Shocks to the System: The Effects of Variation in State Appropriations on Faculty Labor Markets

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Abstract

Higher education is a labor intensive industry, with doctorate-level faculty serving as a primary input and expenditure item. While public and private universities compete in the national (or international) market for faculty, public universities face substantial volatility in funding from state appropriations, which may impact their capacity to hire and provide raises that align compensation with productivity. This paper answers two main questions about the relationship between faculty labor markets and state appropriations. First, do changes in state appropriations affect the level and distribution of salary and employment of faculty at public universities? And second, do the changes in appropriations differentially impact faculty of particular academic fields, ranks, income levels, and genders?

By assembling longitudinal data on faculty salaries from 12 public research universities, I find that state appropriations, in general, are positively correlated with faculty salaries, department size, hiring levels, and the proportion of faculty who continue employment at their university from year to year. However, the magnitudes of response through these outcome variables vary across three main levels. First, there is significant variation in the level of response across academic disciplines, which is likely driven by differential likelihoods of outside offers. Second, there is variation in the level of response by baseline income. After controlling for rank and field, I find that individuals at the bottom of the salary distribution face far more cyclicality in their earnings levels than those at the top. Third, there is evidence of variation in response by gender, which relates to differences in mobility. As a consequence of each of these sources of variation, negative appropriations shocks may exacerbate inequality in compensation that is plausibly tied to mobility and market frictions, rather than productivity.

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1 Introduction

Higher education is a labor intensive industry, with doctorate-level faculty serving as a primary input and expenditure item. Particularly among research universities across the private and public sector, the faculty labor market operates at a national (if not international) scale and level of integration. Public universities, unlike private universities, rely on appropriations from state governments to fund their labor costs. The volatility of state appropriations may impact the capacity of public universities to hire faculty and grant raises.

There are many factors that make the national faculty labor market interesting and unusual. First, the tenure system is largely unique to universities, which makes it difficult for universities to adjust to budget shocks by shedding labor. Second, faculty cannot be substituted across academic disciplines as a means of adjustment to changes in market prices (a history professor is not a substitute for an economics professor). Third, "superstars" are highly valued; the most productive professors in terms of research output are substantially more "valuable"[1] to a university than the average faculty member.[2] Put together, in combination with the fact that funding for public universities is largely determined by state appropriations, the faculty labor market presents an unique setting for this labor market study.

While work has been done on the impacts of declining appropriations on both tuition pricing (Baum, Braga, McPherson, & Minton, 2018) and student outcomes (Bound, Braga, Khanna, & Turner, 2019), the effect of declining appropriations on faculty labor markets is yet to be fully examined. Unlike previous studies of state appropriations, the assembly of longitudinal data on faculty salaries allows this research to observe changes over time in compensation for individuals

[1]Research superstars are valuable in the context of their capacity to raise external research funding and to the extent that research productivity is part of the university objective function. Yet, it should be noted that there are many faculty who bring substantial value in terms of tuition revenue to the university.

[2]Kwiek (2015) finds that the top 10 percent of academics provide approximately half of all academic publications. These top 10 percent likely produce an even greater proportion of total citations.

at the level of the field and department. This paper answers two main questions regarding faculty labor markets and state appropriations. First, do changes in state appropriations affect the level and distribution of salary and employment of faculty at public universities? And second, do the changes in appropriations differentially impact faculty of particular academic fields, ranks, income levels, and genders?

One might expect that appropriations shocks vary in their impact across academic fields because the outside markets and opportunities for obtaining competing job offers vary markedly by discipline. Notably, faculty in computer science, economics, engineering, and other high demand fields may have greater potential to secure offers from other institutions, and therefore a greater ability to leverage outside offers in salary negotiations. The threat of outside offers is less prominent in other fields. Whether or not differences in market options by academic field actually impact how departments respond to changes in their salary pool is not well-understood. In addition to field-level variation, differences in the level of outside offers and presence of market frictions by rank, research productivity, baseline income, and gender may impact labor market responses to state appropriations. Faculty quantity, rank, and relative productivity have clear impacts on student outcomes and research output, all of which may be impacted by appropriations shocks (Bettinger & Long, 2004; Carrell & West, 2010). Developing an understanding as to how appropriations differentially impact faculty in various categories should provide insight into how declining appropriations affect students and knowledge creation.

