceptance rates. The upper bound is constructed by assuming every school that does not use the PharmCAS has a 100 percent acceptance rate while the lower bound is constructed by assuming that every non-PharmCAS school has a zero percent acceptance rate. By 2015, the lower bound of the estimates exceeds the upper bound of our estimates for 2004.[27] So even a very conservative interpretation of this figure would indicate that acceptance rates have risen from 68 percent in the 2003-2004 application cycle to at least 81 percent in the 2019-2020 cycle.

We now turn to exploring pass rates for the North American Pharmacist Licensure Examination (NAPLEX). In recent years, the National Association of Boards of Pharmacy has published first-time pass rates for each pharmacy program. Because there were major changes to the content and length of the exam in 2015 and 2016, it is not clear how to interpret the time-series variation in pass rates.[28] With this caveat in mind, Ried et al. (2023) report that the NAPLEX pass rate fell from 97 percent in 2008, the earliest year that data are available, to 93 percent in 2015, and then to 88 percent in 2019. While some portion of the overall decline in pass rates between 2008 and 2019 could be due to changes in the NAPLEX exam, the pass rate was declining before those changes occurred.

[26] These data are collected by the American Association of Colleges of Pharmacy.

[27] We have collected data on which pharmacy schools used the PharmCAS in the 2003-2004 and 2018-2019 application cycles. We would have preferred the 2019-2020 cycle, but the data were not available for that year. If we create bounds based on enrollment weights, rather than by the fraction of schools as in the text, we get an upper bound of 69.8 percent in 2003-2004 and a lower bound of 71.7 percent in 2018-2019. The analogous numbers for the method used in Figure 6 are quite similar at 68.2 percent and 75.6 percent.

[28] Changes to the NAPLEX included a longer test time, a 35 percent increase in the number of questions asked, more focus on clinical assessment questions, a switch from a computerized adaptive test to a computerized linear test, and others.

Because the majority of the expansion in pharmacy program enrollment was due to the entry of new schools, another way to gauge the change in quality is to compare the distributions of first-time pass rates for pharmacy programs that graduated students prior to 2000 ("Existing") and those that began graduating students in 2000 or later ("New"). We have school level pass rates between the years 2019 and 2024. Figure 7a shows the distributions for the New (blue line) and Existing (red line) groups for 2019. While not every existing school has a higher pass rate than every new school, the pass rates for new schools are lower on average, have a lower median pass rate (85 percent vs 92 percent), and some of the new schools have pass rates as low as 51 percent. As seen in Figure 7b, this general relationship holds true in later years as well. This suggests that the switch to PharmD has, on average, led graduating students to be less prepared to be practicing pharmacists.

It is possible that growth in the number of pharmacists led to lighter workloads and thereby, potentially, higher quality. The 2004 NPWS and the 2014 NPWS both contain the following question: "How would you rate your workload in your workplace?" The five possible answers are excessively low, low, about right, high, and excessively high. Among pharmacists working in a licensed pharmacy in 2004, 43 percent rated their workload as high and another 10 percent rated it as excessively high. By 2014, despite the influx of pharmacists, the percentages rose to 48 percent and 15 percent, respectively. The fraction of pharmacists who responded in each of the other categories fell between 2004 and 2014. We formalize this comparison in a regression analysis of pharmacists' responses to the question on an indicator for it being the 2014 survey and demographic controls. The results are presented in Appendix Table A14 and are consistent with the simple comparisons: pharmacists report higher workloads over time. This is again consistent with a narrative that the quality of pharmacists' output is not rising over time. Taken together, the results presented in this section indicate that the quality of pharmacy graduates seems to have fallen. It is less clear how the quality of practicing pharmacists has been affected, though it does not appear to be the case that quality would have increased solely because of additional time available to complete tasks.[29]

5 Why Did Pharmacy Education Expand?

Having documented both how universities responded to the PharmD transition and its downstream consequences for the pharmacist labor market, we now turn to the mechanism: why did this large growth in pharmacy education happen? We argue that the primary driver was the transition to a graduate degree, which dramatically expanded students' access to federal student loans and thereby generated a large demand shock to pharmacy education.

[29] We have explored two other potential measures of pharmacist quality: malpractice rates and adverse actions against pharmacists. The former is extremely rare while the latter is only loosely tied to the actual services that pharmacists provide. We estimated difference-in-differences models at the state-year level exploiting the opening of a new PharmD program as in our analysis of pharmacist labor markets. Unfortunately, we lacked the statistical power to learn much from these analyses–the standard errors were sufficiently large that we could not rule out very large positive or negative effects.

5.1 Did the Transition to PharmD Increase Student Loans?

We make several arguments that the transition to PharmD increased the use of student loans for pharmacy school. First, and most importantly, federal student loan rules meant that the transition dramatically increased maximum borrowing limits. After the transition, borrowers could borrow more in a single year of PharmD education than they could over the lifetime of a BSPharm education. Second, we confirm empirically that 1) students pursuing a PharmD borrowed more for school when both options were available and 2) that after the transition to PharmD, borrowing markedly increased.

5.2 Federal Student Loan Policy for Pharmacists

We will focus on federal student loan policy because non-federal borrowing comprises a minority of total borrowing (about 20 percent of total borrowing in 2004-05) (Ma et al., 2025) and typically offers worse terms (Consumer Financial Protection Bureau, 2012). In order to access federal loans from the U.S. Department of Education, a student must file the Free Application for Federal Student Aid (FAFSA).[30] We provide a succinct discussion of relevant federal student loan policy drawing on Hegji (2021) and U.S. Department of Education (2025) as references. We will focus on the Stafford Loan program, administered by the Department of Education, which is the majority of federal borrowing, but there are other programs with lower borrowing volumes which are discussed in subsequent footnotes or Appendix E.[31] For Stafford loans, financial need does not affect the maximum borrowing amounts annually or cumulatively and so we will focus primarily on two policy parameters, federal annual borrowing limits and lifetime borrowing limits.[32]

From 1994 to 1998, PharmD students could borrow Stafford loans of at least $18,500 annually and starting in 1996, $31,000. A dependent (traditional) BSPharm student could borrow a maximum of $5,500 in their third or later year using the Stafford loan program. PharmD students could borrow Stafford loans from the Department of Education up to a lifetime maximum of $189,125. Dependent BSPharm students could borrow up to a Stafford lifetime maximum of $23,000. In summary, for dependent students, annual borrowing maximums increased from $5,500 to $31,000 annually and from $23,000 to $189,125 over a lifetime when pharmacy students transitioned from the undergraduate BSPharm to the graduate PharmD degree. The details are different for independent (nontraditional) students, but in all cases the transition to a PharmD dramatically increased both annual and lifetime federal borrowing limits.

From 1998 to 2005, the policy of much higher borrowing limits for PharmD students was largely unchanged as schools began transitioning to PharmDs. In 2006, the Grad PLUS program was

[30] Because federal student loans generally offer better terms, students wishing to borrow above federal maxima typically would file a FAFSA and then would seek out private student loans via another source.

[31] Perkins loans are Department of Education Loans available to pharmacy students, are needs based, and are administered by schools. Schools have limited funds and so there is no guarantee that a pharmacy student attending a school would have access to these funds, let alone a specific amount.

[32] Financial need can affect the terms of the loans in some cases. These two parameters most succinctly capture the differences in available credit but other features also differ; for example, the amount that can be borrowed in a particular year (say the second year of enrollment), interest rates, etc.

created which essentially uncapped borrowing for graduate programs (Black & al., 2023b). This allowed pharmacy students to borrow even more—up to the Cost of Attendance (roughly tuition and fees plus living expenses) at every school offering federal aid with no lifetime cap. So the gap between borrowing limits for PharmDs and (at this point hypothetical) BSPharms opened even wider.

Students not only were eligible for more loans in a PharmD program, they actually borrowed more. The median debt for graduates of pharmacy programs included in the College Scorecard is $141,078. The lifetime maximum for independent undergraduates in 2024 was $57,500 and 93 percent of pharmacy programs have graduates with median debt larger than this amount (Hegji, 2021).[33] In fact, in 2016, the median *annual* federal borrowing among federal borrowers for a professional pharmacy degree was $35,777—greater than the *lifetime* maximum for dependent undergraduate students at the same time Libassi et al. (2025).

We provide additional evidence that the transition to PharmD increased borrowing from the NPWS. The NPWS surveys ask pharmacists how much student debt they had when they were first licensed. This allows us to see how closely related highest degree and debt are within a given year. Figure 8 shows that average debt for PharmDs is higher than BSPharms when they are licensed in the same year. Average debt is increasing from 1991 to 1999 for BSPharm recipients, but the increase in debt for PharmDs is increasing by approximately the same amount. From 1999 to 2005 the debt for BSPharm is decreasing slightly or flat. This is notable for a few reasons. First, this is around the federal maximum a student could borrow for a BSPharm. Second, the average debt is below the maximum allowable for dependent undergraduate borrowers in this time period, while PharmDs are borrowing more than dependent undergraduates could borrow. We also plot data from the Baccalaureate and Beyond surveys from the National Center for Education Statistics. These surveys ask recent graduates several questions and, importantly for our purposes, they ask about debt for undergraduate degrees. Debt for undergraduate degrees is increasing over this time frame, but at a pace far below that experienced by PharmD graduates. This suggests that absent a change to PharmD, student debt would not have seen such dramatic growth.

We show that as PharmDs became more prevalent, student debt increased substantially. Using the surveys from the NPWS, Figure 9 shows that the average debt and fraction of PharmDs (relative to BSPharms) are highly correlated. By 2001, the average debt for newly licensed pharmacists had increased to $47,469—above the maximum that a dependent undergraduate student can borrow.

In sum, we provide policy evidence that the amount of debt that students take out today to pursue a PharmD would not have been possible had the program not shifted from a BSPharm to PharmD. Bolstering this interpretation is the divergence of debt between PharmDs and undergraduate students as well as the tight time series correlation between student debt and the fraction of pharmacists licensed in a given year that are PharmDs. The transition to requiring a PharmD did not only increase access to higher student loan limits; it also eliminated a cheaper pathway

[33] Authors calculations from the Oct 10, 2024 College Scorecard data. This covers the 2018-19 and 2019-2020 cohorts. This debt is only reported for graduates and only includes debt accumulated at the Pharmacy program.

to becoming a pharmacist. PharmD programs no longer had to compete with cheaper BSPharms, which likely contributed to increasing debt after the elimination of BSPharm.

5.3 PharmD or a Reaction to the Labor Market?

Prior to the expansion of pharmacy schools and enrollments, pharmacists had projected that there would be labor shortages in the 1990s and 2000s due to an aging population and increased prescription use (Vlasses, 2019). In addition to the expanded access to student loans, there could have been increasing demand for pharmacy education because of what was happening in the labor market for pharmacists. Figure 10 shows data on the number of full-time pharmacists and their median hourly wage (in year 2020 dollars) from 1980 through 2019.[34] Real, median hourly wages were rising steadily from 1980 through 2000 at the same time that the number of pharmacists was growing. This suggests that demand for pharmacists was rising during this time period by enough to offset the increased supply. Since human capital investments are in part determined by people's expectations about the current and future returns on those investments (Becker, 1964; Zafar, 2011; Arcidiacono et al., 2012), rising pharmacist wages in the 1980s, 1990s, and 2000s could have contributed to an increase in demand for pharmacy education and could have played some role in the expansion of pharmacy education.

In conjunction with data on the number of enrollees in and tuition for pharmacy school, we use a simple model to provide some insight into the importance of rising demand for pharmacy education even in the absence of the switch to PharmD. The idea of the model can be seen in Figure 11 which shows the market for pharmacy enrollments. For the year 2000, we can observe tuition and fees (the price of pharmacy school) and the number of students enrolled (the quantity); this equilibrium is point A, at the intersection of the year 2000 supply and demand curves, $S_{'00}$ and $D_{'00}$ respectively. Similarly, we have an analogous point, C, for the year 2010. C incorporates the impacts of both: 1) the switch to PharmD and 2) any increases in demand for pharmacy education for other reasons, including rising wages of pharmacists.

