The Effect of Minimum Wage Changes on University Research Labs[*]

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Abstract

We study the effect of changes in the minimum wage on the employment of undergraduate research assistants in university labs. Using administrative data from thousands of research labs and a difference-in-differences framework, we find scientists employ 7.1% fewer undergraduates in their labs following minimum wage increases. In the short-run, labs appear to substitute with increased employment of graduate students. In the long-run, labs compensate for higher labor costs by being 10% more likely to utilize supplemental funding. Finally, we estimate the impact of these price shocks on students' exposure to scientific work. We show that undergraduate research assistants who experience minimum wage increases graduate with 8.2% fewer quarters employed in labs, although this is attenuated for students paid by Federal Work Study. Our analysis demonstrates the implications of input price shocks for the scientific workforce and highlights the importance of budget flexibility for sponsored research at universities seeking to provide undergraduates with research experience.

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1 Introduction

A large literature examines how firms respond to changes in the cost of labor inputs, such as minimum wage increases. And yet, despite the importance of scientific research for innovation and economic growth, relatively little is known about how labor market policies impact scientific research in university research labs. Previous estimates of the effects of changes in costs of labor on employment may not be applicable to university labs. The production of scientific knowledge in university labs is unique in that much of the labor—including postdocs, graduate students, and undergraduates—are both an input to the production of scientific research and an output. While university research labs seek to advance knowledge through their research, principal investigators (PIs) also strive to train the next generation of scientists who are enrolled in their universities' educational programs. Moreover, unlike firms, outputs such as papers are not priced, so labs cannot pass on higher labor costs to consumers.

In this paper, we examine the effect of changes in labor costs that result from increases in state minimum wage laws on university lab employment. As many student employees at universities earn low wages, often at or near the minimum wage, such labor cost increases can impact lab hiring and personnel decisions.[1] We use rich administrative data from the accounting records of thousands of labs at U.S. research universities (UMETRICS) in a difference-in-differences event study design. This allows us to compare research labs' employment decisions when facing increases in the minimum wage due to state minimum wage law changes with labs facing stable labor costs at the same time.

We estimate both the short-run effects on employment in labs as well as the longer-run effects on the funding of labs as well as the exposure of lab trainees to scientific work.

For the short-run effects, we examine how PIs respond to higher labor costs in the year following a minimum wage change. PIs have fixed budgets that are set at the time that grants are awarded. If the price for one input increases, then PIs must either use less labor, possibly reducing output (publications), or substitute with another input. We estimate the employment effects of minimum wage changes on labor, including postdocs, graduate students, and undergraduate research assistants in labs and find that scientists employ 7.1% fewer undergraduate research assistants in response to minimum wage changes. We find particularly decreased demand among labs employing more undergraduates prior to the minimum wage change. In addition, we highlight that labs slightly increase

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[1] FLSA actually allows students to be paid 15% less than minimum wage (Freeman, Gray and Ichniowski, 1981).

their use of graduate student labor, suggesting that some tasks previously done by undergraduates may be shifted to graduate students.

We also examine the longer-run effects on lab funding and student trainee exposure to research work. In the long run, PIs can apply for more funding to compensate for the increased labor costs. Indeed, we find that PIs are 10% more likely to utilize supplemental funding in response to the higher labor costs. Funding agencies do not appear to increase funding commensurate with rising labor costs, however, and a back-of-the-envelope calculation suggests that it would cost funding agencies over $150 million dollars in additional funding per year to fully restore employment in university labs.

For student trainees, we demonstrate the impact of these price shocks on their exposure to scientific work. Using a panel of undergraduates who were employed in research labs, we show that following a minimum wage increase, previously employed undergrads were 6.1% less likely to continue working in a university lab. Undergrads who had more prior research experience as well as Federal Work Study students, however, were more likely to remain employed by labs after a minimum wage increase. As undergraduate research experience is important in many fields for continuing on to graduate study and pursuing a scientific career, these labor cost changes may have the ability to influence student trainee academic and career pursuits.

Our findings contribute to two primary strands of literature. First, we add to the economics of science and innovation literature on knowledge production and the scientific workforce. Previous work on the responses of scientists to changes in inputs to scientific production have estimated the long-run impacts of the destruction of physical and human capital (Waldinger, 2016; Baruffaldi and Gaessler, 2018) and the death of important collaborators (Azoulay, Graff Zivin and Wang, 2010). In addition, research has examined the effect of delays in access to funding (Tham, 2023) and increases in overall funding for research labs (Myers, 2020). Unlike the physical destruction of tangible assets or the death of collaborators, where an input becomes unavailable, our study examines how scientists react and adjust to changes in the relative prices of available inputs. Unlike shocks that increase or decrease total available funding for a lab, our analysis examines situations in which a specific input price changes and traces the adaption of scientists in response.

Two works are closely related to our own. Goolsbee (1998) demonstrates that changes in wages show little effect on the labor supply of R&D workers. This work, however, focuses on the labor supply choices of these highly skilled individuals, while our work focuses on the labor demand of trainees. Furman and Teodoridis (2020) examine how a sudden price decrease in a single input to computer vision research induced established computer scientists to work on research utilizing that input. In our study, instead of looking at physical input costs and established researchers, we focus on a price change in the relative cost of different types of labor and examine the impact on scientific trainees. While it is clear from prior work in the economics of science and innovation about the important role of trainees like students and postdocs in the research production process, our study fills a gap in empirical evidence on how scientists allocate student labor in response to wage changes (Carayol and Matt, 2004; Stephan, 1996).

Second, we provide new evidence for the labor economics literature on the impact of the minimum wage. Most research in this area focuses on low-wage workers who would be most likely to be impacted by the increases, typically working in sectors like fast-food or retail. A growing set of papers has examined the impact of minimum wages in new settings, such as the non-profit sector (Meer and Tajali, 2023) and childcare (Brown and Herbst, 2023). Due to data limitations, however, few papers have explored the impact of minimum wage changes on undergraduate student labor. Furthermore, to our knowledge, no previous study has examined how the minimum wage impacts student and trainee employment in university labs, which provide important experience and exposure to students considering scientific careers.

Finally, recent research on the impacts of the minimum wage has tended to find little evidence of disemployment effects (Cengiz et al., 2019) and reallocation of workers to higher-wage and higher-productivity establishments (Dustmann et al., 2021). The reason for the small or null effects may be in part because firms are able to pass on cost increases to consumers. In our setting, however, labs produce unpriced goods, such as scientific papers, and thus have limited means to defray the impact of cost increases in the short-run. In contrast to the literature on employment in the business sector, we discover significant negative employment effects on undergraduates students.

Our findings also have important implications for policymakers. Given the uncertainty of price changes for these specialized inputs, our results point to the need for insurance mechanisms or increased budget flexibility by funders and university administrators. Universities seeking to provide undergraduates with research experience should consider providing faculty with alternate funding sources that are in line with minimum wage levels.

In the next section we discuss the data we use and provide background about minimum wage changes we use in our analysis. In Section 3, we describe the empirical strategy. In Section 4, we present the results, followed by the conclusion.

2 Data

Our analysis uses data linked from multiple data sources providing micro-data on university lab expenditures, employment, and scientific research outputs.

Our primary data source is the UMETRICS database, a collection of administrative records from contributing universities in the United States (Lane et al., 2015). The records in this database are charges to sponsored research grants. These transactions include payments to vendors as well as the employment of workers. Transactions that represent the employment of a worker include the occupational title of the worker and the number of days that the worker was paid from the associated grant.

The UMETRICS data covers the time period between 2000 and 2022.[2] In total, the data in the UMETRICS database cover $98.9 billion of university R&D spending across 33 major research universities in the United States.

For our analysis, we focus on transactions associated with research grants between 2000 and 2019.[3] Only grants that pay a faculty member who also is listed as a principal investigator on an NIH or NSF grant at some point are included. We exclude grants that fund whole centers or departments by filtering out grants that pay more than 12 distinct faculty members[4] or that are NIH grants specifically meant for funding a research center.[5] Finally, the grants in our sample must both employ workers and make purchases of scientific materials at some point during our sample time period.