I show that state appropriations, in general, are positively correlated with faculty salaries, department size, hiring levels, and the proportion of faculty who continue employment at their university from year to year. However, this analysis finds that the magnitudes of response through these outcome variables vary across three main levels. First, there is significant variation in the level of response across academic fields, which is likely driven by differential likelihoods of outside offers. Second, there is variation in the level of response by baseline income. After controlling for rank and field, I find that individuals at the bottom of the salary distribution face far more cyclicality in their earnings levels than those at the top. Third, there is evidence of variation in response by gender, which relates to differences in mobility. Much of the gender-based variation in response to appropriations is concentrated in the economics field. In response to a 10 percent increase in appropriations, salaries for women in economics increase by 3.39 percentage points more than for men on average. Through these sources of variation, negative appropriations shocks exacerbate inequality in compensation that is plausibly tied to mobility based market frictions, rather than productivity.

The rest of this paper proceeds as follows. The first section of this analysis presents the background and research context regarding both faculty labor markets and state appropriations to public universities. The second section introduces a theoretical framework of salary determination for faculty at public universities. The third section describes the data used in this analysis, and presents descriptive statistics. The fourth section outlines the empirical strategy used to test the proposed theoretical framewor. The fifth section will discuss my results. I conclude by considering the implications of my results, in addition to discussing the future work to be done on this topic.

2 Research Context

Economists and policy experts in higher education have devoted considerable research attention to the distinct topics of faculty labor markets and public funding of higher education. Yet, little work has been done to bridge the gap between the two.

2.1 Faculty Labor Markets

Overall earnings inequality among full-time, instructional, tenured and tenure-track faculty at four-year institutions is rising. Between-university heterogeneity and within-university differences between faculty at the same institution have combined to contribute to the rising inequality in faculty labor markets (Monks, 2003).

Between-university inequality, particularly between public and private universities, has risen over recent years. Salaries for faculty at public institutions are generally lower than salaries at private institutions. Ehrenberg (2003) argues that the decline of salaries for faculty at public universities relative to faculty at private universities can be attributed primarily to private institutions' tuition levels rising by more than public tuition levels. Between-university differences in budgetary factors also contribute to this inequality. Differences in endowment per student between public and private universities contribute to the dispersion of salaries between private universities, while differences in the distribution of state appropriations contribute to the dispersion of salaries between public universities.

Nonetheless, a substantial portion of the rising inequality is due to the within-university differences of faculty by field and rank. Residual inequality, which may be tied to research and teaching productivity levels, has also increased. Table 1 demonstrates the growing disparities of faculty salaries by field. Variation of average salaries between faculty in different academic disciplines has significantly increased over time. In addition, within a given discipline, there exists variation by rank. Ehrenberg (2004) shows that salary variation is greatest among full professors and smallest among assistant professors. This phenomenon is likely due to the fact that assistant professors are generally more mobile, and the fact that their entry level salaries more accurately reflect market conditions.

Mobility is a critical component of faculty salaries, as those with greater geographic mobility

Table 1: *Percentage difference between average full professor salary and the average salary for a full professor of English, by field, 1980-81 to 2009-10*

Discipline	1980-81	1985-86	1991-92	1996-97	2001-2	2005-6	2009-10
All-discipline Average	0.048	0.051	0.133	0.139	0.122	0.120	0.134
Fine Arts	-0.088	-0.096	-0.079	-0.097	-0.111	-0.122	-0.124
Education	-0.040	-0.080	-0.012	-0.008	-0.025	-0.038	-0.043
Foreign Languages	0.009	-0.018	-0.015	0.005	-0.039	-0.045	-0.041
Communications	-0.033	-0.067	0.026	0.019	-0.029	-0.033	-0.032
Philosophy	0.023	-0.048	0.020	0.011	-0.029	0.000	0.021
Library Science	-0.015	-0.006	0.099	0.066	0.035	-0.021	0.036
Mathematics	0.076	0.044	0.110	0.115	0.068	0.068	0.072
Psychology	0.050	0.016	0.095	0.097	0.083	0.090	0.089
Physical Sciences	0.077	0.080	0.149	0.145	0.128	0.121	0.129
Social Sciences	0.048	0.032	0.090	0.087	0.092	0.141	0.168
Health Sciences	0.203	0.198	0.343	0.364	0.313	0.181	0.189
Engineering	0.081	0.143	0.290	0.278	0.240	0.243	0.252
Computer Science	0.134	0.176	0.322	0.281	0.287	0.275	0.284
Economics	0.139	0.113	0.284	0.257	0.264	0.324	0.412
Business	0.114	0.152	0.338	0.387	0.408	0.465	0.509
Law	0.332	0.410	0.542	0.584	0.535	0.540	0.595