In the ideal world, we would observe $\tilde{D}_{'10}$, the hypothetical demand curve that does not incorporate the impacts of the switch to PharmD, and as a consequence, point B, the resulting equilibrium between $\tilde{D}_{'10}$ and the supply curve for 2010. Although we cannot observe $\tilde{D}_{'10}$, we can estimate it. To do so, we use the idea that in the past, wage growth for pharmacists impacted demand for pharmacy education. Our approach will capture the impacts of anything that is correlated with wage growth, not just wage growth itself. If the relationship between pharmacists' wage growth and demand for pharmacy education is stable over time, then we can use that to construct $\tilde{D}_{'10}$. We assume that pharmacists' wage growth in one decade affects the demand for

[34] We use data from three sources, the decennial censuses (1980, 1990, and 2000), the Annual Social and Economic Supplement (ASEC) from the Current Population Survey (1981-1989 and 1991-1999), and the American Community Survey (ACS) (2001-2019). The estimates from the ASEC are much noisier because the sample sizes are only 15 percent of the sample sizes from the ACS. The small sample sizes in the ASEC do not allow us to make reliable estimates of the number of pharmacists in the US. We focus on the median rather than the mean to minimize well-known issues related to the topcoding of income in these data sources.

pharmacy education in the following decade and that this relationship is stable over time. With that, we calculate point B and from there, the fraction of the observed change from 2000 to 2010 that can be accounted for by rising pharmacists' wages.

The final assumptions needed to estimate the model are 1) a functional form for the supply and demand curves and 2) an elasticity of demand for pharmacy education. We could assume an elasticity of supply, but instead we leverage the fact that the supply of pharmacy schools was approximately constant between 1990 and 1995.[35] This allows us to treat the differences in the 1990 and 1995 equilibria as movements along a supply curve, pinning down the elasticity of supply. We are not aware of an estimate of the elasticity of demand for pharmacy school. Instead, our baseline elasticity of demand comes from Denning (2017) which estimates the elasticity for community college, though we test the sensitivity of our results to the particular elasticity chosen.

With this setup, we estimate that rising pharmacist wages, and all factors associated with those increased wages, can account for approximately 21 percent of the observed increase in enrollments between 2000 and 2010. In Appendix F, we provide additional details of this exercise and assess the sensitivity of our results to our assumptions. Our results are fairly robust to the range of assumptions we explore, and they suggest that rising pharmacist wages are unlikely to be driving the majority of the increase in demand after 2000: there is a lot of room for the transition to PharmD to have played a key role in rising demand for pharmacy education.

In addition to changes in demand due to rising pharmacist wages, it may be that the non-monetary returns to becoming a pharmacist have been increasing with the transition to PharmD. To gauge whether this channel is playing a large role, we take advantage of a question posed in the NPWS surveys. The particular question of use here is "Please use the scale below to report your thoughts about pharmacy as a profession. ...If I could go into a different profession other than pharmacy which paid the same, I would probably do so" (Midwest Pharmacy Workforce Research Consortium, 2000; Gaither et al., 2014). Respondents choose a value from one through five where 1 = strongly disagree and 5 = strongly agree. We have data on this question in both 2000 and 2014. We run simple regressions of the form

$$y_{it} = \beta_0 + \beta_1(Year_t = 2014) + X_{it}\Gamma + \varepsilon_{it}$$

where y_{it} is the response to the question, $Year_t = 1$ is an indicator for whether the observation is from the 2014 survey year, X_{it} contains linear and quadratic controls for the pharmacist's age, an indicator for gender, and a set of dummy variables for the year the pharmacist was first licensed.

Table 7 reports the regression results. The point estimate in the first column indicates that relative to 2000, in 2014, pharmacists agreed slightly more that they would choose to work in a different profession if it offered equal pay. The second column uses the binary version of the dependent variable and again suggests that if anything, pharmacists were more likely to want to switch away to another profession. While the point estimates are positive, they are not statistically

[35] While there were a few schools that opened up during this time period, they would not have graduated cohorts until the late 1990s.

distinguishable from zero. This again suggests that the non-monetary benefits of a pharmacist job are not increasing substantially between 2000 and 2014, and so were unlikely to be driving the growth in demand for pharmacy education.

6 Conclusion

This paper uses a sharp policy change in pharmacy education to study how universities and labor markets respond to a supply-side shock. When the entry-level credential for pharmacists shifted from an undergraduate to a graduate degree in 2000, it triggered one of the most striking expansions in professional education in recent U.S. history—the number of pharmacy programs nearly doubled and enrollment grew by more than 60 percent over fifteen years.

Our results on how universities responded to this shock speak directly to longstanding questions about institutional behavior. The revenue generated by new PharmD programs was large: private non-profit pharmacy schools had revenues 172 percent of expenditures, and the majority reported returning profits to the broader university. Consistent with Bowen's Law, universities did not use these profits to cross-subsidize undergraduates through expanded enrollment or lower tuition. Instead, they invested in institutional quality—hiring faculty, increasing research expenditure, and expanding support infrastructure—with the gains extending well beyond the pharmacy school itself. These findings provide rare causal evidence on how universities behave as firms when revenue opportunities arise, and suggest that the revenue theory of cost offers a useful framework for understanding university responses to policy-driven financial shocks.

The downstream effects on the pharmacist labor market were substantial and, in important respects, the opposite of what the standard licensing literature would predict. Raising licensing requirements typically restricts supply, raises wages, and ensures a quality floor (Friedman and Kuznets, 1945; Kleiner and Xu, 2025). Here, the interaction between stricter credentialing and existing federal loan policy produced an expansion of supply, a decline in wages of approximately 5 percent, and suggestive evidence of falling graduate quality.

Our results highlight two underappreciated features of subsidy incidence and licensing policy. First, the quantity margin of the Bennett Hypothesis has received far less attention than the price margin, yet our setting shows that enrollment expansions can be both large and welfare-relevant. The expansion of pharmacy education generated significant consumer surplus despite higher prices and debt for students, because increased access to borrowing allowed universities to overcome fixed entry costs and expand the set of educational options available. This suggests that targeted financial aid for specific programs may be a useful policy lever for expanding supply in high-demand fields—though, as our labor market results make clear, the general equilibrium effects on wages and quality deserve careful attention. Second, the equilibrium effects of licensing policy depend critically on the broader regulatory environment in which it operates. Policies that interact with student loan rules, accreditation standards, or other institutional features may produce outcomes far removed from those predicted by partial-equilibrium analysis.

More broadly, our findings underscore the value of studying universities as firms and of tracing the full chain of responses to policy shocks—from the financial decisions of educational institutions through to the labor markets that absorb their graduates.

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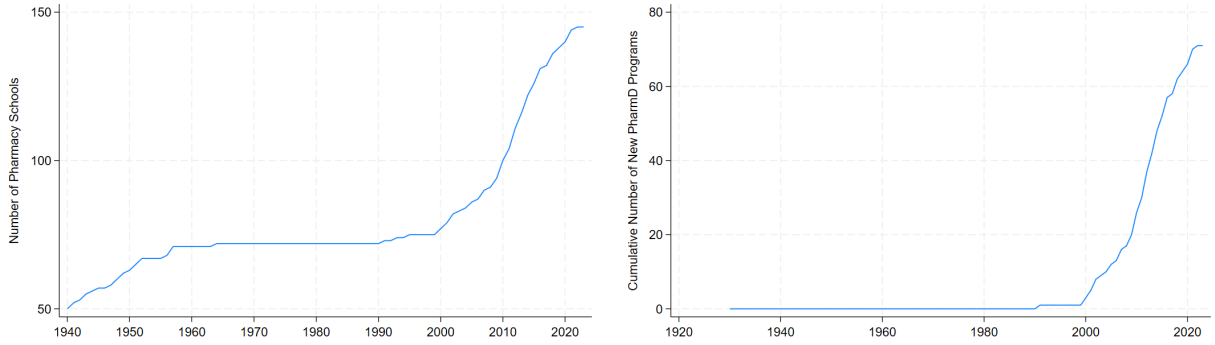
7 Figures and Tables

Figure 1: Number of Pharmacy Programs Over Time

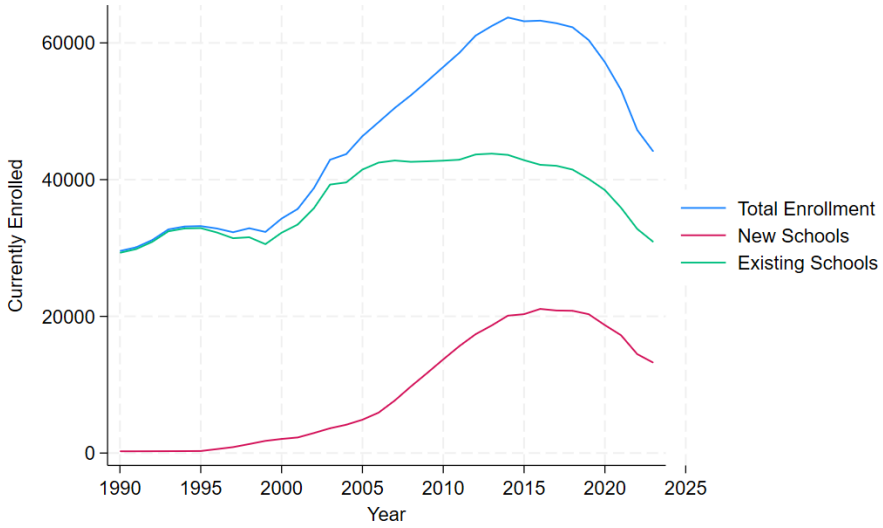


(a) Number of Pharmacy Schools

(b) Cumulative Number of New PharmD Programs that did not Offer BSPharm Previously

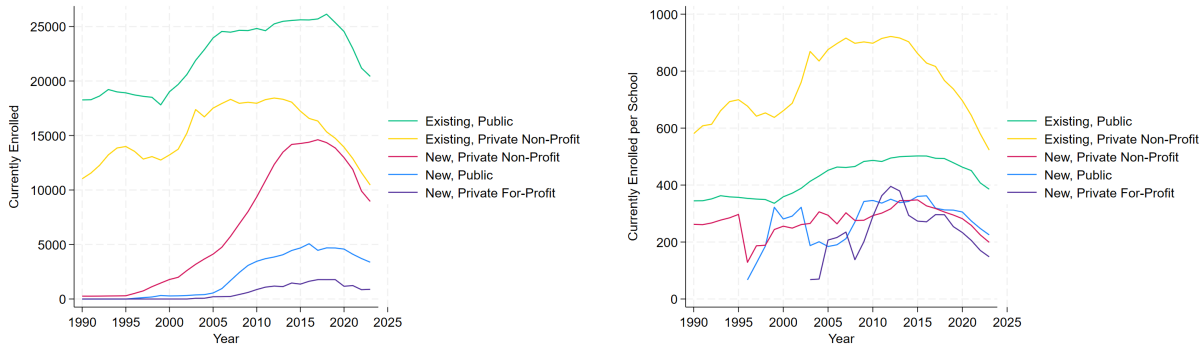
Figures based on data authors collected from the Accreditation Council for Pharmacy Education. Figure 1a presents the number of pharmacy programs that graduated students in each year (BSPharm or PharmD). Figure 1b shows the number of schools that graduated PharmD students and had not previously graduated BSPharm students.

Figure 2: Pharmacy School Enrollment Over Time



Data collected from American Association of Colleges of Pharmacy and the Accreditation Council for Pharmacy Education. New schools are those that created a PharmD program and did not previously have a BSPharm program. Existing schools are those that did previously have a BSPharm program.