2.1 Lab Panel Datasets

We use UMETRICS to construct two datasets to estimate the impacts of minimum wage changes on lab employment decisions. First, we build a PI x quarter panel dataset by aggregating transactions from across the grants associated with a PI. Observations include the following variables: the total spending at vendors, the number of days of employment for postdocs, graduate students, undergraduates, and research staff, and the number of distinct employees of each of the proceeding occupations. [6]

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[2] Each contributing university in the UMETRICS sample joined and began contributing data at a different time. Documentation on the number of universities contributing data in each year can be found in the UMETRICS documentation at `https://iris.isr.umich.edu/research-data/2020datarelease/`.

[3] We cut the data at 2019 in order to avoid the disruption that occurred during the COVID-19 pandemic.

[4] We use this cutoff as it represents the 99th percentile in the number of distinct faculty members paid a grant in our data.

[5] We exclude NIH grants with activity codes such as G12, M01, P01, P20, P2C, P30, P40, P42, P50, P51, P60, PL1, PM1, PN1, PN2, T42, U48, U54, UL1, and ULTR.

[6] We use the number of days of labor, which is in contrast to others who have used the total wage bills as outcomes in order to adjust for differences in quality of workers (Fox and Smeets, 2011; Akerman, Gaarder and Mogstad, 2015). In this

Some PIs do not have active grants and do not transact in every quarter. Therefore, we balance the observations of PIs between the quarter in which we observe their first transaction and their last observed transaction. Details about the data constructions are provided in the Appendix.[7]

This panel dataset contains 264,136 Lab x Quarter observations. As shown in Panel B of Table 1, the average lab spends $112,570.30, and employs 1.18 undergraduate research assistants and 1.88 graduate students per quarter.

Second, for robustness, we also repeat our analysis of the employment effects of the minimum wage changes at the grant x quarter level. We, therefore, create an ancillary dataset at this level by taking the raw UMETRICS data and aggregating transactions to the grant x quarter level. This dataset contains 382,485 observations, and summary statistics about it can be found in Table 1 Panel C.

2.2 Scientific Production Dataset

In order to examine the effect on the production of scientific papers, we build a third dataset, a PI x year panel, by similarly aggregating the UMETRICS data to this level. [8]

For each observation in the Lab x year panel, we attach the number of scientific publications published by that PI's lab in that year. We utilize multiple databases to count the number of scientific papers produced. For each grant associated with each lab, we searched and collected all of the publications in the Web of Science bibliometric database that acknowledge that grant or list the PI as an author. In addition, we collected all the publications listed in the PubMed database that acknowledged the grant. As a measure of the impact of these publications, we collect the total number of forward citations to those publications during the subsequent five years as well as whether or not those publications would be classified as "disruptive" using the classification of Funk and Owen-Smith (2017). We run this analysis at the Lab x year level.

This panel dataset contains 188,633 Lab x year observations. As shown in Panel D of Table 1, on average a lab has 0.98 publications per year listed in Web of Science and 3.92 listed in PubMed. The higher number of publications in PubMed is reflective of the fact that the crosswalk between the UMETRICS data and the PubMed database was produced using a more robust method. While the crosswalk to Web of Science is less comprehensive than the one to PubMed, we use both in our

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setting, postdocs, graduate students, and undergraduate workers are likely paid one wage within occupational band.

[7] Our method for aggregating to the PI level is consistent with other papers using UMETRICS data, including Ross, et. al. (2021).

[8] We can not assign published papers to the precise year in which the research work for that paper was conducted. Morevoer, while some publications have information about the particular month or quarter in which they were published, it is hard for us to associate a publication with the exact quarters in which the work was conducted for that publication.

analysis since only Web of Science has data on forward citations and the measure of the disruptiveness of the publications.

2.3 Undergraduate Panel Dataset

Fourth, in order to trace if the labor cost changes impact the employment of undergraduates across labs, we build a undergraduate x quarter panel dataset. For each undergrad we observe working in a lab in the UMETRICS data, we create eight observations starting from September of the year that they turned 18. Thus, the panel is a strongly balanced panel of undergraduates who at some point worked in a lab in the UMETRICS data. For each observation in the panel, we flag if the undergrad worked in any research lab. This allows us to observe if an undergrad who stops working in one lab is able to find work in another during their time in college. For each undergrad, we also flag if that student is ever paid on an account where the title of the account has the phrase "Federal Work Study." If so, we consider that student to be a Federal Work Study (FWS) student. Finally, we also flag if the student is female. This data is provided by UMETRICS and created through imputation based on the students' first names.

This panel dataset contains 200,168 observations. On average, as shown in Panel F of Table 1, 42% of the observations in this dataset are female undergrad RAs and 7% are FWS students. Across the dataset, in 44% of the observations then the student is paid by some lab at their university.

2.4 Minimum Wage Data

For each observation in the above described datasets, we attach the effective state minimum wage at that time. For each university in our dataset, we identified the effective minimum wage based on the geographic location of the university. The minimum wage data comes from Zipperer and Vaghul (2016). The effective minimum wage is defined as the maximum of the federal minimum wage and the minimum wage of the state in which the university is located.[9]

While the UMETRICS data does not provide salary information for individuals in our dataset, previous studies indicate that student employees at universities frequently earn minimum wage.[10] Indeed, minimum wage increases induce employers to switch to student and teenage employees (Lang and Kahn, 1998). Many staff positions at universities also receive minimum wage compensation. A

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[9] A university might have a different effective minimum wage because of a law passed at the sub-state level. For example, the city of Berkeley in California has its own local minimum wage. We ignore these minimum wage laws as the smaller the geographic level at which a law was passed, the more likely that it could potentially have been created for reasons endogenous to the productivity and employment levels at a particular university.

[10] FLSA actually allows students to be paid 15% less than minimum wage (Freeman, Gray and Ichniowski, 1981).

survey conducted by the College and University Professional Association for Human Resources of a select set of universities found that in 2018 approximately 15% of technical and paraprofessional staff at universities earned minimum wage (Brantley, 2021). Lastly, for undergraduate seeking employment, the minimum wage often determines the wages of jobs that could be alternative sources of employment relative to working as research assistants.

Some might still question if the wages of undergraduate research assistants are really affected by changes in the minimum wage. While our analysis in this paper leverages state minimum wage changes, we demonstrate that federal minimum wage changes appear to influence the wages of college students employed by universities by graphing the distribution of these workers' wages before and after a federal minimum wage from $6.55 in 2008 to $7.25 in 2009 using nationally representative data. Figure **??** plots the distribution of wages of employees at universities age 18 to 22 in both 2008 in blue and in 2010 in orange. Noticeably, the distribution shifts to right in 2010, with a clear decline in employees making below the mandated minimum wage. In addition, the distribution in 2010 shows bunching at or near the new mandated minimum wage level. This figure demonstrates that mandated minimum wage laws—even is those laws do not always cover undergraduate employees—still influence the wages paid to undergraduate research assistants.

In our analysis in this paper, we leverage state minimum wage changes, where state legislatures voted such changes into law. These changes are therefore exogenous to productivity or hiring decisions of individual research labs within universities. A change in the minimum wage is defined as any time that the effective minimum wage increases over the previous time period. We also focus in some of our analysis on "prominent minimum wage changes," which we define as when the effective minimum wage increases from one period to the next by a magnitude above the 75th percentile of minimum wage changes.

2.5 Descriptive Statistics

Figure 1 shows the effective minimum wage across universities in the sample. Figure A1 shows the distribution price changes that occur within our sample. Many changes are less than 5%, however, a small number of large changes of more than 20% also occur in our sample.

In addition to variation in the minimum wage level and minimum wage changes, there is considerable variation across universities in the timing of these changes. Figure A2 shows when minimum wage changes occur. The majority of these changes occur during the first quarter of the year, however, a bit under 40% of the minimum wage changes occur in other quarters. In Figure A3, the distribution of the length of time between minimum wage changes for universities is displayed. This plot shows that most universities have these changes occurring every year, however, some minimum wage levels are fixed for longer periods.

We show in Table 1 summary statistics for the attributes of the (lab, quarter) observations. Table 1 also shows summary stats of the annual level dataset.

Labs vary in the usage of workers of different occupational levels. In Figure A4, we show the distribution of the share of days of work that are undertaken by undergraduate employees. We also display this across labs in different scientific fields.