Note: All-discipline average includes medical faculty. Source: American Association of University Professors.

have more opportunities to seek outside offers. Faculty with high moving costs will tend to have greater seniority and lower pay if their employer has the ability to price discriminate in salary setting (Ransom, 1993). Institutional seniority is generally negatively correlated with wages, because those faculty who tend to stay with the same employer for an extended period of time are those with high moving costs and limited outside offers.

Outside offers are a crucial determinant of salaries and raises. Universities employ an "implicit peer review strategy" by using outside offers to initiate nonstandard pay raises for faculty (Siow, 1998). This implicit peer review strategy can explain the inverse correlation between wages and institutional seniority. Moore, Newman, and Turnbull (1998) show that after controlling for publication quality, this inverse correlation becomes significantly weaker. In effect, the measure of research quality closely matches the effect of outside offers which is consistent with the implicit peer review strategy and the fact that pay raises are largely given in response to outside offers. This mechanism of assigning raises in response to outside offers favors faculty with the highest productivity levels and the greatest mobility. Favoring mobility has the potential to discriminate against women (compared to men with similar characteristics); women are more likely to face family or dual-career issues that tie them to local labor markets. The presence of a gender promotions gap and the within-rank gender pay gap can at least be partially explained by the fact that men receive more outside offers than women with comparable productivity levels (Blackaby, Booth, & Frank, 2005).[3]

2.2 Appropriations

It has been well documented that state appropriations have, in general, been declining over recent years. Bound et al. (2019) document this trend by showing that real appropriations per full-time equivalent student have decreased over time at AAU universities, research universities, and non-research universities. The authors also document both the cyclicality of state appropriations and the heterogeneity of appropriations levels between states. Some states, such as Minnesota, Pennsylvania, and Wisconsin have experienced very significant declines in state appropriations over time, while others, such as Texas and New York, have remained stable. Declines are, as expected, exacerbated in times of recession. The heterogeneity of appropriations over both locality and time allows researchers to study the impact of appropriations shocks on higher education outcome variables.

State governments often target higher education funding for spending cuts in times of need. Higher education is the third-largest component of state spending, only behind K-12 education and health care. However, spending on higher education is relatively free of federal mandates and matching requirements, which cannot be said of K-12 education and health care. Therefore, governments have greater relative flexibility in cutting appropriations to public universities (Barr

[3] Before this publication, Booth, Francesconi, and Frank (2003) actually find that men and women receive promotions at similar rates, but show that women receive smaller subsequent pay raises upon promotion.

& Turner, 2013).[4] Because state appropriations to mandatory spending are a source of budget flexibility, there tends to be greater variation in appropriations spending compared to other mandatory spending categories.

Demand for higher education significantly increased in the 2008 recession, as evidenced by a rise in total enrollment from from 18.2 million to 21 million between fall 2007 and fall 2010.[5] At the same time, Barr and Turner (2013) find that a 5-point increase in the unemployment rate results in a 20 percent reduction in appropriations for higher education, including stimulus funds. This combination of increased demand and decreased funding through non-tuition revenue presents a constraint to education quality. Although universities may attempt to dampen the shocks to their total budget by increasing tuition revenue, the authors conclude that declines in appropriations are unlikely to be fully recovered through increased tuition outside of the most selective research universities.

Bound et al. (2019) find that a 10 percent decrease in state appropriations leads to a 3.6 percent decrease in bachelor's degrees awards, and a 7.2 percent decrease in doctoral degrees awarded. The magnitude of this effect is smaller at larger research universities that have the ability to increase tuition and/or attract greater numbers of out-of-state and international students, although the effect is still statistically greater than zero. They also document that at research institutions, universities reduced funding toward instructional resources and support services when appropriations declines could not be replaced by other sources.

Shocks to resources during the 2008 recession did in fact have negative impacts on both

[4] Johnson, Oliff, and Williams (2011) document that states do cut funding to higher education more frequently than to K-12 education or health care in response to budget cuts. In addition, Kane, Gunter, and Orszag (2003) and Kane, Orszag, and Apostolov (2005) provide evidence of increased Medicaid spending crowding out state higher education funding, which leads to negative effects on higher education quality. However, Bound et al. (2019) come to different conclusions and argue that Medicaid spending does not explain variation in state appropriations.