Figure 3: Enrollment by School Type

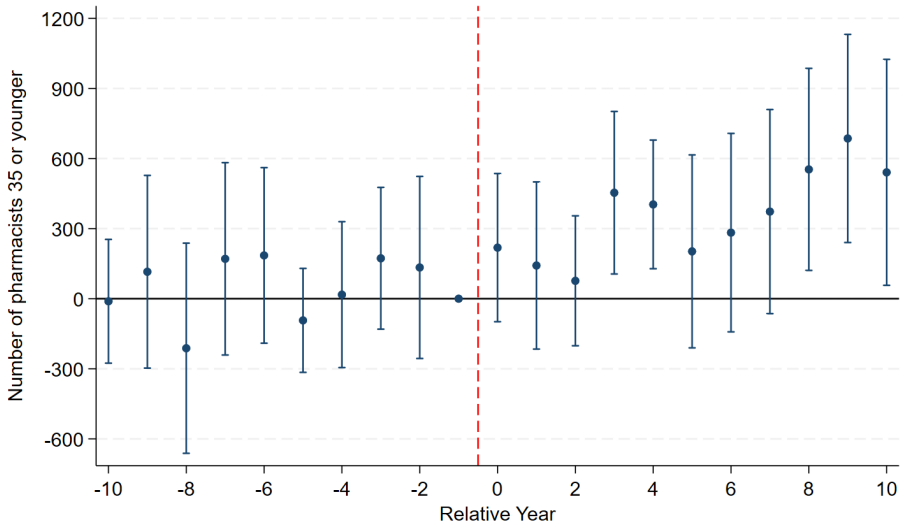


(a) Total Enrollment

(b) Enrollment per School

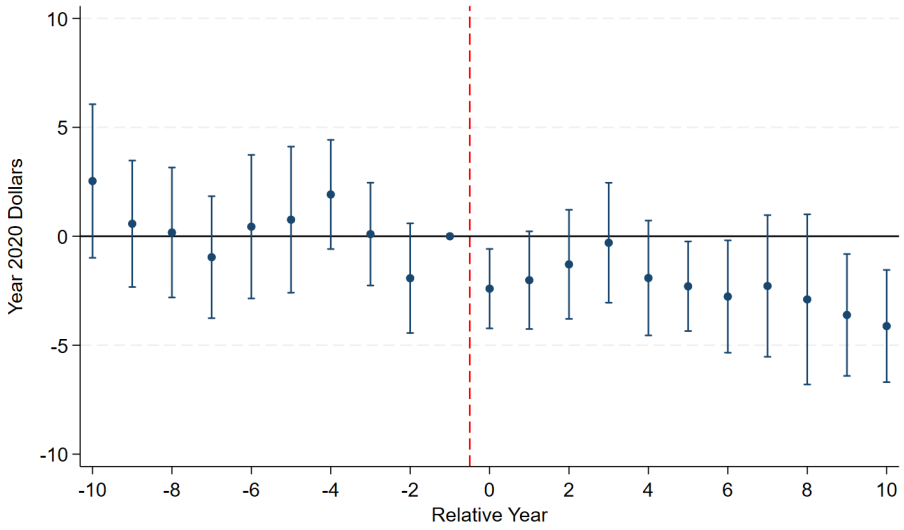
Data collected from American Association of Colleges of Pharmacy and the Accreditation Council for Pharmacy Education. New schools are those that created a PharmD program and did not previously have a BSPharm program. Existing schools are those that did previously have a BSPharm program. School type, e.g. public, private non-profit, comes from the National Center for Education Statistics (via IPEDS).

Figure 4: Pharmacists $\leq$ 35 Years Old



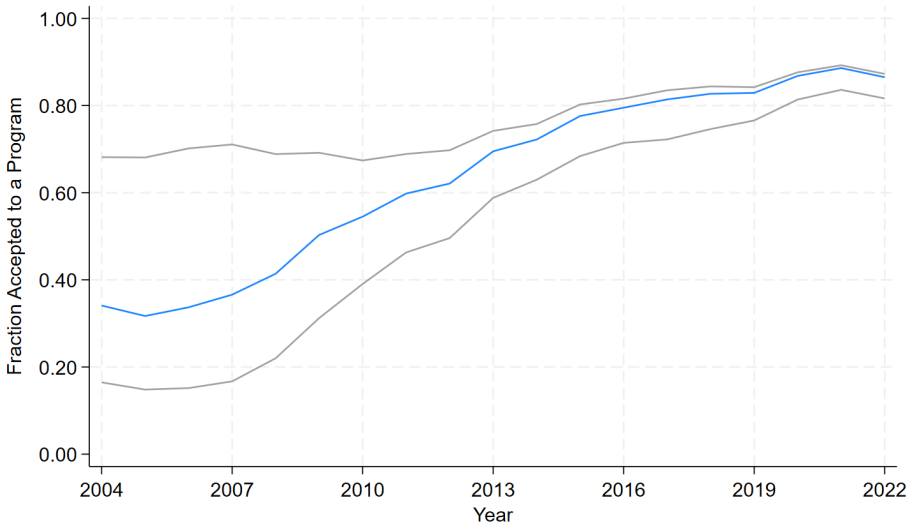
Data are from the 2000 census and the 2001-2022 American Community Survey. Point estimates and 95 percent confidence intervals are reported.

Figure 5: Median Wage and Salary per Hour



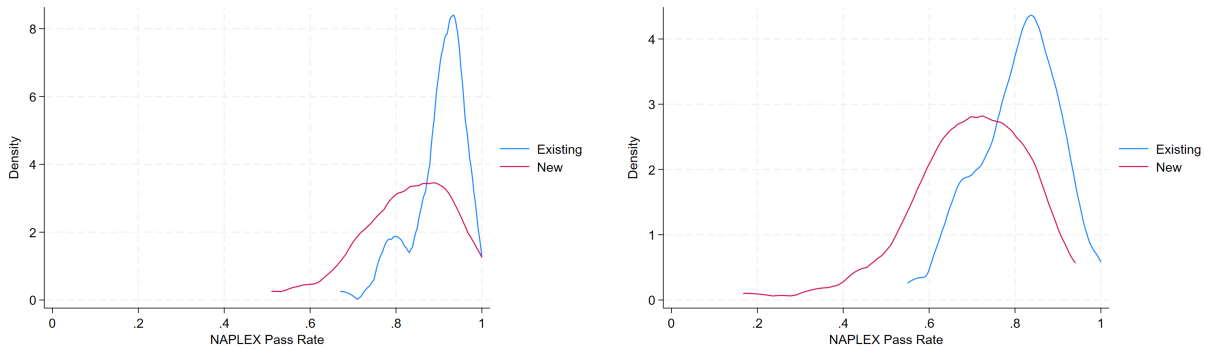
Data are from the 2000 census and the 2001-2022 American Community Survey. Point estimates and 95 percent confidence intervals are reported.

Figure 6: Fraction of Applicants Accepted to Pharmacy School



Data are from the Association of American Colleges of Pharmacy. The blue line represents the reported fraction of applicants accepted. The gray lines provide bounds on the fraction accepted that account for the increase in the fraction of pharmacy programs that are included in the data over time.

Figure 7: NAPLEX Pass Rates

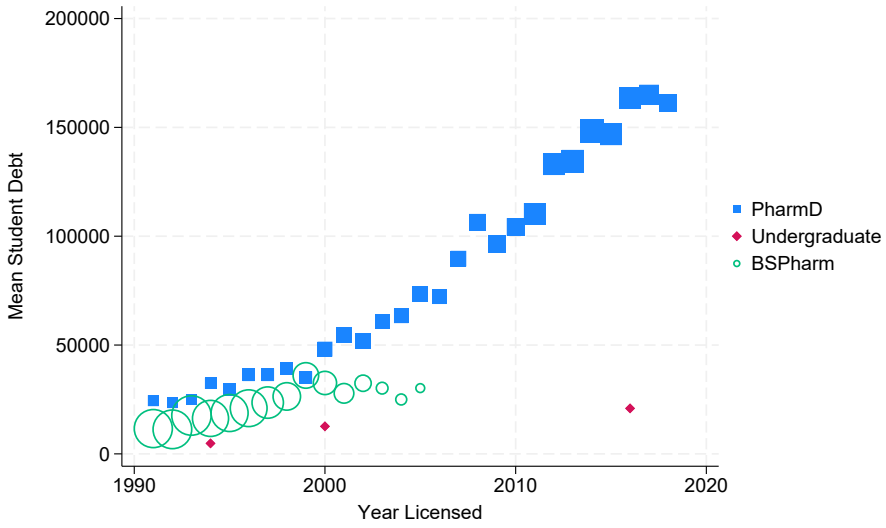


(a) 2019 Scores by Program Type

(b) 2024 Scores by Program Type

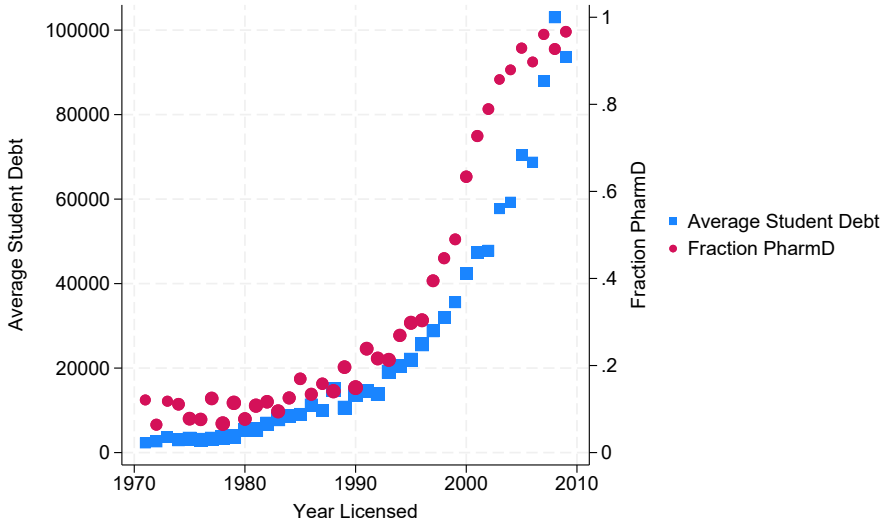
Data are first-time pass rates on the North American Pharmacist Licensure Examination (NAPLEX) which is overseen by the National Association of Boards of Pharmacy. "New" schools are those that created a PharmD program and did not previously have a BSPharm program. "Existing" schools are those that did previously have a BSPharm program.

Figure 8: Debt by Education



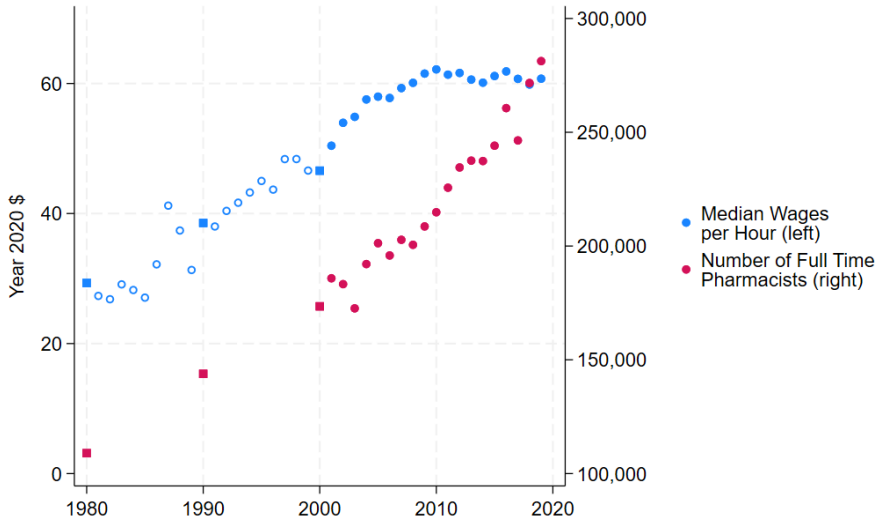
Data for PharmD (blue squares) and BSPharm (green circles) comes from the 2004, 2009, 2014, 2019 National Pharmacy Workforce Study surveys. The markers for PharmD and Undergraduate are proportional to the number of observations in each year licensed. The red diamonds for the undergraduates are based on data from the U.S. Department of Education, National Center for Education Statistics Baccalaureate and Beyond surveys 1994, 2008, 2016. Codes to retrieve results: vgzbgx, kcfbfi, myqmwb.