3 Empirical Strategy

Our empirical strategy uses a generalized difference-in-differences design to estimate the causal effect of the minimum wage changes. To identify the effects we exploit three types of variation: variation in the timing of the minimum wage changes across universities, variation in the magnitude of the changes across minimum wage increases, and variation in the exposure to minimum wage changes based on the intensity of employment of undergraduate research assistants across labs.

We use the following primary specification:

$$E[Y_{f,t}] = \sum_{j=-4}^{5} \gamma_j D^j_{f,t} + \mu_f + \mu_t + \delta \Omega_{f,t} + \epsilon_{f,t} \tag{1}$$

The dependent variable $Y_{f,t}$ is the outcome of interest of lab f in quarter t. The independent variables include $D^j_{f,t}$, which is a variable that takes the log-difference in the minimum wage j periods in the future. We bin the end points, so that all years outside of the event window are included in the endpoints. We also include fixed effects for the lab, μ_f, as well as the quarter μ_t. The variable $\Omega_{f,t}$ includes fixed effects for the time period before, during, and immediately following minimum wage changes of less than \$0.25. Following Cengiz et al. (2019), we include these controls as such small changes in the minimum wage are unlikely to impact labs like larger minimum wage changes.

As many of the primary outcomes of interest (number of undergraduate and graduate students, postdocs, and research staff employees working a lab) are discrete, we estimate Equation 1 using a Poisson model. In addition, because of the academic calendar, the effect of minimum wage changes is likely to evolve over the course of the subsequent year. Therefore, we estimate the effects of the minimum wage change over the four quarters after each change.

The event study estimates are useful for a variety of reasons. First, they help us trace the dynamic effects of the minimum wage change. Specifically, we can establish if the effects are level shifts in the outcome or dynamic changes. Second, they help us establish that the there are no pre-trends in the outcomes of interest.

Using the estimates of γ_j from Equation 1, we compute both the overall average effect on the levels of employment in a lab as well as the elasticity of demand for different types of labor. We calculate the change in the number of employed workers within a lab between time $t = -1$ and one year later by computing $\Delta Q = \overline{D} * \frac{1}{5}\sum_{j=-1}^{4}\gamma_j$. This equation has two components. The first is the average percentage change in the minimum wage across prominent changes in our dataset. The second is the average change in employment per quarter. This estimate reflects the percentage change in the employment of lab workers following an average minimum wage change.

Because the specification in Equation 1 is estimated with a Poisson model and the independent variables on the right hand side represent the percentage change when the minimum wage changes, we can also calculate the elasticity of the change in employment. For this calculation, we simply remove the scaling term: $\epsilon = \frac{1}{5}\sum_{j=-1}^{4}\gamma_j$

In addition to the event study approach, we also estimate a two-way fixed effects model. The specification is:

$$E[Y_{f,t}] = \beta \ln(mwage)_{f,t} + \mu_f + \mu_t + \delta\Omega_{f,t} + \epsilon_{f,t} \tag{2}$$

The parameter of interest in the above equation is β, which represents the average causal effect of an increase in the minimum wage on the outcome. While two-way fixed effects models have many challenges to their interpretation, we use this model for estimates of the effect of minimum wage changes on publications using our annual panel data.

There are a few threats to the causal interpretation of our analysis based on the above specifications.

First, the identifying assumption of the generalized difference-in-differences setup is that changes in employment for labs at universities that faced no minimum wage change or small minimum wage changes predict the counterfactual path for employment in labs at universities that faced larger minimum wage changes. If labs in states that had large minimum wage increases are systematically different than labs in states that had smaller or no minimum wage increases, then these groups may not be suitable counterfactuals.[11] Table A2 compares the attributes of labs that faced smaller and larger minimum wage changes over the course of our sample period. The results in that table demonstrate that the labs in these two groups appear similar on observables.

Second, if the minimum wage in a state is adjusted in response to the productivity or organizational changes within university labs, then the results would be biased due to endogeneity. This seems unlikely for a variety of reasons. Most of the universities studied in our sample make up a relatively small share of their respective state's overall employment. While some universities are located in cities or counties that have minimum wage rates that are distinct from their state minimum wage, for those universities, we perform our analysis using the state minimum wage.[12] This is because the state minimum wage is still likely to impact employment at university labs, and yet the state wage is less likely to be driven by employment at those universities.

Third, given that minimum wage changes occur in a staggered fashion across the labs in our data, one might wonder if the issues identified by Meer and West (2016) and Goodman-Bacon (2018), where negative weighting arises when treatment effects vary over time, are a factor in our analysis. Our empirical strategy is less prone to such concerns as we rely on a generalized difference-in-differences setup, which leverages both timing and magnitude of changes in the minimum wage for identification.

In addition, in order to address any concerns about the how the weights of the staggered setup may be impacting our results, we leverage the approach of de Chaisemartin and D'Haultfœuille (2020). The advantage of this approach is that it can account for when a minimum wage change multiple times by focusing on comparisons between the labs that experienced minimum wage change with those that did not in the same time period. Intuitively, along with the variation in the magnitude of the minimum wage changes, these are the comparisons that we wish to leverage for identification. One caveat is that this approach assumes that a lab's potential outcomes for a current change in the minimum wage does not depend on previous minimum wage changes, known as the "no carryover" assumption (Roth et al., 2023). This assumption, however, may not be restrictive in this context, since many decisions made by labs are on a short-term horizon: employment decisions likely revolve

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[11] For example, if states that implemented larger minimum wage changes also provided funding increases to university labs that exceeded the trajectory of those given to labs in states with smaller minimum wage changes.

[12] Berkeley, California is an example of a city with a sub-state minimum wage.

around the turnover of students within an academic year and grants last for limited period. Furthermore, we restrict our attention with regard to employment changes to the one year following minimum wage changes. Finally, the consistency of results across our empirical approaches and the additional leverage from utilizing variation in the magnitude of the minimum wage changes gives us confidence in the direction of the effects.

4 Results

4.1 Effect on Labor Demand

Figure 2A plots the event study coefficients from estimating Equation 1 around minimum wage changes. Each line represents the estimates when the dependent variable is the number of days that different types of labor (undergrad, graduate student, postdoc, and staff) are employed in labs. The plotted coefficients are scaled by the size of an average prominent minimum wage change (8.3%). In the quarters prior to the minimum wage change, the coefficients are not statistically distinguishable from the zero. In the quarters following the minimum wage change, the use of undergraduate labor declines significantly. For example, the coefficient for one quarter after a minimum wage translates to a 7.1% decrease in undergrad time.

In contrast, the use of graduate student time increases on average after the minimum wage change. Two quarters after a minimum wage change, the average lab increased their usage of graduate labor by 11%.

Postdoc labor remains largely flat during the time before and after the minimum wage change. Postdocs are typically paid according to rates set by a university or funding agencies, and postdocs tend to do work that is different from undergraduate research assistants in a lab. Therefore, it would be surprising if postdocs time changed during the time period after the minimum wage.

The figure demonstrates a number of important results. First, the flat pre-trends show that even though many minimum wage changes are known well in advance, PIs do not appear to make large adjustments in anticipation. Second, the effect of the minimum wage is primarily seen in the reduction of lowest paid workers, namely undergraduate research assistants and, to a lesser extent, research staff. Third, the small but visible increase in graduate student labor suggests possible substitution effects, with graduate students perhaps taking on more of the work that undergrads and research staff did previously following the minimum wage change.

Are labs reducing the amount of work they are giving to undergraduate research assistants or are labs decreasing the number of undergraduate workers they employ? Figure 2B plots the scaled coefficients from estimating Equation 1 with a dependent variable of the number of distinct workers employed in an occupation. Similar to Figure 2A, the plot demonstrates that the number of undergraduate employees declines during the year after the minimum wage change. In contrast, the number of graduate students trends upwards, although not significantly so in any quarter. This plot shows that a portion of the decrease in the days of work by undergraduates is coming from employing fewer undergraduates in labs.

The reduction in employment of undergraduate research assistants could be coming from changes on the intensive or extensive margins. On the intensive margin, labs with many undergrad workers might decide they get by with fewer RAs. On the extensive margin, smaller labs might decide to forgo hiring an undergrad RA at all. Which margin seems to explain the reduction in employees following the minimum wage change?