[5] This data comes from Snyder and Dillow (2012). Much of this enrollment expansion occurs outside of the research sector. Enrollment at two-year colleges and community colleges is the largest driver of the expansion.

salaries and tenure-track hiring. Using evidence from job-postings, Turner (2013) finds that the recession led to sharp contraction in hiring activity. This research serves as the primary evidence of the negative impact of appropriations changes on faculty employment activity. Declining appropriations risk harming research output and program quality, which in turn has the potential to negatively impact the supply of skilled laborers. My research adds to this literature through the novel use of individual-level faculty data to study a wider time series beyond the 2008 recession.

By studying the differential impact of appropriations on faculty labor markets, this paper aims to develop an understanding of the mechanisms through which appropriations declines impact a university's utility function. If appropriations declines vary in their impact on faculty by field, rank, productivity level, or gender, then appropriations shocks could impact the skilled labor force and academic research output in unforeseen ways. With the rising within-university inequality in faculty salaries documented in Monks (2003), and the clear evidence of declining appropriations, examining the interaction between these phenomena is an important contribution to the overall research on higher-education financing. Given that appropriations to public universities will continue to vary with state financial constraints which may well be magnified in the years following the COVID-19 pandemic, understanding determinants of salary setting may provide an opportunity for universities to better align compensation and hiring with individual productivity and university objectives.

3 A Theoretical Framework of Salary Determination

This section will discuss a general framework of salary determination, and propose a set of hypotheses regarding how faculty salaries at public universities are affected by shocks to state appropriations.

Faculty labor markets are unique in many ways, and operate distinctly from standard labor markets. First, rather than maximizing profit, universities are in the business of creating knowledge. In academic research, quantity is not necessarily a substitute for quality; one professor who consistently produces groundbreaking research may be more valuable to a university than multiple professors of average ability.[6] Faculty labor markets share many features of the "superstars" model (Rosen, 1981). This model applies to jobs where small numbers of people earn large levels of income and dominate their fields. The main implication of this model is that technological changes allow for the best performers in a given field to increase their relative productivity and reap a greater share of revenue. In the market for professors, both labor market competition and technological changes exacerbate within-university wage inequality.

Second, the tenure system is largely unique to universities, which makes firing relatively unlikely.[7] Therefore, declines in appropriations are likely to be manifested through salary and reductions in hiring, rather than through exit.

Third, the market is segmented by academic field - an economics professor is not a substitute for a history professor. Therefore, factors such as monopsony power and the supply of labor vary by field. Furthermore, the benefits that result from hiring faculty in one department generally do not spill over into other departments. For example, hiring a new history professor provides little utility to the economics department at the same university.

Fourth, universities compete for faculty on a national scale. For example, the University of North Carolina competes with the University of Wisconsin for the hiring of faculty, despite the difference in geography. The heterogeneity of university characteristics plays a role in competition, and therefore salary is not necessarily the only determinant in a decision between

[6] Hamermesh, Johnson, and Weisbrod (1982) find that research quality and influence on other research is more influential than quantity with regards to salary levels by showing that an additional reference adds more to salary than does the publication of another book or article.

[7] K-12 educators also can achieve effective tenure.

multiple offers. Factors such as available resources, peer effects, prestige, and opportunities for career advancement play an important role in the decision-making process. However, while competition is national, appropriations are distributed on a state-by-state basis (Goolsbee & Syverson, 2019). Public universities generally lack control over their funding, which is determined by state governments. Therefore, the effect of state appropriations on the national market can be studied by treating appropriations shocks as exogenous.

Finally, certain aspects of monopsony and matching models apply. This monopsony setting follows from the dynamic monopsony models proposed in Manning (2003). In these models, firms have some wage-setting power, even in the presence of many competitors, due to search frictions and/or high levels of differentiation. There are reasons to believe that individual universities play some role in setting wages, in combination with competitive market forces. Labor market frictions such as search costs and moving costs provide the university with some level of market power over their faculty. Due to these labor market frictions, even if a faculty member receives an outside offer greater than their current salary, it may not be in their best interest to leave. This mechanism grants universities with some ability to compensate faculty below their market competitive wage.