Figure 9: Fraction PharmD and Debt Over Time



Data comes from the 2004, 2009, 2014, 2019 National Pharmacy Workforce Study surveys. The red circles are proportional to the number of observations in each year licensed. The outcome is the amount of student debt at the time of graduation from pharmacy school and the fraction of respondents who had a PharmD as their highest degree.

Figure 10: Real Hourly Wages and the Number of Pharmacists Over Time



The blue symbols are estimates of full-time pharmacists' median hourly wages. Hollow blue circles use data from the Annual Social and Economic Supplement; solid blue circles use data from the American Community Survey; solid blue squares use data from the decennial censuses. Red symbols are estimates of the number of full-time pharmacists. The solid red squares use data from the decennial censuses; the solid red circles use data from the American Community Survey. The Annual Social and Economic Supplement data are not large enough to create reliable estimates of the number of pharmacists between 1980 and 1999.

Figure 11: Market for Pharmacy School Enrollments

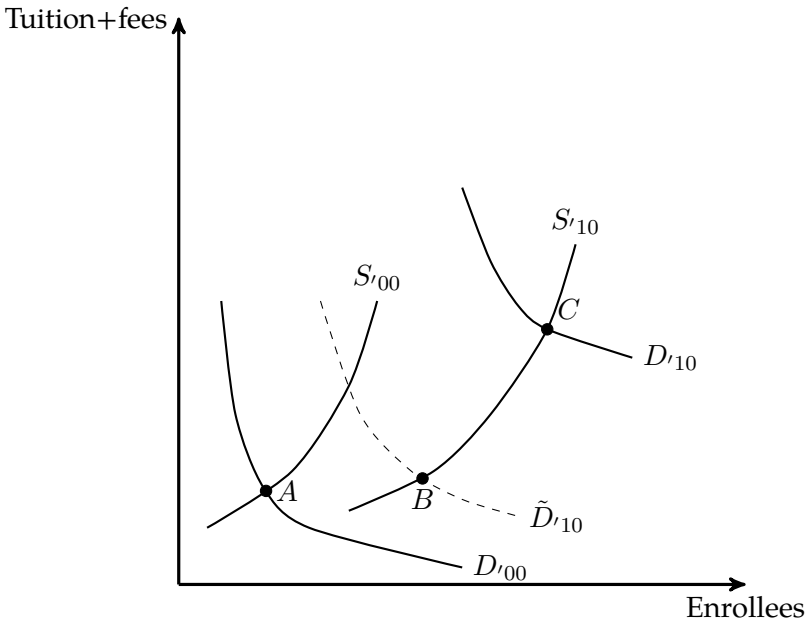


Table 1: Balance Sheet Items

	(1) Revenues	(2) Assets	(3) Liabilities
DiD	0.117***	0.072**	-0.076
	(0.032)	(0.037)	(0.103)
Mean (millions)	415.0	735.0	356.5
Observations	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 2: Enrollment Characteristics and Undergraduate Pricing

	(1)	(2)	(3)	(4)	(5)	(6)
	Enrollment					
	Total	Undergrad	Graduate	Minority	Tuition	Institutional Grants
DiD	0.165***	0.020	0.728***	0.193***	-0.023	-0.133
	(0.039)	(0.057)	(0.209)	(0.069)	(0.044)	(0.132)
Mean	4,100	3,259	841	1,332	14564	4,401
Observations	4,879	4,879	4,879	4,879	4,522	4,029

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Aggregated Expenditures by Category

	(1) Total	(2) Salaries	(3) Instruction	(4) Benefits	(5) Research	(6) Acad. Supp	(7) Student Serv.	(8) Inst. Supp.
DiD	0.117***	0.097***	0.114***	0.085	0.647**	0.130***	0.060	0.209***
	(0.026)	(0.032)	(0.038)	(0.070)	(0.304)	(0.048)	(0.060)	(0.073)
Mean (millions)	389.1	170.6	122.3	39.5	69.4	35.6	18.7	33.3
Observations	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 4: Salary Expenditures by Category

	(1) Instruction	(2) Research	(3) Acad. Supp	(4) Student Serv.	(5) Inst. Supp.
DiD	0.102***	0.534*	0.077	0.050	0.060
	(0.039)	(0.309)	(0.051)	(0.064)	(0.043)
Mean (millions)	77.3	32.5	18.1	8.8	15.2
Observations	4,794	4,794	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 5: Instructional Faculty Counts

	(1) Total Faculty	(2) Professors	(3) Associate Professors	(4) Assistant Professors	(5) Lecturers
DiD	0.187***	0.053	0.103	0.190*	0.267***
	(0.034)	(0.046)	(0.079)	(0.097)	(0.086)
Mean	471	142	121	134	73
Observations	4,352	4,352	4,352	4,352	4,352

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 6: New PharmD Programs and Pharmacists' Labor Market Outcomes

	(1) Number Pharmacists, Age≤35	(2) Median Wage and Salary/hr	(3) Median Income/hr	(4) Average Hours	(5) Fraction Fulltime
DiD	287.875**	-2.725**	-2.936**	0.093	-0.013
	(120.291)	(1.121)	(0.992)	(0.610)	(0.020)
Mean	1,510.944	57.200	59.373	38.344	0.725

Wage and salary and income data are from the five percent microdata sample of the 2000 census and the 2001-2022 American Community Surveys. Data are at the state-year unit of observation. Standard errors are cluster bootstrapped with clusters at the state level. The mean of the dependent variable is the average of the outcome variable for the treated states in the years prior to being treated. Wages include wage and salary income; earnings include all income. * p<0.10, ** p<0.05, *** p<0.01

Table 7: Pharmacists' Preferences for Switching Professions

	(1) Full scale, values 1-5	(2) Binary	(3) Full scale, values 1-5	(4) Binary
Year=2014	0.021	0.020	0.034	0.026
	(0.104)	(0.038)	(0.105)	(0.038)
PharmD control			x	x
Mean	3.184	0.417	3.184	0.417
Observations	3,008	3,008	3,008	3,008

Data are from the 2000 and 2014 NPWS. The dependent variable is whether the pharmacist would go into a different profession that paid the same if that were an option. The second two columns include an indicator for whether the individual has a PharmD. * p<0.10, ** p<0.05, *** p<0.01

A Additional Tables and Figures

Table A1: Pharmacy Schools by Rank, Sector, and Year of PharmD Start

Rank	School Name	Sector	Start of PharmD	Treated in School Regressions
12	University of California, San Diego Skaggs School of Pharmacy & Pharmaceutical Sciences	Public	2002	X
44	Thomas Jefferson University Jefferson College of Pharmacy	Private Non-Profit	2008	X
44	Texas Tech University Health Sciences Center Jerry H. Hodge School of Pharmacy	Public	1996	
49	Texas A & M University Health Science Center Irma Lerma Rangel School of Pharmacy	Public	2006	X
60	University of California, Irvine School of Pharmacy & Pharmaceutical Sciences	Public	2021	
60	University of South Florida Health Taneja College of Pharmacy	Public	2011	X
60	Southern Illinois University Edwardsville School of Pharmacy	Public	2005	X
69	East Tennessee State University Bill Gatton College of Pharmacy	Public	2007	X
73	Medical College of Wisconsin School of Pharmacy	Private Non-Profit	2018	
73	Loma Linda University School of Pharmacy	Private Non-Profit	2002	X
73	Northeast Ohio Medical University College of Pharmacy	Public	2007	X
73	Western University of Health Sciences College of Pharmacy	Private Non-Profit	1996	
80	University of North Texas Health Science Center UNT System College of Pharmacy	Public	2013	X
80	St. John Fisher University Wegmans School of Pharmacy	Private Non-Profit	2006	X
80	Chapman University School of Pharmacy	Private Non-Profit	2015	X
80	Wilkes University Nesbitt School of Pharmacy	Private Non-Profit	1996	
86	Shenandoah University Bernard J. Dunn School of Pharmacy	Private Non-Profit	1996	

Rank	School Name	Sector	Start of PharmD	Treated in School Regressions
86	University of the Incarnate Word Feik School of Pharmacy	Private Non-Profit	2006	X
86	University of Findlay College of Pharmacy	Private Non-Profit	2006	X
86	Regis University Rueckert-Hartman College for Health Professions School of Pharmacy	Private Non-Profit	2009	X
86	Western New England University College of Pharmacy and Health Sciences	Private Non-Profit	2011	X
86	Belmont University College of Pharmacy and Health Sciences	Private Non-Profit	2008	X
95	Lipscomb University Health Sciences Center College of Pharmacy	Private Non-Profit	2008	X
95	Manchester University College of Pharmacy, Natural and Health Sciences	Private Non-Profit	2012	X
95	Binghamton University State University of New York School of Pharmacy and Pharmaceutical Sciences	Public	2017	
95	Pacific University School of Pharmacy	Private Non-Profit	2006	X
99	MCPHS University School of Pharmacy - Worcester	Private Non-Profit	2001	
99	Touro University - California College of Pharmacy	Private Non-Profit	2005	
99	University of Maryland Eastern Shore School of Pharmacy and Health Professions	Public	2010	X
99	University of Texas at El Paso School of Pharmacy	Public	2017	
99	Palm Beach Atlantic University Lloyd L. Gregory School of Pharmacy	Private Non-Profit	2001	X
99	University of Hawaii at Hilo Daniel K. Inouye College of Pharmacy	Public	2007	X
99	Roseman University of Health Sciences College of Pharmacy	Private Non-Profit	2001	
99	Concordia University Wisconsin School of Pharmacy	Private Non-Profit	2010	X
99	Wingate University School of Pharmacy	Private Non-Profit	2003	X
99	Union University College of Pharmacy	Private Non-Profit	2008	X
111	Notre Dame of Maryland University School of Pharmacy	Private Non-Profit	2009	X
111	Marshall University School of Pharmacy	Public	2012	X
111	High Point University Fred Wilson School of Pharmacy	Private Non-Profit	2016	X