Figure 3 plots the scaled coefficients from Equation 1 when the dependent variable is an indicator for a lab employing at least one worker in an occupation and the equation is estimated via OLS. The line for employing an undergraduate shows a marked decline in the year following the minimum wage change. Specifically, a quarter after the minimum wage change, the probability of employing an undergraduate in a lab decreases by 2.8 percentage points relative to the quarter prior to the minimum wage change on average. The employment of graduate student workers ticks up slightly over the course of the same time period. The employment of postdocs and research staff again show little movement.

This figure demonstrates that a large portion of the effect on undergraduate labor derives from changes in labs that are on the margin of employing undergraduates. The pronounced decline in the probability of employing any undergraduates in this figure demonstrates that these labs, following the minimum wage change, did have even a single undergraduate worker.

The result that much of the movement comes from extensive margin changes is confirmed in Table 2. This table shows the estimates of ΔQ and ϵ when Equation 1 is estimated using a variety of dependent variables. Column (1) displays the results with the dependent variable of days of undergraduate employment, Column (2) shows the results from the number of distinct undergraduate employees, and Column (3) shows the results from the LPM model for if the lab employs at least one undergraduate. Column (4) estimates the equation using the number of days per employee who remain employed in the lab. Column (5) shows the results of the number of days of undergraduate employment for the labs that continue employing undergraduates after the minimum wage change. The significant and negative coefficients on Columns (1)-(3) and the insignificant coefficients on Columns (4) and (5) confirm the results from the previous figures. The majority of the movement following the minimum wage changes occur on the extensive margin, while the intensive changes are less pronounced.

4.2 Heterogeneity across labs

Which labs reduce their usage of undergraduate employees the most?

In Table 3, we explore the heterogeneous effects of the minimum wage changes by estimating Equation 1 on different types of labs. Columns (1) and (2) show the results for labs considered "not-intensive" and "intensive" in their usage of undergraduate research assistance, respectively. The estimated change in the use of undergrad time for the not-intensive labs is negligible and not significant, while the decrease in the usage of undergraduate labor for intensive labs is of similar magnitude to the overall effect previously estimated. This finding aligns with labs that heavily utilize undergrad time being more sensitive to changes in the labor cost, while labs with minimal or no usage of undergrad time largely ignoring the input price change.

In Columns (3) and (4), we restrict the sample to the fields of Biology and Physics & Engineering respectively, and in Columns (5) and (6), we restrict the sample to labs funded by NIH and NSF respectively. These estimates show that biology and labs funded by NIH are more sensitive to the change in the minimum wage, while NSF sponsored labs are less so. This could be because of differences in the way that undergrad work contributes to these labs or because of differences in funding agency policies regarding supplements and cost adjustments.

Columns (7) and (8) restrict to labs with grants that have fewer than two years of remaining expenditures to them and those labs with grants having more than two years left. The coefficient on the labs with less than two years remaining is not significant, while those with more than two years remaining are significant statistically and economically. The takeaway is that when you have little time left on a grant PIs do not make much of a change, but if they have more time left, they are more responsive.

4.3 Substitution to Graduate Labor

To what extent is there substitution with graduate student labor following minimum wage changes? In Table 4, we examine this by estimating Equation 1 using the number of days of graduate employment as the dependent variable. In Column (1), we find a positive and significant ΔQ, 0.068, indicating that indeed there is an uptick in the number of days of graduate work in labs following minimum wage changes. In contrast, Column (2) displays the results when regressing the number of distinct graduate students on the minimum wage changes. While we find a positive coefficient, the coefficient is not statistically significant. These results indicate that the time that grad students work in labs increase, but the number of distinct grad student employees does not change significantly. This is plausible since adjusting the number of grad students working in a lab is challenging in the short-run and likely to only occur at the beginning or end of an academic year.

In Columns (3)-(6), we estimate Equation 1 for the work of graduate students splitting our sample between universities with and without graduate student unions. We find that both sets of schools show the positive uptick in the use of graduate student labor following the minimum wage change. This is somewhat surprising as one might have expected that there would be less substitution to graduate labor for tasks that had previously been done by undergraduates in schools with unions, as collective bargaining agreements might protect graduate students from doing additional tasks. On the other hand, if universities with grad unions are also the universities in which graduate student workers more central to the work in labs then it is possible that the uptick simple reflects the importance of graduate students on those campuses.[13]

4.4 Robustness

Aspects of both the setting and the econometric specifications may influence the estimated effects. Therefore, in this section we demonstrate the robustness of our analysis.

First, funding for labs typically comes in the form of grants with set start and end dates. If minimum wage changes occur around the same time when the grants supporting labs expire this could create a spurious correlation between minimum wage changes and the decline in employment in a lab.

In Table 5, we add a control variable to Equation 1 indicating if one of the grants funding a lab was in its final quarter. This will account for whether a lab is winding down one of its grants. Column (1)-(3) demonstrates that the estimates with this additional control are similar to those found in Table 2. Thus, it is unlikely that the life-cycle of funding for labs is driving this result.

Second, it is possible that different universities had different patterns regarding employment. For

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[13] Appendix Table A6 displays the mean attributes of lab x quarter observations for labs at universities with and without graduate student unions.

example, it is possible that some universities were increasing their involvement of undergraduate students in research labs while other universities might have been shifting away from using undergraduate RAs. If minimum wage changes correlated systematically with these patterns, we may get biased estimates of the effect of the minimum wage changes on employment. Therefore, in Columns (4)-(6), we add in separate time trends for each university. We do that in addition to including the fixed effect for the lab having a grant ending in a quarter. The results are not fundamentally different.

Third, recent insights into staggered difference-in-difference models have revealed the need to carefully understand the heterogeneity across events when interpreting the results of TWFE and event study models (Meer and West, 2016; Roth et al., 2023). While our main analysis, using Equation 1, is not a typical difference-in-difference, since it utilizes both the variation in the timing and the magnitude of the minimum wage changes, we nevertheless take steps to check the robustness of our findings.

In order to address concerns about how these varying weights might impact our estimates, we re-estimate our main effects using the procedure of de Chaisemartin and D'Haultfœuille (2020) (hereafter DCDH). Because the DCDH procedure results have only been probed using OLS regressions, we use this procedure with dependent variables of inverse hyperbolic sine (IHS) transformed number of days of undergraduate labor, IHS transformed number of undergraduate workers, and an indicator for if a lab employed at least one undergraduate worker. In addition, following the advice of Roth (2024), we use long-differences for both pre-treatment and post-treatment in order to make the event study plot similarly interpretable to one from a TWFE.

The estimated coefficients on the leads and lags from this procedure are plotted in Figure 4. The point estimates are also listed in Table 6. While the estimated effects are less precisely estimated, the general pattern remains. In the quarters prior to the minimum wage change, the estimates are close to zero. In the quarters following the minimum wage change, the estimates shift to be consistently below zero although not always statistically significant.

Lastly, lab level analysis may obscure the changes going on at the project level. While we do our main analysis at the lab-level, as we assume that PIs have some ability to use funding from one project for other projects, if our mapping of grants to labs is incorrect it may impact the estimated treatment effect. In order to demonstrate that this is not a concern, we re-run our main analysis using grant-by-quarter panel as well. The results of this analysis is shown in Table 7. The estimates in this table show as similar pattern to the lab-level analysis and reinforce that the lab definitions do not drive the estimated impact of the minimum wage changes on lab-level employment outcomes.

We take these robustness checks to be reassuring that our findings are not driven by the empirical framework or the life-cycle of sponsored research funding.

4.5 Scientific Productivity

The previous sections establish that changes in the minimum wages can have significant effects on the employment of undergraduate research assistants and research staff. In this section, we explore what impact those labor cost changes ultimately have on the production of scientific research. Because it is challenging to associate a scientific publication with the specific quarter in which the scientific work was done, we estimate the models in this section using lab-by-year data.

Table 8 shows the estimates of Equation 2 when the dependent variable is the number of publications associated with the lab in a year.[14] Column (1) uses the number of WoS publications associated to the lab in the year, Column (2) uses the number of PubMed Publications, and Column (3) uses the citation-weighted number of WoS Publications in the year using 5 year forward citations. Across all of the specifications, the coefficients are negative, small, and not statistically significant.

We believe that this implies that while there may be some small adjustment cost due to the change in the minimum wage, the effect on scientific production is likely to be minor. More research—requiring more data—will be required to understand if the change in the personnel working in the lab also impacts the direction of research projects undertaken.