3.1 How Universities Offer Wages to Faculty

I assume that universities maximize a function of student outcomes and research output, subject to a budget constraint. In this sense, research universities maximize an objective function that is distinct from profit maximization. Following from papers like Bound et al. (2019) and Epple, Romano, Sarpca, Sieg, and Zaber (2019), I assume the university maximizes a function of student achievement a, research output o:

$$U = f(a, o) \tag{1}$$

A public university's budget constraint is a function of state appropriations A, tuition revenue TR, grants G, and donations D:

$$F = A + TR + G + D \tag{2}$$

Universities can increase their total funding through increases of each these four variables. Most commonly, in order to keep F constant when A is declining, universities attempt to increase TR by either increasing tuition costs or recruiting greater numbers of out of state and international students who pay higher tuition rates (Bound et al., 2019). These efforts do not necessarily increase tuition revenues enough to completely match appropriations declines, and the success of the response is generally greater at larger research institutions (Baum et al., 2018). While it is important to keep this fact in mind, this model will hold the number of students and tuition revenues constant in order to isolate the effects of appropriations.

In this model, a key variable is the department-level budget at school s in academic field f in year t. This budget, b_{sft}, is a fraction (α_{fs}) of the university's total funding such that $b_{sft} = F_{st}\alpha_{fs}$. Through F, changes in appropriations impact each department's budget, which departments use to allocate salaries and hire faculty. In the current iteration of this framework, the fraction α_{fs} is assumed to remain constant. This is an assumption that could be relaxed in a future iteration.

Universities have monopsony power in faculty wage setting, leading to some salaries operating below competitive levels due to frictions in the market (Ransom, 1993). Consider an individual faculty member, i. This individual may have high teaching quality and research output, but earns below their competitive wage due to the presence of market frictions. In year $t = 0$, the offered wage for individual i at school s in academic field f is $w_{isf0} = W_{isf} - \delta m_{isf}$, where W_{isf} is the individual's competitive wage, m_{isf} the individual's moving costs, search costs, etc., and δ is a discount factor (making δm_{isf} the annualized costs of moving). These three variables (W_{isf}, m_{isf}, and δ) are assumed to be constant over time for individual i. I also assume that dollar values are constant.

In year $t = 1$ individual i may be offered a raise, R_{isf1}, such that $w_{isf1} = w_{isf0}R_{isf1}$. The availability and value of this raise is dependent on the growth or decay of the department's budget and the likelihood of an outside offer. I denote $R_{isft} = R(B_{sft}, L_{isft})$, where $B_{sft} = \frac{b_{sft} - b_{sf[t-1]}}{b_{sf[t-1]}}$ is the percentage change in the department's budget from $t - 1$ to t, and L_{isft} represents the likelihood of individual i receiving an outside offer in year t. The likelihood of an outside offer is a function of the percentage difference between one's wage and their competitive wage, $\frac{W_{isf} - w_{isf[t-1]}}{w_{isf[t-1]}}$. This is scaled by two factors. First, γ_{sft} captures field-level differences in hiring activity. Fields where outside job offers to faculty are more frequent have higher values of γ_{sft}. Outside options are determinant of faculty salaries, and their external pressure creates salary differences across fields that continue to grow (Hearn, 1999). Second, η_{isf} captures individual i's desirability as an outside hire, which is closely tied to their productivity level and competitive wage. Because aspects of the superstars model apply, the most productive faculty have the most outside options, all else equal. Because both of these factors positively impact the likelihood of an outside offer, I choose to model the likelihood of a future outside offer as $L_{isft} = \gamma_{sft}\eta_{isf}\frac{W_{isf} - w_{isf[t-1]}}{w_{isf[t-1]}}$.

Consider the case where $\forall t, B_{sft} = \frac{b_{sft} - b_{sf[t-1]}}{b_{sf[t-1]}} \geq 0$. A plausible model for R_{isft} is then:

$$R(B_{sft}, W_{isf}, w_{isf[t-1]}, \gamma_{sft}, \eta_{isf}) = \gamma_{sft}\eta_{isft}B_{sft}\frac{W_{isf} - w_{isf[t-1]}}{w_{isf[t-1]}} + 1 \tag{3}$$

By construction, the offered raise will be zero ($R = 1$) when any one of the following circumstances prevails: (i) the individual already receives a competitive wage, (ii) there is no likelihood of an outside offer, or (iii) there is no change in the department's budget.