Rank	School Name	Sector	Start of PharmD	Treated in School Regressions
111	Touro University Touro College of Pharmacy	Private Non-Profit	2008	X
111	University of New England Westbrook College of Health Professions School of Pharmacy	Private Non-Profit	2009	X
111	Harding University College of Pharmacy	Private Non-Profit	2008	X
111	Rosalind Franklin University of Medicine and Science College of Pharmacy	Private Non-Profit	2011	X
111	Cedarville University School of Pharmacy	Private Non-Profit	2012	X
111	University of Texas at Tyler Ben and Maytee Fisch College of Pharmacy	Public	2015	X
111	University of Saint Joseph School of Pharmacy and Physician Assistant Studies	Private Non-Profit	2011	X
122	Keck Graduate Institute (KGI) School of Pharmacy and Health Sciences	Private Non-Profit	2014	
122	Fairleigh Dickinson University School of Pharmacy & Health Sciences	Private Non-Profit	2012	X
122	Sullivan University College of Pharmacy and Health Sciences	Private For-Profit	2008	
122	Presbyterian College School of Pharmacy	Private Non-Profit	2010	X
122	Philadelphia College of Osteopathic Medicine - Georgia School of Pharmacy	Private Non-Profit	2010	X
127	Lake Erie College of Osteopathic Medicine School of Pharmacy	Private Non-Profit	2003	X
127	Roosevelt University College of Science, Health and Pharmacy	Private Non-Profit	2011	X
127	University of Charleston School of Pharmacy	Private Non-Profit	2006	X
130	Appalachian College of Pharmacy	Private Non-Profit	2006	
130	D'Youville University School of Pharmacy	Private Non-Profit	2010	X
132	West Coast University School of Pharmacy	Private For-Profit	2014	
132	Marshall B. Ketchum University College of Pharmacy	Private Non-Profit	2017	
132	South University School of Pharmacy	Private For-Profit	2003	
132	Husson University College of Health and Pharmacy School of Pharmacy	Private Non-Profit	2009	X
136	Chicago State University College of Health Sciences and Pharmacy	Public	2008	X
136	South College School of Pharmacy	Private For-Profit	2012	

Rank	School Name	Sector	Start of PharmD	Treated in School Regressions
136	California Northstate University College of Pharmacy	Private For-Profit	2009	
136	William Carey University School of Pharmacy	Private Non-Profit	2018	
140	Larkin University College of Pharmacy	Private Non-Profit	2016	
141	American University of Health Sciences School of Pharmacy	Private For-Profit	2020	
	Hampton University School of Pharmacy	Private Non-Profit	1998	X

These data on the dates of opening come from the Accreditation Council for Pharmacy Education (ACPE). The rank data come from the 2024 US News Best Pharmacy School rankings. Sector comes from IPEDS. Included as Treated in School Regressions indicates which openings are included in the regressions of school level outcomes. The vast majority of PharmD programs not included in the IPEDS analysis were excluded because they opened too early (before 2002) or too late (after 2016) for us to have data both before and after the opening. The majority of others that were excluded due to being for-profit (only a handful of programs) or because of inconsistent reporting to IPEDS. For instance, Appalachian College of Pharmacy did not report to IPEDS prior to its opening in 2006.

Table A2: Balance Sheet Items

	(1) Revenues	(2) Assets	(3) Liabilities
DiD - 75th	0.117***	0.072**	-0.076
	(0.032)	(0.037)	(0.103)
DiD - 70th	0.078**	-0.002	-0.134
	(0.032)	(0.044)	(0.094)
DiD - 80th	0.115***	0.073*	-0.027
	(0.034)	(0.039)	(0.085)
Mean (millions)	415.0	735.0	356.5
Observations - 75th	4,794	4,794	4,794
Observations - 70th	5,950	5,950	5,950
Observations - 80th	3,944	3,944	3,944

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A3: Enrollment Characteristics and Undergraduate Pricing

	(1)	(2)	(3)	(4)	(5)	(6)
	Enrollment					
	Total	Undergrad	Graduate	Minority	Tuition	Institutional Grants
DiD - 75th	0.165***	0.020	0.728***	0.193***	-0.023	-0.133
	(0.039)	(0.057)	(0.209)	(0.069)	(0.044)	(0.132)
DiD - 70th	0.175***	0.021	0.769***	0.176**	-0.009	-0.104
	(0.039)	(0.055)	(0.208)	(0.069)	(0.042)	(0.118)
DiD - 80th	0.151***	0.021	0.728***	0.192***	-0.004	-0.169
	(0.041)	(0.057)	(0.210)	(0.071)	(0.047)	(0.147)
Mean	4,100	3,259	841	1,332	14564	4,401
Observations - 75th	4,879	4,879	4,879	4,879	4,522	4,029
Observations - 70th	6,052	6,052	6,052	6,052	5,559	5,083
Observations - 80th	4,012	4,012	4,012	4,012	3,740	3,315

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A4: Aggregated Expenditures by Category

	(1) Total	(2) Salaries	(3) Instruction	(4) Benefits	(5) Research	(6) Acad. Supp	(7) Student Serv.	(8) Inst. Supp.
DiD - 75th	0.117***	0.097***	0.114***	0.085	0.647**	0.130***	0.060	0.209***
	(0.026)	(0.032)	(0.038)	(0.070)	(0.304)	(0.048)	(0.060)	(0.073)
DiD - 70th	0.084***	0.077***	0.089**	0.094	0.566**	0.136***	0.088	0.161**
	(0.026)	(0.030)	(0.036)	(0.071)	(0.283)	(0.048)	(0.063)	(0.073)
DiD - 80th	0.119***	0.094***	0.128***	0.083	0.718**	0.136***	0.068	0.240***
	(0.029)	(0.033)	(0.038)	(0.073)	(0.344)	(0.050)	(0.061)	(0.074)
Mean (millions)	389.1	170.6	122.3	39.5	69.4	35.6	18.7	33.3
Observations - 75th	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794
Observations - 70th	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950
Observations - 80th	3,944	3,944	3,944	3,944	3,944	3,944	3,944	3,944

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A5: Salary Expenditures by Category

	(1) Instruction	(2) Research	(3) Acad. Supp	(4) Student Serv.	(5) Inst. Supp.
DiD - 75th	0.102***	0.534*	0.077	0.050	0.060
	(0.039)	(0.309)	(0.051)	(0.064)	(0.043)
DiD - 70th	0.100***	0.485*	0.084*	0.088	0.032
	(0.034)	(0.283)	(0.046)	(0.067)	(0.036)
DiD - 80th	0.114***	0.516	0.088	0.047	0.072*
	(0.037)	(0.354)	(0.055)	(0.065)	(0.041)
Mean (millions)	77.3	32.5	18.1	8.8	15.2
Observations - 75th	4,794	4,794	4,794	4,794	4,794
Observations - 70th	5,950	5,950	5,950	5,950	5,950
Observations - 80th	3,944	3,944	3,944	3,944	3,944

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A6: Instructional Faculty Counts

	(1) Total Faculty	(2) Professors	(3) Associate Professors	(4) Assistant Professors	(5) Lecturers
DiD - 75th	0.187***	0.053	0.103	0.190*	0.267***
	(0.034)	(0.046)	(0.079)	(0.097)	(0.086)
DiD - 70th	0.168***	0.044	0.101*	0.211***	0.232***
	(0.032)	(0.042)	(0.061)	(0.081)	(0.084)
DiD - 80th	0.166***	0.057	0.058	0.102	0.205**
	(0.036)	(0.052)	(0.108)	(0.115)	(0.095)
Mean	471	142	121	134	73
Observations - 75th	4,352	4,352	4,352	4,352	4,352
Observations - 70th	5,440	5,440	5,440	5,440	5,440
Observations - 80th	3,568	3,568	3,568	3,568	3,568

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A7: Balance Sheet Items Controlling for Other Programs

	(1) Revenues	(2) Assets	(3) Liabilities
DiD - No Controls	0.117***	0.072**	-0.076
	(0.032)	(0.037)	(0.103)
DiD - Controls	0.113***	0.065*	-0.077
	(0.031)	(0.035)	(0.108)
Mean (millions)	415.0	735.0	356.5
Observations - No Controls	4,794	4,794	4,794
Observations - Controls	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table A8: Enrollment Characteristics and Undergraduate Pricing Controlling for Other Programs

	(1)	(2)	(3)	(4)	(5)	(6)
	Enrollment					
	Total	Undergrad	Graduate	Minority	Tuition	Institutional Grants
DiD - No Controls	0.165***	0.020	0.728***	0.193***	-0.023	-0.133
	(0.039)	(0.057)	(0.209)	(0.069)	(0.044)	(0.132)
DiD - Controls	0.168***	0.023	0.733***	0.201***	-0.027	-0.106
	(0.040)	(0.056)	(0.219)	(0.071)	(0.049)	(0.143)
Mean	4,100	3,259	841	1,332	14564	4,401
Observations - No Controls	4,879	4,879	4,879	4,879	4,522	4,029
Observations - Controls	4,879	4,879	4,879	4,879	4,522	4,029

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A9: Aggregated Expenditures by Category Controlling for Other Programs

	(1) Total	(2) Salaries	(3) Instruction	(4) Benefits	(5) Research	(6) Acad. Supp	(7) Student Serv.	(8) Inst. Supp.
DiD - No Controls	0.117***	0.097***	0.114***	0.085	0.647**	0.130***	0.060	0.209***
	(0.026)	(0.032)	(0.038)	(0.070)	(0.304)	(0.048)	(0.060)	(0.073)
DiD - Controls	0.116***	0.095***	0.115***	0.074	0.668**	0.130***	0.061	0.208***
	(0.027)	(0.033)	(0.037)	(0.071)	(0.329)	(0.050)	(0.060)	(0.067)
Mean (millions)	389.1	170.6	122.3	39.5	69.4	35.6	18.7	33.3
Observations - No Controls	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794
Observations - Controls	4,794	4,794	4,794	4,794	4,794	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A10: Salary Expenditures by Category Controlling for Other Programs

	(1) Instruction	(2) Research	(3) Acad. Supp	(4) Student Serv.	(5) Inst. Supp.
DiD - No Controls	0.102***	0.534*	0.077	0.050	0.060
	(0.039)	(0.309)	(0.051)	(0.064)	(0.043)
DiD - Controls	0.102***	0.592*	0.073	0.054	0.053
	(0.039)	(0.325)	(0.052)	(0.065)	(0.044)
Mean (millions)	77.3	32.5	18.1	8.8	15.2
Observations - No Controls	4,794	4,794	4,794	4,794	4,794
Observations - Controls	4,794	4,794	4,794	4,794	4,794

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A11: Instructional Faculty Counts Controlling for Other Programs

	(1) Total Faculty	(2) Professors	(3) Associate Professors	(4) Assistant Professors	(5) Lecturers
DiD - No Controls	0.187***	0.053	0.103	0.190*	0.267***
	(0.034)	(0.046)	(0.079)	(0.097)	(0.086)
DiD - Controls	0.185***	0.052	0.102	0.178*	0.271***
	(0.038)	(0.051)	(0.091)	(0.103)	(0.094)
Mean	471	142	121	134	73
Observations - No Controls	4,352	4,352	4,352	4,352	4,352
Observations - Controls	4,352	4,352	4,352	4,352	4,352

Dependent variables are logged. The sample period spans the 2001 AY to the 2017 AY. The regressions are weighted by full-time enrollment in 1997. Mean reports the unlogged pre-treatment averages for PharmD institutions. Standard errors clustered by institution are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table A12: New PharmD Programs and Labor Market Outcomes

	(1) Median Wage and Salary/hr, Pharmacists	(2) Median Income/hr, Pharmacists	(3) Median Wage and Salary/hr, Non-Pharmacist BAs	(4) Median Income/hr, Non-Pharmacist BAs	(5) Difference in Median Wage and Salary/hr	(6) Difference in Median Income/hr
DiD	-2.725**	-2.936**	-0.380	-0.679	-2.330**	-2.072*
	(1.121)	(0.992)	(0.522)	(0.535)	(1.087)	(1.064)
Mean	57.200	59.373	28.742	32.879		

Each column is a separate regression. The first two columns repeat results for pharmacists provided in Table 6. Columns (3) and (4) present results from the same regressions run in columns (1) and (2), but now the dependent variable is only for non-pharmacists with at least a BA degree. In columns (5) and (6), the dependent variable is the difference between pharmacists and non-pharmacists with at least a BA for the specified wage or income variable. Standard errors are clustered at the state level. * p<0.10, ** p<0.05, *** p<0.01