4.6 Aggregate Effects and Relocation

The effect of minimum wage changes on labs will depend in part on the extent to which labs can get more funding to offset the input cost increase caused by the minimum wage increases or relocate some of the work of their lab to labs of collaborators in other states with lower wages. In this section, we examine the extent to which there is evidence that PIs are taking either of these actions.

In Table 9, Column (1), we estimate Equation 1 with a dependent variable of the number of grants that a lab has funding it in a quarter. Column (2) estimates the same equation with a dependent variable of if the lab started receiving funding from a new grant as the outcome via OLS. Column (3) estimates the same equation but with a dependent variable of the log-total dollars of spending by the lab. Across all three specifications, the estimated coefficients are not significant. This implies that in the short-run, PIs are not increasing the number of distinct funding sources that they have or the total

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[14] Note that we use Equation 2 rather than Equation 1 here because we do this analysis at the annual level.

amount of funding that they have to spend.

Column (4) of Table 9 shows the estimates from a linear probability model with a dependent variable of if the lab has funding from a grant labeled as a supplement. Lab PIs may be able to request supplementary funds from certain funding agencies because of additional scientific work that they wish to conduct or in order to handle increased costs. The positive and significant coefficient, while small, is economically significant. The coefficient implies 0.2 percentage-points increase (or about 10% higher relative to the sample mean) in the probability of having supplementary grant funding for the lab.

Column (7) repeats this analysis for the sub-sample of labs that are funded by NIH grants. NIH specifically allows grantees to apply for supplements of up to 10% of their grant amount under certain conditions. The estimated coefficient on the probability of a supplement in the quarters following the minimum wage change increases by 0.5 percentage points or about 25% relative to the sample mean.

We also test if PIs are relocating the scientific work for their lab to collaborators in other states when the minimum wage increases in their state. We test for this in Column (5) by examining if the total amount of dollars subawarded (provided from a primary grant to a collaborator) increases follow a minimum wage change. We find a negative and insignificant coefficient.

We also test if the subaward money is more likely to be sent to labs in locations with lower minimum wage levels following a minimum wage change. For this analysis, we use a dependent variable of the dollars of subaward funds weighted by the minimum wage in the state for which the subaward is being sent. If the coefficient on this was negative that would indicate that subaward dollars are being sent to places with lower minimum wage rates. Column (6) shows the estimated coefficient, which is again, not significant.

We interpret these results to mean that PIs either have limited options in changing their subaward allocation after the start of their awards or are not using this mechanism in the short-run.

4.7 Reallocation

In this section, we explore movement of workers across labs in response to the minimum wages changes. The recent minimum wage literature has pointed to such “reallocation" effects as an important mechanism by which labor markets adjust to the higher wages facing employers, by re-allocating labor to the higher productivity firms (Dustmann et al., 2021). In this case, since undergraduate research assistants are both labor inputs and an output of the lab, the expected effects on reallocation are more ambiguous. If minimum wage changes affect which labs employ undergraduate research assistants, it might change the experience and training that these individuals receive. If the most productive labs are the first to cut undergraduate research assistants because they are focused solely on production and not training, then the experience of undergraduates who continue to work in labs will be different than if the high productivity labs continued to employ undergraduates.

Our previous results demonstrated that following a minimum wage increase, labs decreased their use of undergraduate labor. In this section, leveraging our unique dataset on all sponsored research at the universities in our sample, we examine if those undergraduates find other opportunities to be involved in research activities. Table 10 shows the estimates from Equation 2 using data from our undergraduate panel. The dependent variable is an indicator for if the undergraduate is employed in any lab in our sample. The independent variable is an indicator for if the university that the undergrad attends experienced a minimum wage change. The regressions also include fixed effects for each individual undergraduate as well as their cohort, defined as the first year that we observe that student being employed in our data.

Table 10 Column (1) shows that the probability of being employed in a lab decreases by 2.7 percentage points or 6.14% relative to the mean of the sample. In Column (2), we include controls for the experience of the undergraduate in a lab, which we measure as the number of prior quarters that the undergrad has been employed in a lab. We also include the interaction of the minimum wage change and the experience of the undergrad. These estimates show that students with more experience are less likely to be employed. The reason for this negative association is because we do not observe when the student graduates; Therefore, in the later observations, the student is less likely to be employed as they are more likely to have already graduated. The interaction term between experience and a minimum wage change is positive. This implies that undergraduates with more experience working in scientific research are also more likely to continue working in labs.

In Column (3), we include an interaction term between a minimum wage occurring and the undergraduate being female. The interaction term tells us if female undergraduates leave research assistant positions at a differential rate following the minimum wage changes. The estimated coefficient is small and not significant implying that the effect on the rate of working in a lab is similar for men and women undergraduates.

Column (4) includes an interaction term with the undergraduate student having ever been paid on an account associated with Federal Work-Study (FWS) students. The interaction term is positive and significant implying that FWS students may be more likely to continue working as research assistants even after a minimum wage change. This could be because FWS subsidizes the cost to research labs.

For students who remain employed in a lab, they may not remain in the same lab. Dustmann et al. (2021) demonstrated that workers reallocated towards higher productivity firms following minimum wage increases. We explore a similar dynamic within universities. Specifically, we examine if the students who remain employed tend to work in higher productivity labs.

To operationalize this, for students employed in a lab, we estimate Equation 2 with the dependent variable to be the number of publications in PubMed produced each year in the lab employing the student. As before, we include fixed effects for the individual student and the cohort year.

Column (5) displays the estimates. The positive coefficient on the minimum wage changing indicates that students who remain employed work in labs that produce more papers per year than the labs that they worked in prior to the minimum wage change. This could indicate that students who continue working in labs find their way towards higher productivity labs or that the labs that continue hiring students after a minimum wage increase tend to be the more productive labs.

These results highlight that the impact of the minimum wage changes on the exposure of undergraduate students to scientific research is both significant and not uniform. First, labs are less likely to employ RAs, but the undergrad students are also less likely to find other labs to work in too. Second, minimum wage changes are more likely to impact students early in their undergrad years than those with more experience. Third, students from FWS backgrounds may be less impacted, which implies that students from less affluent backgrounds are not being differentially negatively impacted. This loss in exposure to scientific labs, however, may impact career choices later.

5 Conclusions

In this paper we have estimated the elasticity of academic scientists for lab personnel using rich administrative data from thousands of research labs facing price changes due to state minimum wage law changes.

We find that scientists employ fewer undergraduates and research staff in response to minimum wage changes, particularly those employing more undergraduates and research previously, and slightly increase their use of graduate students. We further investigated whether there were reallocation effects in which labs undergraduate research assistants were working in after minimum wage changes. Finally, we examined whether PIs changed the location of their subawards in response to minimum wage changes, but found no significant effects.

Our results demonstrate that even small changes in the cost of labor can have significant impacts on the employment of trainee researchers, such as undergraduate research assistants. This reduction in employment also means a reduction in the undergraduate students being exposed to scientific research, which may influence career choices in the future.

What would it cost to avoid the reduction in employment of undergraduate research assistants? We perform a rough estimate of this cost by considering how much labor costs would have increased for the undergraduate research assistants whose employment was reduced following the minimum wage changes. Specifically, we multiply the increase in the minimum wage by the estimated average reduction in undergraduate days of work. We assume that the average undergraduate research assistant works 4 hours per day of employment.[15] Finally, we multiply this average number of hours by the number of labs in our dataset.

The results of this back-of-the-envelope calculation shows that for funding agencies to compensate all labs for the minimum wage increase for all of their undergraduate research assistants, the total cost would be on the order of \$10.04 million per year. For funding agencies to compensate only the labs for the share of undergraduate labor that typically declines following a minimum wage increase, the total would be approximately \$2.32 million per year. In 2019, the universities in our sample enrolled approximately 1 million undergraduate students in 2019. The total number of undergraduate students enrolled in U.S. universities in that year was 15 million. Assuming similar rates of students participating research across all universities in the country, the total cost to compensate for all the undergrad research assistants may be on the order of \$150 million per year.