Using the above, I construct a two period model with an increasing budget. I assume that competitive wages and moving costs are constant between periods. Note that in period $t = 0$, wages are below competitive levels for some faculty. While newly hired professors generally receive wages at competitive levels, these professors do not necessarily receive immediate raises to match any increases in productivity. This model starts in a period where productivity exceeds wages due to market frictions, and where competitive wages are constant thereafter.

$$w_{isf0} = W_{isf} - \delta m_{isf} \tag{4}$$

$$w_{isf1} = w_{isf0}\left(\gamma_{sf1}\eta_{isf}B_{sf1}\frac{W_{isf} - w_{isf0}}{w_{isf0}} + 1\right) \tag{5}$$

Plugging the first equation into the second equation and taking the derivative with respect to B_{sf1} yields the comparative statics result in equation (7).

$$w_{isf1} = (W_{isf} - \delta m_{isf})\left(\gamma_{sf1}\eta_{isf}B_{sf1}\frac{\delta m_{isf}}{W_{isf} - \delta m_{isf}} + 1\right) \tag{6}$$

$$\frac{\partial w_{isf1}}{\partial B_{sf1}} = \gamma_{sf1}\eta_{isf}\delta m_{isf} \tag{7}$$

This shows that the effect of budget levels on wages is positively related to the likelihood of outside offers, research and teaching productivity, and the gap between offered wages and competitive wages.

Extending this analysis to period t, I get

$$w_{isft} = (W_{isf} - \delta m_{isf}) \prod_{j=1}^{t} \left(\gamma_{sfj} B_{sfj} \frac{W_{isf} - w_{isf[j-1]}}{w_{isf[j-1]}} + 1 \right) \tag{8}$$

Holding previous year's budgets constant, it is apparent that the response of wages to the budget is positively related to γ_{sft}, η_{isf}, and $\frac{W_{isf} - w_{isf[j-1]}}{w_{isf[j-1]}}$. As the gap between one's wage and their competitive wages closes, the effect of the budget on wages decreases.

In reality, budgets decrease, but faculty cannot receive "negative raises."[8] Therefore, a model in the general case is:

$$w_{isft} = (W_{isf} - \delta_{isf} m_{isf}) \prod_{j=1}^{t} max \left\{ \gamma_{sfj} \eta_{isf} B_{sfj} \frac{W_{isf} - w_{isf[j-1]}}{w_{isf[j-1]}} + 1, 1 \right\} \tag{9}$$

Over time as t increases, wages approach the competitive wage. The rate at which this done varies with W, δm, γ, and η_{isf}.[9]

[8] In real terms, wages may decrease from year to year. Nominal wages generally do not decrease.

[9] Because of the tenure-system, faculty who experience productivity declines and as a result earn above their competitive wage cannot be fired. If productivity decreases in year t, then $W_{isf} - w_{isf[t-1]} < 0$, which leads to $R_{isft} = 1$ (which indicates no raise).

3.2 Allocating Salaries Within Departments

A department is able to offer a different salary to each individual faculty member. With some uncertainty about a professor's willingness to move in response to a wage offer, the expected cost to a department for a specific wage offer is:

$$EC(w_{isft}) = p(w_{isft}, W_{isf}, m_{isf}, \gamma_{sft}, \eta_{isf})w_{isft} + [1 - p(w_{isft}, W_{isf}, m_{isf}, \gamma_{sft}, \eta_{isf})]W_{isf} \quad (10)$$

The individual wage offer w_{isft} is determined by equation (9). Here, $p()$ represents the probability of a given faculty member accepting an offered wage, and is a function of the offered wage, the competitive wage, moving costs, and γ_{sft}. A plausible structure for p is:

$$p(w_{isft}, W_{isf}, m_{isf}, \gamma_{sft}, \eta_{isf}) = p\left(\frac{1}{\gamma_{sft}\eta_{isf}}[w_{isft} - W_{isf} + \delta m_{isf}]\right) \quad (11)$$

The closer one's wage offer is to their competitive wage, the more likely he or she will be to accept the wage offer. Those with higher moving costs will be more likely to accept any given wage offer as well. In addition, faculty who are more productive or who are in fields with greater outside options are less likely to accept a given wage offer, all else equal. I assume that the function $p()$ is continuous, nonnegative, and monotonically increasing in w_{isft}.[10]