Table A13: New PharmD Programs and Pharmacists' Labor Market Outcomes, by Gender

	(1) Number Pharmacists, Age≤35	(2) Median Wage and Salary/hr	(3) Median Income/hr	(4) Average Hours	(5) Fraction Fulltime
Male					
DiD	188.948**	-1.984	-0.763	-0.064	-0.006
	(68.014)	(1.231)	(1.078)	(0.649)	(0.021)
Female					
DiD	85.784	-3.112*	-2.899*	-0.598	-0.020
	(77.667)	(1.329)	(1.290)	(0.768)	(0.027)

The top panel presents estimates for men, the bottom panel for women. Wage and salary and income data are from the five percent microdata sample of the 2000 census and the 2001-2022 American Community Surveys. Data are at the state-year unit of observation. Standard errors are cluster bootstrapped with clusters at the state level. The mean of the dependent variable is the average of the outcome variable for the treated states in the years prior to being treated. * p<0.10, ** p<0.05, *** p<0.01

Table A14: Changing Workloads for Pharmacists Over Time

	(1) Workload, 1-5 scale	(2) Workload, 1-5 scale	(3) If high or excessively high	(4) If high or excessively high
Year=2014	0.019***	0.016**	0.010***	0.008**
	(0.003)	(0.006)	(0.002)	(0.004)
Age		0.003		0.001
		(0.004)		(0.003)
Year licensed		0.003		0.002
		(0.004)		(0.003)
Male		0.010		-0.004
		(0.037)		(0.023)
BSPharm degree		-0.015		0.003
		(0.047)		(0.029)
Mean	3.636	3.636	0.574	0.574
Observations	2,116	2,116	2,116	2,116

Data are from the 2004 and 2014 National Pharmacist Workforce Study surveys. The sample is restricted to pharmacists working in licensed pharmacies. The workload variable takes on five distinct values with lower values indicating a lighter workload. The dependent variable in columns (3) and (4) indicates that the respondent chose "high" or "excessively high" as their response. Heteroskedasticity-robust standard errors are shown. * p<0.10, ** p<0.05, *** p<0.01

Table A15: Hourly Earnings at Independent and Chain Pharmacies

	Staff pharmacist		Manager/Owner	
	(1)	(2)	(3)	(4)
Large chain pharmacy	0.129***	0.112***	0.084**	0.086**
	(0.037)	(0.031)	(0.041)	(0.038)
Controls		X		X
Observations	1,107	1,082	861	831

The dependent variable is the natural log of hourly earnings (inclusive of all earning from working at the pharmacy such as wages, bonuses, earnings from ownership, etc.). Data are from the 2000, 2004, and 2009 NPWS. The sample is restricted to practicing pharmacists who work at either a large chain pharmacy, a small chain pharmacy, or an independent pharmacy. The omitted group is those working at either a small chain or an independent pharmacy. Columns (1) and (2) restrict to staff pharmacists; columns (3) and (4) restrict to owners or managers at a pharmacy. Controls include year fixed effects, year of licensure fixed effects, state fixed effects, and an indicator for male. * p<0.10, ** p<0.05, *** p<0.01

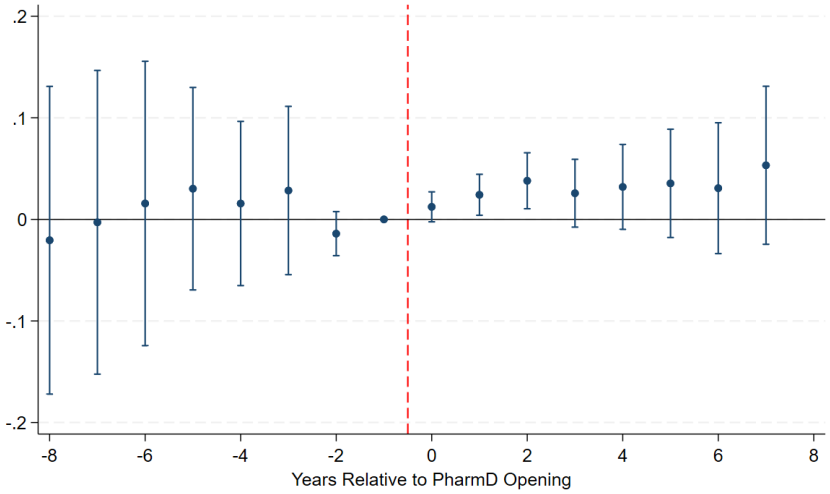
Table A16: New PharmD Programs and Pharmacists' Labor Market Outcomes

	(1) Median Wage and Salary/hr	(2) Median Income/hr	(3) Average Hours	(4) Fraction Fulltime
DiD, baseline	-2.725**	-2.936**	0.093	-0.013
	(1.121)	(0.992)	(0.610)	(0.020)
DiD, CBP	-1.777	-1.681	0.601	-0.009
	(1.977)	(1.831)	(0.924)	(0.030)
DiD, BLS	-1.598	-1.766	0.554	-0.008
	(1.831)	(1.590)	(0.824)	(0.029)
Mean	57.200	59.373	38.344	0.725

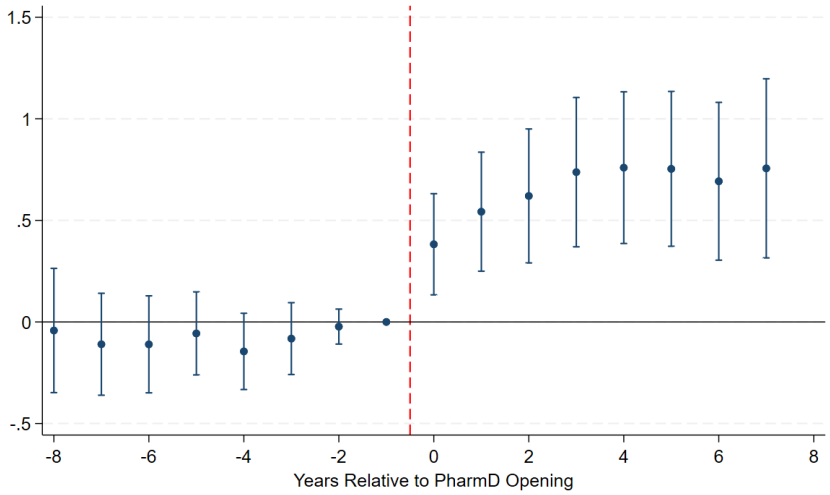
The top row reports our baseline results. The second row includes a control for the number of pharmacies in the state based on County Business Patterns data. The third row includes an analogous control based on Bureau of Labor Statistics data. Wage and salary and income data are from the five percent microdata sample of the 2000 census and the 2001-2022 American Community Surveys. Data are at the state-year unit of observation. Standard errors are cluster bootstrapped with clusters at the state level. The mean of the dependent variable is the average of the outcome variable for the treated states in the years prior to being treated. Wages include wage and salary income; earnings include all income. * p<0.10, ** p<0.05, *** p<0.01

Figure A1: Effects of Opening a PharmD program on Enrollment

(a) Changes in Undergrad Enrollment

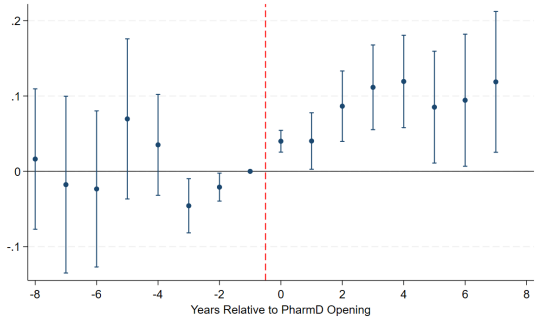


(b) Changes in Grad Enrollment

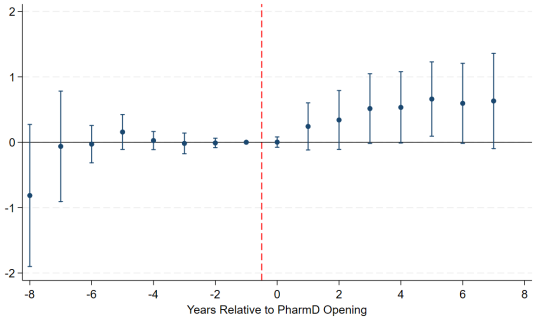


These plot event study coefficients from estimation of discussed in Section 3. The data come from the National Center for Educational Statistics Integrated Postsecondary Education Data System.

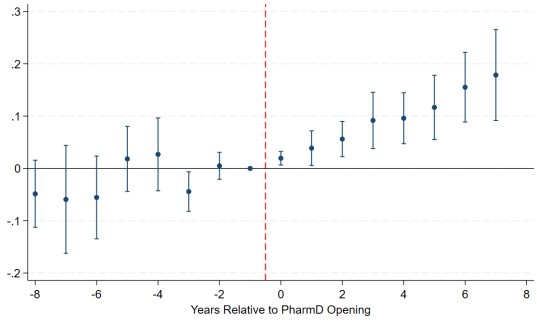
Figure A2: Effects of Opening a PharmD program on Institutional Behavior