While these figures seems small relative to the total budgets of U.S. scientific funding agencies, our results demonstrate that even relatively small changes in the labor costs of labs can have sizeable impacts. Given the uncertainty of changes in the cost of labor, our results point to the need for insurance mechanisms or increased budget flexibility by funders and university administrators. Universities seeking to provide undergraduates with research experience should consider providing faculty with alternate funding sources that are in line with minimum wage levels.

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[15] We got this figure through a FOIA request of one large university in our sample.

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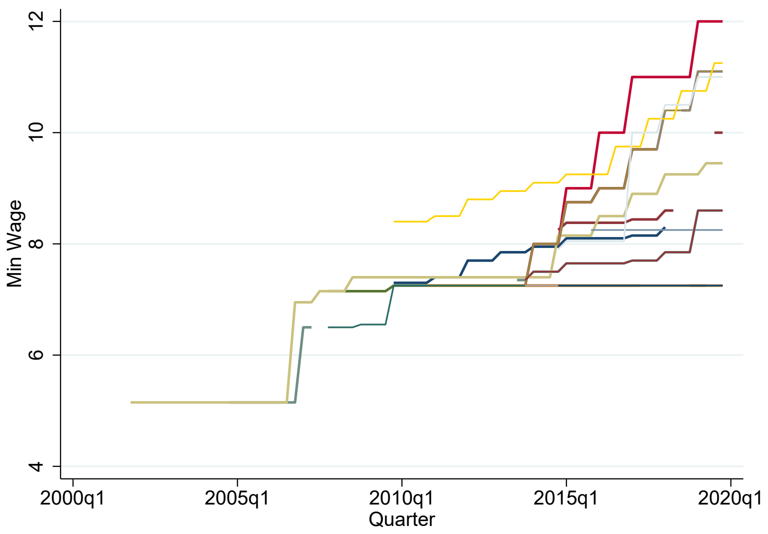
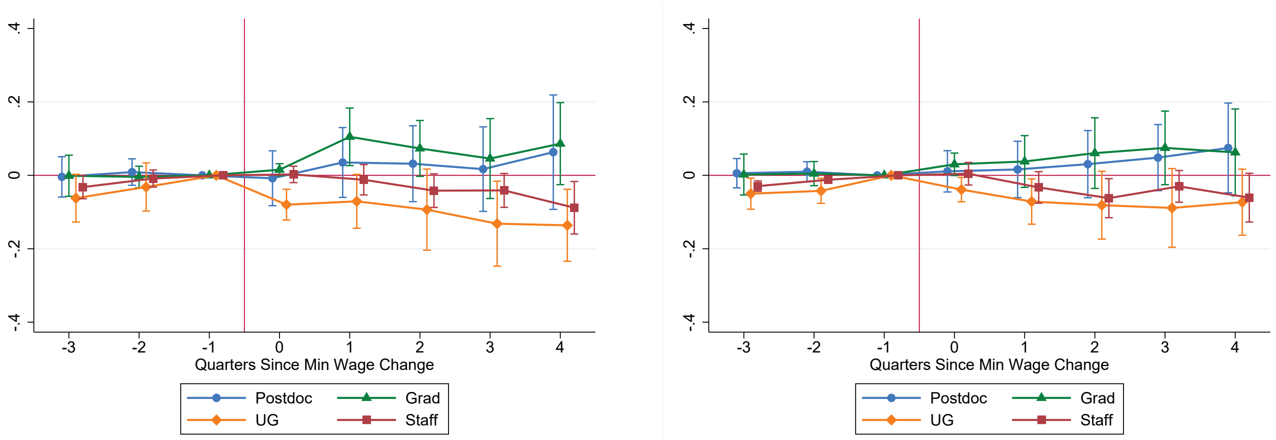
6 Figures and Tables

Figure 1: Minimum Wage Levels at Universities in Sample



Note: The above figure shows the minimum wage in each quarter at the universities in our sample. Each line in the graph represents one of the universities in the sample.

Figure 2: Main Effects Poisson Regressions

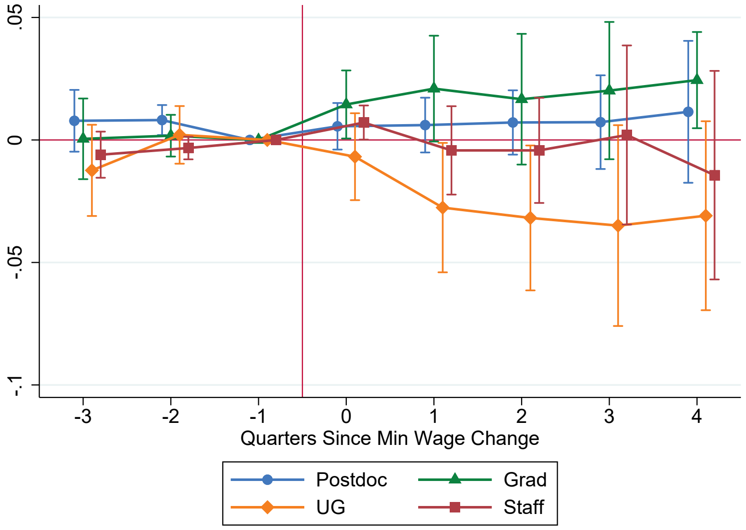


(A) Employee Days

(B) Distinct Employees

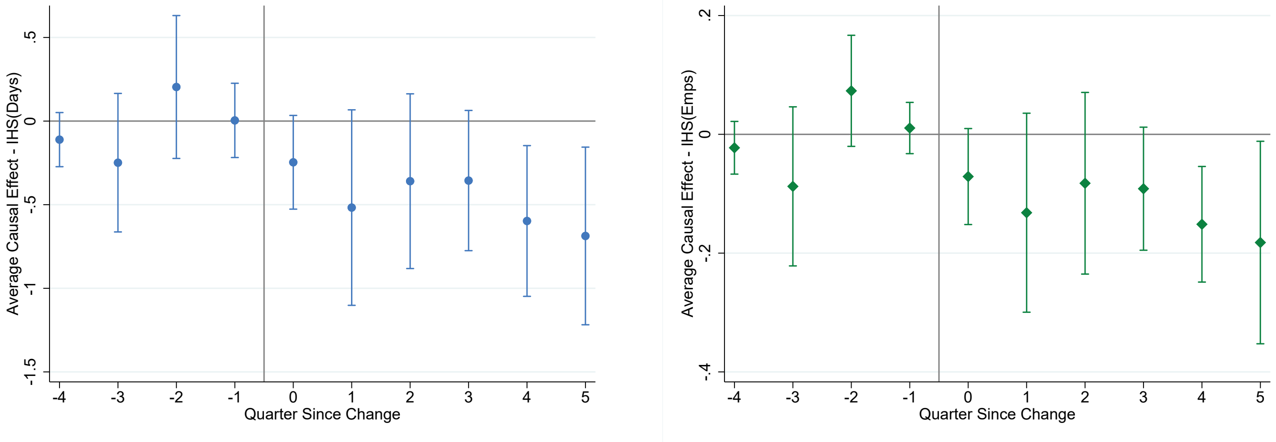
Note: The above figures plot the estimated coefficients from Equation 1 using a Poisson model and data from the Lab x Quarter Panel. In Figure (a), the dependent variable is the number of days of employment. In Figure (b), the dependent variable is the number of distinct employees working in the lab in each quarter. Both of these figures plot the coefficients from estimating the equation separately by type of worker.

Figure 3: Probability of Employing Worker



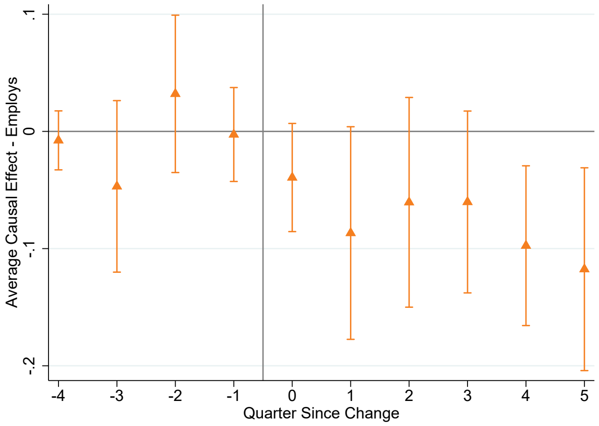
Note: The above figures plot the estimated coefficients from Equation 1 using OLS and data from the Lab x Quarter Panel. The dependent variable is whether or not the lab employed at least one employee of each type of labor. The figure plots the coefficients from estimating the equation separately by type of worker.