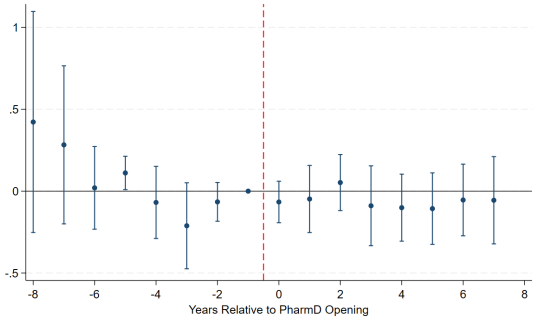
(a) Instructional Salary



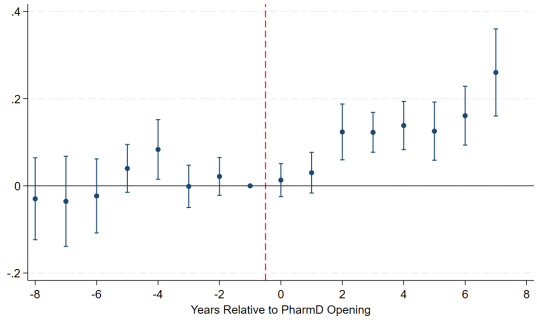
(b) Research Salary



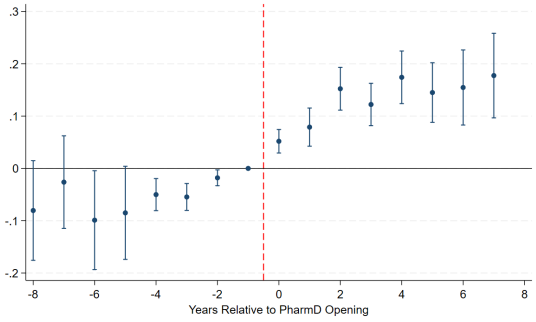
(c) Expenditures



(d) Institutional Grants



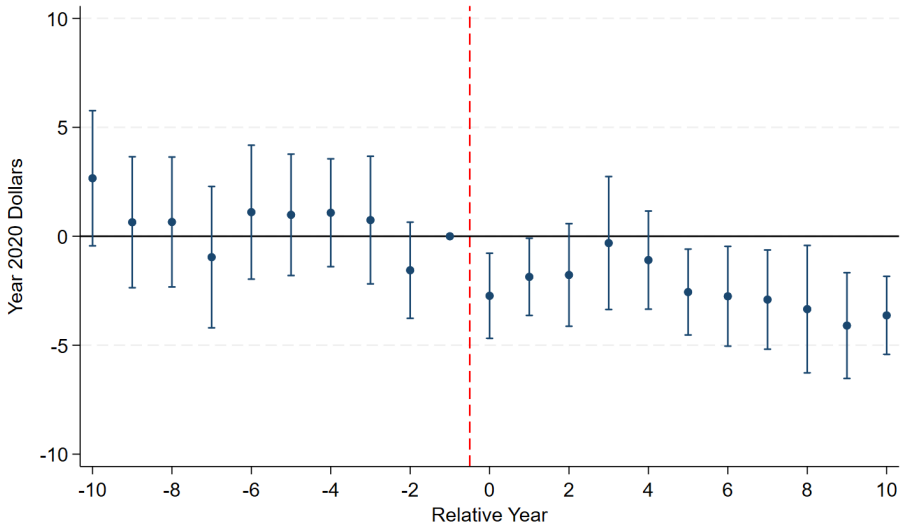
(e) Total Revenue



(f) Total Employment

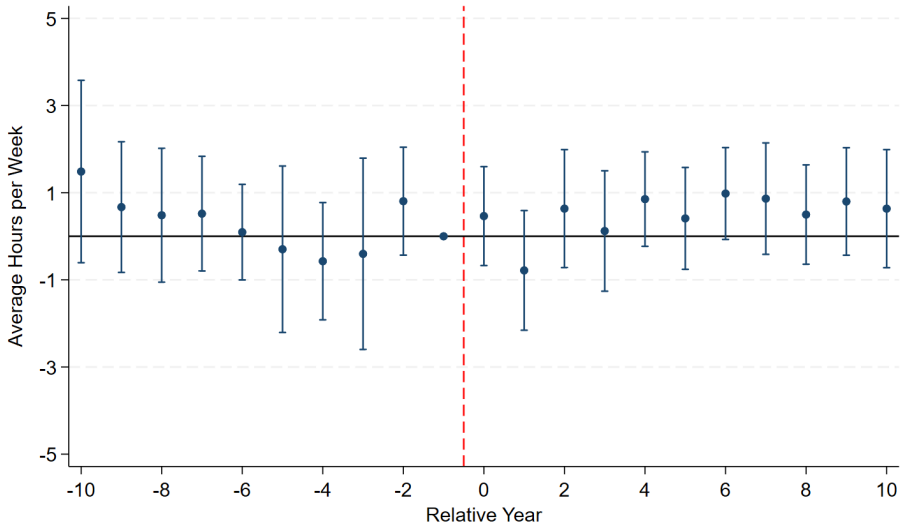
These plot event study coefficients from estimation of discussed in Section 3. The data come from the National Center for Educational Statistics Integrated Postsecondary Education Data System.

Figure A3: Median Income per Hour



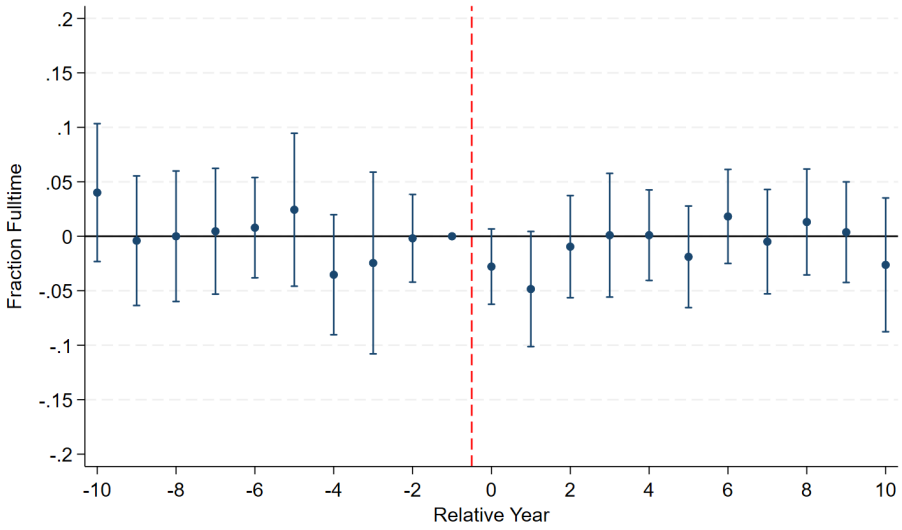
Data are from the 2000 census and the 2001-2022 American Community Survey. Point estimates and 95 percent confidence intervals are reported.

Figure A4: Average Hours Worked per Week



Data are from the 2000 census and the 2001-2022 American Community Survey. Point estimates and 95 percent confidence intervals are reported.

Figure A5: Fraction of Pharmacists Working Full Time



Data are from the 2000 census and the 2001-2022 American Community Survey. Point estimates and 95 percent confidence intervals are reported.

B Accreditation

In 2019, the executive director of ACPE (who has held that role for 20 years) wrote an opinion piece explaining why the ACPE continues to approve new pharmacy school openings despite calls to act as a gatekeeper to restrict new programs to keep salaries high. Part of this quoted below.

> We live in a free market society. When I started in my position, pharmacy had 78 accredited schools, and we were graduating approximately 7,000 students a year. Because projections were made of an upcoming pharmacist shortage due to an aging population with increasing medication needs, existing colleges and schools of pharmacy expanded their class sizes and/or opened branch campuses. Many new schools began to apply for accreditation.
>
> Now we have 143 accredited schools and are graduating approximately 14,500 students per year. Until recently, this dramatic increase in graduates has been accommodated by the job market, with almost all students having employment options, although lately, not always in their preferred geographic area.
>
> This is the type of market response I learned about years ago in economics. Had ACPE acted to limit the growth of existing programs or new ones, many of the new graduates would have been robbed of the opportunity to practice pharmacy.
>
> Educational program accreditors do not exist to control the employment markets of their associated professions. ACPE's standards are based on quality, not quantity. Our focus is making sure students have the best information to make career and program decisions at the time of application. Source: Vlasses (2019)

This view is not universally held. A change.org petition starting in 2019 has nearly 25,000 signatures and calls for a pause to all new accreditation (until 2030) among other restrictions.[36]

[36] https://www.change.org/p/protect-the-profession-we-honor-and-cherish-for-the-coming-decade-and-beyond?recruiter=935439682

C Details of the IPEDS data

There are two main issues that must be addressed when using IPEDS data. First, IPEDS surveys have changed over time. This requires researchers to aggregate variables to be consistent over time or to harmonize the variables in some other manner. Second, multi-campus institutions report their data inconsistently over time. In some cases, the data is aggregated up to the entire system while in others, it is reported at a more granular level. Below, we provide information on how we address each of these issues.

C.1 Creating consistent measures

We use data from the Institutional Characteristics, Fall Enrollment, Human Resources, and Student Financial Aid surveys to build a panel spanning the 1992-1993 and 2017-2018 academic years in addition to the Urban Institute's harmonization of the Finance survey data. We harmonize/aggregate variables from these surveys as follows:

- Post-baccalaureate enrollment contains two categories of students, graduate and first-professional, that are reported together in some years and separately in others. We combine the groups in the years where necessary and refer to these students as "graduate" students.
- The variables in the Finance surveys vary by year and type of school, e.g. public/private, non-profit/for-profit. We use the Urban Institute's harmonization of these surveys (which in turn built upon the work of the Delta Cost Project). Details on the Urban Institute's process and data can be found in Blom et al. (2020).

C.2 Multi-campus Institution Reporting

In IPEDS, multi-campus institutions, e.g. the University of California system or the University of Wisconsin system, report some variables together for all campuses and other variables individually, and that reporting changes over time. To address this issue, we aggregate campuses within the institution. The details of this aggregation follow.

First, we implement a set of sample restrictions to help identify the flagship school in each system. We 1) require that schools with new pharmacy programs have IPEDS data for two years prior to opening their pharmacy program, 2) restrict control schools to have graduate programs for more than 85 percent of the sample years, 3) remove theological schools, 4) require that institutions have at least 500 students, 5) remove for-profit institutions, 6) remove institutions that change their identifier (OPEID, discussed shortly), and 7) remove institutions located outside of the United States. From there, we use each campus's identifier, the OPEID, which is an eight digit code assigned to campuses by the U.S. Department of Education's Office of Postsecondary Education. For the vast majority of institutions, each campus within the institution is assigned the same OPEID. Thus, with the set of flagship institutions and their OPEIDs, we go back to the whole sample and aggregate all of the campuses into the flagship campus's observation if they share the same OPEID. The exception is when an OPEID contains a campus that is for-profit. If that is the case, then we exclude all campuses with that OPEID.

Once the variables have been aggregated to the OPEID level, we take data from the 1997-1998 academic year and see how many different campuses fed into the variables for each OPEID. Then by OPEID, we divide each variable in each year by the relevant number of campuses. By doing so, the flagship campus becomes a representative for the entire system. On average, approximately ten percent of the observations in our sample represent multi-campus institutions and, conditional on being multi-campus, there are 2.7 campuses per institution.

D Entry and Welfare

Market Structure

Each pharmacy program is a differentiated product because of branding, geographic isolation, and other factors. This implies that each school will have some pricing power. Each program also faces competition from other programs, but also from other majors or careers that students consider. This suggests that each program is not operating as a monopolist. In addition, as discussed in Section 2, there appears to be very little in the way of barriers to entry in the pharmacy school market.

With those observations in hand, assume we have schools that are choosing whether or not to open up a pharmacy program. While the university might care about its overall reputation for quality, we will treat the professional pharmacy program as a profit center. In that case, all that matters is whether the pharmacy school will make profits or not, given the actions of other programs. Suppressing the prices of other programs to simplify notation, the present value of profits for a potential pharmacy school are:

$$\max_{q_t} \sum_{t=0}^{\infty} \beta^t \left[p(q_t) q_t - VC(q_t) \right] - F \tag{3}$$

where t indexes time, β^t is the discount rate, $p(q_t)$ is the inverse demand curve/price (tuition+fees), q_t is the number of students enrolled, $VC(q_t)$ are the variable costs of production, and F are the fixed costs of production.

Because there is nothing inherently dynamic about the profit maximization problem, conditional on being in the market, we get the usual Lerner Rule relating the markup and price to the elasticity of demand. If we let ε be the price elasticity of demand for enrollment in the pharmacy school and $MC(q_t)$ be the marginal cost,

$$\frac{p(q_t) - MC(q_t)}{p(q_t)} = -\frac{1}{\varepsilon} \tag{4}$$

Because there are no barriers to entry, schools will enter the market up to the point where long-run profits are equal to zero. This standard zero-profit condition implies that the marginal program will have

$$\sum_{t=0}^{\infty} \beta^t \left[p(q_t^*) q_t^* - VC(q_t^*) \right] = F \tag{5}$$

where F is the fixed cost of entry. Then with the simplifying assumption that per-period profits are constant, the zero-profit condition implies that for the marginal entrant, $F = profits_t/(1-\beta)$.

Estimating Welfare

Ideally, for each pharmacy program, we would have the following data: per-period profits, the number of enrolled students, and the price (tuition+fees). With that data, we could estimate each program's elasticity of demand and put an upper bound on its fixed costs. Unfortunately, we do not have program-level data on profits. However, as discussed in Section 2, we do have some information on average and median profits for a number of pharmacy schools. Using that information in conjunction with equilibrium price and enrollments, denoted p^* and q^* respectively, and assumptions on the functional form for demand and the discount factor ($\beta = 0.97$), we can

recover the ingredients needed to estimate the social welfare impacts of a representative pharmacy school.

First, for a specified value of profits and an observed p^*, we can use the Lerner Rule to back out the elasticity of demand. We assume that the demand curve has a constant elasticity: $q_t = ap_t^{\varepsilon}$. With equilibrium values for q^*, p^* and an estimated demand elasticity from the Lerner Rule, we can pin down $\tilde{a} \equiv q_t^*/p_t^{*\varepsilon}$ to have the entire demand curve. In that case, suppressing time subscripts, we can calculate per-period consumer surplus as

$$CS \equiv \int_0^{q^*} \left[\left(\frac{q}{\tilde{a}} \right)^{1/\varepsilon} - p^* \right] \mathrm{d}q = \left(\frac{1}{a} \right)^{1/\varepsilon} \frac{\varepsilon}{\varepsilon + 1} q^{* \frac{\varepsilon+1}{\varepsilon}} - p^* q^*. \tag{6}$$

The welfare impact of an entrant can then be calculated as

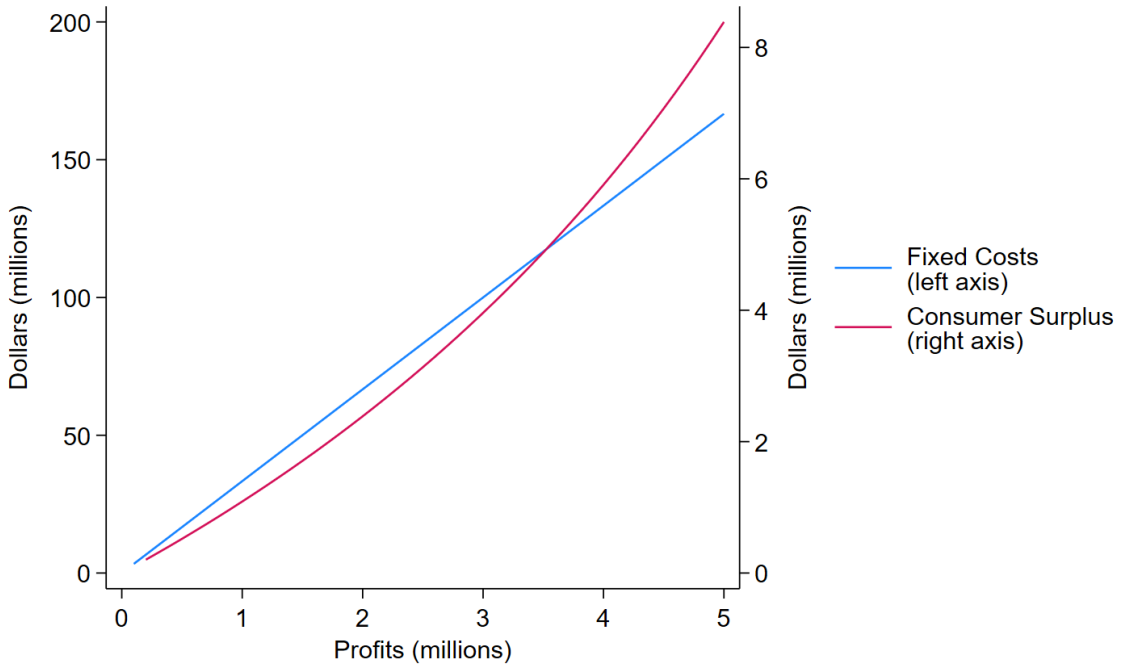
$$\Delta Welfare = \frac{CS}{1-\beta} + \frac{Profits}{1-\beta} - F$$

where both the consumer surplus and profits are per-period values.

In our data, the median pharmacy program earns approximately \$4.7 million in profits per year. In our price and enrollment data, among the pharmacy programs that were created after 2000, the average tuition and enrollment in 2019 is \$43,435 and 285, respectively. If the marginal pharmacy program had these attributes, then we would estimate that it had fixed costs of roughly \$157 million and that it generates approximately \$7.6 million of welfare benefits per year.

To see how these values change with the marginal entrant's profits, Appendix Figure D1, plots the fixed costs and per-year welfare benefits of entrants for various values of assumed profits.

Figure D1: Fixed Costs and Consumer Surplus as a Function of Profits



The figure shows that as profits rise, the marginal entrant's fixed costs must also rise. This

is a natural consequence of the zero-profit condition. The figure also shows that as per-period profits for the pharmacy program rise, per-period consumer surplus also rises for the marginal entrant. If the program is making $1 million in profits, consumer surplus is $1.09 million. If the program makes $2 million, consumer surplus is $2.39 million. By the time the program earns $5 million, consumer surplus becomes $8.39 million. If the market is in a long-run equilibrium, then the marginal firm's per-period profits are exactly offset by the fixed cost of entry leaving consumer surplus as the overall impact on social welfare in the market for pharmacy education.

Of course, this back-of-the-envelope approach is somewhat limited in what it can address and it relies on a number of additional assumptions that might not be true (e.g. no income effects on enrollment demand, that potential enrollees have good information on all of the factors relevant to going to pharmacy school so that their revealed choices are informative about welfare, etc.). If we were to adopt additional structure, there are a number of interesting counterfactuals that could be addressed. However, that is beyond the scope of the current paper.

E Educational Loans from non Department of Education Federal Sources

Non Department of Education federal loans that could be used for pharmacy include include HEAL Loans and loans from the Health Resources and Services Administration (HRSA) (Kehres, 2025).

Students could borrow using the Health Education Assistance Loan (HEAL) program which was administered by the Department of Health and Human Services. HEAL loans were for students that were not in default on existing loans and had unmet need (U.S. Department of Education, 2025). In general, the increase in borrowing capacity from the HEAL program applied to both PharmD and BSPharm students and so we do not focus on it in the discussion. The maximum a student could borrow in HEAL Loans is $12,500 annually in the years after the students' third year. In 1998, the HEAL program was phased out and the Stafford program was changed so BSPharm students could borrow the HEAL amounts as part of the Stafford program, increasing loan limits for Stafford students. At this point, many programs were transitioning to the PharmD and all programs transitioned by 2001.

The two HRSA loans relevant for pharmacy education are the Health Professions Student Loan (HPSL) and the Loan for Disadvantaged Students (LDS), which are similar except that LDS loans can only be made to students from economically (currently defined to be less than 200 percent of the federal poverty line) or environmentally disadvantaged backgrounds (U.S. Department of Health and Human Services, Health Resources and Services Administration, 2011; U.S. Department of Health and Human Services, Health Resources and Services Administration, Bureau of Health Workforce, 2199). These two loan programs have meaningful differences from loans from the Department of Education. First, these are not guaranteed to be available to students but are subject to funding availability. Both programs operate as school-administered revolving funds capitalized by federal contributions that were last awarded in 1983 for HPSL and 2002 for LDS, meaning the pool of available funds at any given institution depends entirely on repayments from prior borrowers. Individual campuses exercise substantial discretion in determining eligibility and award amounts, and students at schools with smaller or depleted revolving funds may receive little or nothing. Second, unlike Department of Education loans, both programs require students to provide parental financial information regardless of their dependency status, adding an eligibility hurdle that may screen out otherwise needy students. Third, while there is no statutory dollar cap on annual borrowing – students could in principle borrow up to the full cost of attendance minus other aid – the practical constraint is the size of the school's revolving fund. Finally, because no new federal capital contributions have been made since 1983 for HPSL and 2002 for LDS, pharmacy schools that were established after those dates would have no revolving fund from which to disburse these loans, meaning students at newer institutions had no access to these programs at all.

F Estimating the Fraction of Growth in Pharmacy Enrollments that is Correlated with Pharmacists' Wage Growth

In this appendix section, we explore the sensitivity of our estimate of the fraction of growth in pharmacy enrollments that is due to pharmacists' wage growth (and anything correlated with observed wage growth) along four dimensions. The first is the elasticity of demand for enrollment in pharmacy schools. The second is the functional form of the supply and demand curves in the market for pharmacy education. The third is the degree to which potential pharmacy students are able to forecast wage growth in the market for pharmacists. The fourth is how to scale the relationship between pharmacists' wage growth and demand for pharmacy enrollments over time. Note that all wages were converted to real 2010 dollars for this exercise.

As stated in the text, we have not found any estimates of the elasticity of demand for a spot in a pharmacy school. In our main model specification, we assume that the elasticity of demand is -0.29 based on Denning (2017). However, it seems likely that this might overstate the elasticity of demand since it comes from the context of community colleges. Students at community colleges are more likely to be on the margin of schooling or not than high-achieving students enrolling in advanced degree programs. Because of that, we re-estimate our model under the assumption that demand is completely inelastic and under the assumption that the elasticity is -0.10.[37]

In our primary specification, we assumed that the supply and demand curves both had a constant elasticity. In many cases, a natural alternative would be to assume that the demand curves are linear; when changes in the market equilibrium are relatively small, linearity is a reasonable approximation. We did not default to linearity in our case because enrollments grew so much over time. However, in this appendix, we will present results under the assumption that both the supply and demand curves are linear.

The third dimension we will allow to vary in this appendix is the information that the potential pharmacy student uses to forecast wage growth in the pharmacy market. Past research suggests that medical students form wage expectations that are not simply today's wages nor are they able to perfectly predict what their wages will be in the future (i.e. not an extreme form of rational expectations) (Nicholson and Souleles, 2001). We test out a number of different alternatives: 1) wage growth from the previous ten years, 2) wage growth from the present to the next ten years (comparable to the rational expectations approach), 3) the same as 1), but using wage growth relative to wage growth for those with a BA, 4) the same as 2), but using wage growth relative to wage growth for those with a BA.

The final piece of the model that we vary is how the relationship between pharmacists' wage growth and pharmacy school enrollments is scaled over time. In our preferred setup, we estimate the growth in pharmacy school enrollments between 1990 and 2000 and compare that the growth in pharmacists' wages from 1980 to 1990. Once we have that number, we have to decide how to apply that the present time. We do this in two ways. Our baseline method is to scale the growth in enrollments by each dollar of growth in pharmacists' wages. Our second method is to scale enrollment growth by a percentage point increase in pharmacists' wage growth.

The results are presented below in Appendix Table F1. The top panel in the table corresponds to supply and demand curves that each have their own constant elasticity; the bottom panel assumes the supply and demand curves are linear. Within each panel, the row corresponds to the

[37] Note that inelastic demand in the aggregate does not imply that the demand for each individual school is inelastic. Consider a constant elasticity of demand utility function with two nests, one for PharmD education and one for food. Within each nest, individual schools or foods have elastic demand. However, a PharmD education is not a good substitute for food; this would tend to mean that PharmD education and food have a low elasticity of substitution, and so price-inelastic demand for each aggregate.

elasticity of demand specified in the first column. Subsequent columns describe the way that pharmacists' wages affect pharmacy school enrollments as well as how these changes are scaled to the 2000 to 2010 time period. Each entry in the table is the fraction of the observed increase from 2000 to 2010 in pharmacy enrollments that could be attributed to the growth in pharmacists' wages (and correlates of wages).

Table F1: Fraction of Observed Demand Related to Pharmacist Wages (and Correlates), 2000 - 2010

	Lagged wage growth, per dollar of growth	Lagged wage growth, per percentage point	Current wage growth, per percentage point	Lagged relative wage growth, per unit of relative wages	Lagged relative wage growth, per percentage point
Constant elasticity supply and demand					
$\varepsilon = -0.29$	0.21	0.12	0.13	0.25	0.22
$\varepsilon = -0.10$	0.23	0.16	0.17	0.27	0.24
$\varepsilon = 0$	0.24	0.18	0.19	0.27	0.25
Linear supply and demand					
$\varepsilon = -0.29$	0.44	0.36	0.37	0.47	0.44
$\varepsilon = -0.10$	0.33	0.27	0.28	0.37	0.34
$\varepsilon = -1^{-10}$	0.24	0.18	0.19	0.27	0.25

The elasticity of demand is given by the specified value of ε. The elasticity of supply is estimated from 1990 and 1995 data.

For specifications with constant elasticity supply and demand curves, reducing the elasticity of demand tends to increase the fraction of enrollment growth that can be attributed to pharmacist wage growth and its correlates; for linear supply and demand, the opposite is true. Moving from a scaling factor that is per dollar of growth to a scaling factor that is per percentage point tends to reduce the fraction that can be explained by pharmacists' wages. Using relative wages rather than the levels of wages produces results quite similar to our baseline specification.

While there is some variation in the fraction that can be explained by wages, there is always a substantial fraction left over not explained by wages.