Figure 4: Staggered DiD Estimates Using de Chaisemartin and D'Haultfœuille (2020) Method



(A) Employee Days

(B) Distinct Employees



(C) Employed

Note: The above figures plots the estimated coefficients from estimating the de Chaisemartin and D'Haultfœuille (2020) procedure on observations from the Lab x Quarter Panel. In Figure (a), the dependent variable is the IHS transformed number of days of undergraduate employment in a lab. In Figure (b), the dependent variable is the IHS transformed number of distinct undergraduate employees working in a lab. In Figure (c), the dependent variable is an indicator for the employment of at least one undergraduate employee in a lab.

Table 1: Mean Attributes of Observations in Dataset

	Mean	P25	P50	P75
Panel A: Labs (N=11,182)				
PI Female	0.22	0.00	0.00	0.00
PI Age	47.84	39.72	47.00	55.33
Grants	2.20	1.17	1.78	2.70
Direct Expend	100,852.53	36,620.19	68,329.47	120,804.45
Vendor Spend	13,572.46	2,050.98	6,061.11	14,746.73
Postdocs	0.58	0.00	0.22	0.80
Grads	1.69	0.30	1.10	2.30
UGs	1.14	0.25	0.63	1.33
Staff	2.80	0.50	1.59	3.47
Panel B: Lab x Quarter (N=264,136)				
PI Female	0.21	0.00	0.00	0.00
PI Age	48.45	41.00	48.00	56.00
Grants	2.47	1.00	2.00	3.00
Direct Expend	112,570.30	29,164.21	65,466.60	134,062.20
Vendor Spend	15,581.74	200.00	3,471.71	13,817.06
Postdocs	0.65	0.00	0.00	1.00
Grads	1.88	0.00	1.00	3.00
UGs	1.18	0.00	0.00	1.00
Staff	3.42	0.00	2.00	4.00
Panel C: Grant x Quarter (N=382,485)				
Direct Expend	67,060.36	10,410.24	25,750.68	57,364.00
Vendor Spend	8,598.89	0.00	468.61	4,544.66
Postdocs	0.34	0.00	0.00	0.00
Grads	1.14	0.00	0.00	1.00
UGs	1.76	0.00	1.00	1.00
Staff	2.29	0.00	1.00	2.00
Panel D: Lab x Year (N=188,633)				
WoS Publications	0.98	0.00	0.00	0.00
PubMed Publications	3.92	1.00	2.00	4.00
5 Year Citations	18.71	0.00	0.00	0.00
Panel E: UGs (N=25,021)				
Female	0.42	0.00	0.00	1.00
Age	21.34	18.75	20.25	22.75
Fed Work-Study	0.07	0.00	0.00	0.00
Employed in Lab	0.44	0.25	0.38	0.63
Panel F: UG X Quarter (N=200,168)				
Female	0.42	0.00	0.00	1.00
Age	21.34	19.00	20.00	23.00
Fed Work-Study	0.07	0.00	0.00	0.00
Employed in Lab	0.44	0.00	0.00	1.00

Note: The above table provides summary statistics for the variables from across the various datasets used in our analysis.

Table 2: Effect of Minimum Wage Changes on the Employment of Undergraduates

	(1) Emp. Days Poisson	(2) Emps. Poisson	(3) Employ OLS	(4) Days/Emp OLS	(5) Intensive Poisson
ΔQ	-0.102***	-0.071*	-0.026**	-0.014	-0.052
	(0.040)	(0.037)	(0.013)	(0.014)	(0.036)
ϵ	-1.230***	-0.849*	-0.318**	-0.171	-0.641
	(0.477)	(0.445)	(0.159)	(0.179)	(0.451)
N	264136	264136	264136	112984	112984
N Labs	11182	11182	11182	10315	10315
Lab FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	No	No
R2	0.54	0.39	0.32	0.37	0.60
Dep. Mean	86.16	1.18	0.43	4.20	200.85

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 using data from the Lab x Quarter Panel. In Column (1), the dependent variable is the number of days of undergraduate employment in labs estimated using a Poisson model. In Column (2), the dependent variable is the number of distinct undergraduates employed in labs estimated using a Poisson model. In Column (3), the dependent variable is an indicator for the lab employing at least one undergraduate estimated using OLS. In Column (4), the dependent variable is the log-transformed number of days per employed undergraduate in labs that employed at least one undergraduate estimated using OLS. In Column (5), the dependent variable is the number of days of undergraduate employment in labs that employed at least one undergraduate estimated using a Poisson model.

Table 3: Heterogeneous Effects of Minimum Wage Changes on the Employment of Undergraduates

	Emp. Days UG							
	(1) UG Not Intense	(2) UG Intense	(3) Bio	(4) Physics & Eng.	(5) NIH	(6) NSF	(7) <2	(8) >2
ΔQ	0.016	-0.169***	-0.132**	0.039	-0.139***	-0.084	-0.128**	-0.080***
	(0.074)	(0.058)	(0.054)	(0.110)	(0.053)	(0.054)	(0.061)	(0.030)
ϵ	0.186	-2.151***	-1.528**	0.469	-1.605***	-1.096	-1.676**	-0.894***
	(0.884)	(0.744)	(0.628)	(1.308)	(0.617)	(0.707)	(0.799)	(0.331)
N	119906	86133	146218	25927	141510	71337	124631	115714
N Labs	5204	4060	6392	854	6269	3582	9691	7538
Lab FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	No	No	No	No	No
R2	0.46	0.50	0.56	0.57	0.56	0.56	0.54	0.60
Dep. Mean	49.60	163.68	87.20	94.20	87.97	99.02	82.83	107.14

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 with a dependent variable of the number of undergraduate days of employment using Poisson on sub-samples of data from the Lab x Quarter Panel. Column (1) estimates this using labs that do not intensively employ undergrads. Column (2) estimates this using labs that do intensively employ undergrads. Column (3) estimates this using labs in the fields of biology and medicine. Column (3) estimates this using labs in the fields of physics and engineering. Column (5) and (6) estimates this using labs with funding from the NIH and NSF respectively. Column (7) and (8) estimates this using labs with grants that have less than 2 years remaining and more than 2 years remaining respectively.

Table 4: Effect of Minimum Wage Changes on Graduate Student Employment

	All		No Union		Unionized	
	(1) Emp. Days Grad Poisson	(2) Emps. Grad Poisson	(3) Emp. Days Grad Poisson	(4) Emps. Grad Poisson	(5) Emp. Days Grad Poisson	(6) Emps. Grad Poisson
ΔQ	0.068**	0.056	0.144*	0.108*	0.094**	0.117***
	(0.033)	(0.040)	(0.077)	(0.064)	(0.040)	(0.036)
ϵ	0.782**	0.638	1.416*	1.069*	1.134**	1.418***
	(0.379)	(0.463)	(0.763)	(0.632)	(0.489)	(0.440)
N	228535	228621	91005	91033	137530	137588
N Labs	9402	9407	4568	4570	4834	4837
Lab FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	No	No	No
R2	0.62	0.39	0.61	0.37	0.62	0.40
Dep. Mean	173.55	2.11	179.71	2.23	169.48	2.03

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 using Poisson on sub-samples of data from the Lab x Quarter Panel. Column (1) and Column (2) estimate with the dependent variable of the days of employment of grad students and the number of distinct grad students employed in labs across the full dataset. In Columns (3) and (4), we repeat these estimates on the sample of labs at universities without a graduate student union. In Columns (5) and (6), we repeat these estimates on the sample of labs at universities with graduate student unions.

Table 5: Employment Effects With Grant Life-cycle Controls

	Last Qtr FE			Time Trends		
	(1) Emp. Days Poisson	(2) Emps. Poisson	(3) Employ OLS	(4) Emp. Days Poisson	(5) Emps. Poisson	(6) Employ OLS
ΔQ	-0.102***	-0.071*	-0.026**	-0.093***	-0.068*	-0.031**
	(0.040)	(0.037)	(0.013)	(0.046)	(0.039)	(0.013)
ϵ	-1.230***	-0.850*	-0.318**	-1.114***	-0.824***	-0.377**
	(0.477)	(0.445)	(0.159)	(0.558)	(0.475)	(0.160)
N	264136	264136	264136	264136	264136	264136
N Labs	11182	11182	11182	11182	11182	11182
Lab FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	Yes	Yes	Yes
R2	0.54	0.39	0.32	0.54	0.39	0.33
Dep. Mean	86.16	1.18	0.43	81.69	1.18	0.43

Standard errors in parentheses

* $p < 0.10$), ** $p < 0.05$), *** $p < 0.01$)

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 using data from the Lab x Quarter Panel. In Column (1), the dependent variable is the number of days of undergraduate employment in labs estimated using a Poisson model. In Column (2), the dependent variable is the number of distinct undergraduates employed in labs estimated using a Poisson model. In Column (3), the dependent variable is an indicator for the lab employing at least one undergraduate estimated using OLS. In all columns, we include a fixed effect for if the lab had a grant which stopped being charged in that quarter. In addition, in columns (4)-(6), we include institution by quarter time trends.

Table 6: Effect of Minimum Wage Changes on Undergraduate Employment Using de Chaisemartin and D'Haultfœuille (2020) Procedure

	(1) IHS(Days)	(2) IHS(Emps)	(3) Employs
$t = 5$	-0.687**	-0.182**	-0.118***
	(0.271)	(0.087)	(0.044)
$t = 4$	-0.597***	-0.151***	-0.098***
	(0.230)	(0.050)	(0.035)
$t = 3$	-0.356*	-0.092*	-0.060
	(0.214)	(0.053)	(0.040)
$t = 2$	-0.359	-0.082	-0.061
	(0.267)	(0.078)	(0.046)
$t = 1$	-0.517*	-0.132	-0.087*
	(0.298)	(0.085)	(0.046)
$t = 0$	-0.247*	-0.071*	-0.039*
	(0.143)	(0.041)	(0.024)
$t = -1$	0.004	0.011	-0.003
	(0.113)	(0.022)	(0.020)
$t = -2$	0.204	0.073	0.032
	(0.218)	(0.048)	(0.034)
$t = -3$	-0.249	-0.088	-0.047
	(0.211)	(0.068)	(0.037)
$t = -4$	-0.111	-0.023	-0.008
	(0.083)	(0.023)	(0.013)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above table displays the estimated coefficients from estimating the de Chaisemartin and D'Haultfœuille (2020) procedure on observations from the Lab x Quarter Panel. In Column (1), we use the dependent variable of the IHS transformed number of days of undergrad work. In Column (1), we use the dependent variable of the IHS transformed number of undergraduates working in the lab. In Column (3), we use the dependent variable of an indicator for the lab employing at least one undergraduate.

Table 7: Grant-Level Analysis

	All			NIH Grants		
	(1) Emp. Days Poisson	(2) Emps. Poisson	(3) Employ OLS	(4) Emp. Days Poisson	(5) Emps. Poisson	(6) Employ OLS
ΔQ	-0.091***	-0.057**	-0.022**	-0.091**	-0.063	-0.039***
	(0.021)	(0.028)	(0.010)	(0.037)	(0.042)	(0.013)
ϵ	-1.155***	-0.722**	-0.281**	-1.106**	-0.764	-0.475***
	(0.269)	(0.348)	(0.128)	(0.442)	(0.503)	(0.158)
N	183262	183262	183262	71808	71808	71808
N Labs	17694	17694	17694	7408	7408	7408
Lab FE	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	No	No	No
R2	0.56	0.36	0.35	0.58	0.37	0.37
Dep. Mean	70.68	1.00	0.48	76.32	1.05	0.51

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 using data from the Grant x Quarter Panel. In Column (1), the dependent variable is the number of days of undergraduate employment charged to a grant estimated using a Poisson model. In Column (2), the dependent variable is the number of distinct undergraduates charged to a grant estimated using a Poisson model. In Column (3), the dependent variable is an indicator for a grant employing at least one undergraduate estimated using OLS.

Table 8: Effect of Minimum Wage Changes on Scientific Paper Production

	(1) WoS Publications Poisson	(2) PubMed Publications Poisson	(3) 5 Year Citations Poisson
Ln(MWage)	-0.330	-0.044	-0.401
	(0.560)	(0.400)	(0.946)
N	28659	55446	23938
N Labs	11182	11182	11182
Lab FE	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
R2	0.75	0.64	0.79
Dep. Mean	1.19	4.48	18.50

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the estimated coefficients from estimating Equation 2 using a Poisson model and data from the Lab x Year Panel. In Column (1), the dependent variable is the number of publications linked to grants from the lab published in the year and linked to Web of Science. In Column (2), the dependent variable is the number of publications linked to grants from the lab published in the year and linked to PubMed. In Column (3), the dependent variable is the number of publications linked to grants from the lab published in the year and linked to Web of Science and weighted by the number of citations to those publications in the five years after publication.

Table 9: Aggregate Effects of Minimum Wage Changes

	All						NIH Funded
	(1) Grants Poisson	(2) New Grant OLS	(3) Spending OLS	(4) Supplement OLS	(5) Subaward Poisson	(6) Min Wage (wt) Poisson	(7) Supplement OLS
ΔQ	-0.004	-0.014	-0.013	0.002^{***}	-0.101	0.001	0.005^{***}
	(0.012)	(0.015)	(0.022)	(0.000)	(0.135)	(0.058)	(0.001)
ϵ	-0.051	-0.166	-0.155	0.019^{***}	-1.214	0.012	0.054^{***}
	(0.146)	(0.182)	(0.267)	(0.006)	(1.622)	(0.702)	(0.014)
N	264136	264136	264136	264136	142701	139118	143458
N Labs	11182	11182	11182	11182	5367	5224	6452
Lab FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inst Trends	No	No	No	No	No	No	No
R2	0.21	0.14	0.50	0.48	0.59	0.31	0.47
Dep. Mean	2.47	0.19	10.97	0.02	26,941.47	3.74	0.02

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above tables displays the ΔQ and ϵ estimates based on estimating Equation 1 using data from the Lab x Quarter Panel. Column (1) uses a dependent variable of the number grants being charged by a lab in a quarter and Poisson. Column (2) uses a dependent variable of an indicator for the lab charging a new grant starting in that quarter and OLS. Column (3) uses a dependent variable of the log transformed direct expenditures of a lab and OLS. Column (4) uses a dependent variable of an indicator for the lab charging a supplement starting in that quarter and OLS. Column (5) uses a dependent variable of the total amount of subaward dollars associated with a lab in a quarter and Possion. Column (6) uses a dependent variable of the total amount of subaward dollars associated with a lab in a quarter weighted by the minimum wage in the state where the subaward is being sent and Possion. Column (7) uses a dependent variable of an indicator for the lab charging a supplement starting in that quarter and OLS using the subset of labs funded by NIH.

Table 10: Effect of Minimum Wage Changes on Undergraduates Working in Labs

	UG-Lab Panel				
	(1) Employed OLS	(2) Employed OLS	(3) Employed OLS	(4) Employed OLS	(5) PubMed Pubs OLS
Min Wage Change	-0.027*	-0.081***	-0.015**	-0.023**	0.180*
	(0.015)	(0.012)	(0.005)	(0.008)	(0.090)
Experience		-0.063***	-0.057***	-0.057***	
		(0.014)	(0.013)	(0.013)	
Min Wage Change x Experience		0.022***			
		(0.005)			
Min Wage Change x Female			-0.003		
			(0.010)		
Min Wage Change x FWS				0.076***	
				(0.019)	
N	200168	200168	200168	200168	80589
N UGs	25021	25021	25021	25021	19706
UG FE	Yes	Yes	Yes	Yes	Yes
Cohort FE	Yes	Yes	Yes	Yes	Yes
R2	0.61	0.62	0.62	0.62	0.93
Dep. Mean	0.44	0.44	0.44	0.44	4.29
F-stat	3.36	76.64	63.70	35.79	4.01

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: The above table shows the estimates from OLS regressions on an indicator for the minimum wage changing using observations from the Undergraduate x Quarter Panel. Across all the columns, the dependent variable is an indicator for the undergrad being employed in a lab. Experience is measured as the number of quarters in which the undergrad was previously employed. FWS is an indicator for the undergrad having ever been paid on a Federal Work-Study account in our dataset.