Due to the tenure system, exit largely stems from faculty opting to leave in the presence of an outside offer. One's offered wage, which is dependent on the department's budget, is a driver of the probability of staying. If B_{sft} decreases, w_{isft} stays constant and becomes lower relative to comparable faculty at other universities. The availability of funds at other universities relative to funds at school s increases the value of γ_{sft}, which captures the field-level differences in the

[10] The basis of this portion of the model follows from Ransom (1993).

likelihood of outside offers.[11] Changes in γ_{sft} connect budgetary changes to the $p()$, and in turn, the department's expected cost for a given wage offer. Decreases in $p()$ imply that faculty are more likely to choose to exit in response to an outside offer. Decreases in $p()$ also imply that $1 - p()$, the probability of receiving an increase in wage to W_{isf} in response to an outside offer, increases. Therefore, if $p()$ decreases due to changes in γ_{sft}, the expected cost of retaining said employee increases, and the department is more likely to have to choose between allowing their faculty member to leave for another offer, or increase their wage to W_{isf}.[12]

If the department opts to allow individual i to leave instead of increasing their wage to W_{isf}, then they will likely increase their hiring market activity. Assuming that universities must keep a constant level of faculty to meet student needs, then if a faculty member i leaves, the university must hire a replacement. Universities will hire a new faculty member, where the expected cost of the new hire is $EC(Hire_t) = W_{hire} + c_{hire}$. Here, c_{hire} represents the economic costs of search and hiring. Universities will opt to hire if $EC(Hire_t) < W_{isf}$, which implies that new hires will generally earn less and be of lower rank than the exiting faculty. In the long-run, departments will smooth their faculty size through the hiring market by hiring new candidates when others accept outside offers. However, hiring takes time. Therefore, in the short-run when departments have yet to adjust, decreases in appropriations may decrease department size.

This framework of department-level behavior suggests that appropriations will positively impact the number of faculty who continue their employment from one year to the next, and negatively impact the frequency of exits. These relationships are driven through $p()$. Further, the model suggests that department size should be positively correlated with appropriation levels in

[11] This relationship can be shown by solving for γ in equation 5, which finds that $\gamma_{sf1} = \frac{w_{isf1} - w_{isf0}}{B_{sf1}(W_{isf} - w_{isf0})}$. The budget has an inverse relationship with γ_{sft}.

[12] Note that in this framework, the money for retention cases comes outside of b_{sft}. I assume that universities have limited funds on reserve to retain faculty if needed. Departments face a tradeoff between dipping into scarce reserves to retain faculty and allowing them to leave. Excess budgets for retention cases are exogenous.

the short run before universities can adjust through the labor market.

This framework may be expanded upon in future iterations by relaxing certain assumptions. First, this framework assumes that α_{fs}, the fraction of a university's funding distributed to the department in field f, is constant throughout time. In reality, this fraction may vary with student demand. By relaxing this assumption and allowing this fraction to vary, one may be able to analyze the interaction between appropriations and changes in student preference. Second, I hold market level wages, W_{ifs}, constant. Allowing this value to experience exogenous shocks throughout time would add another dimension to the model. For example, one may ask what happens when someone who already earns far below their competitive wage experiences another large productivity increase. Third, this model does not entirely explain variation on the hiring margin. While it does address hiring as a mechanism to replace exiting faculty, it does not necessarily account for field-level variation in new tenure-track hires. Hiring promising assistant professors has future benefits beyond period t, and accounting for this fact in a department's decision-making process may be an additional layer to this framework. Lastly, this framework does not account for efforts to dampen appropriations shocks through efforts to increase tuition revenue. The schools who can achieve this the are likely more successful in retaining their faculty and are more competitive in the hiring market.

3.3 Predictions from the Proposed Framework

This framework of salary determination leads to several predictions regarding the effect of state appropriations on faculty at public universities. In general, the framework shows that appropriations should be positively correlated with salary levels, the frequency of raises, department size, and the number of individuals who accept their wage offer and continue with their employment. It also shows that appropriations should be negatively correlated with retention cases. However, the framework also suggests that the magnitude of the effect of appropriations on these outcome variables should differ among variables such as academic field, rank, productivity level, and gender.

Given the notable differences in the level of outside options and salary levels by field, this model explains why departments and faculty in different fields respond differently to appropriations. These differences are captured through γ_{sft}, which is increasing in the level of outside options in a given field. Given the comparative statics result in equation (7), the model predicts that faculty in fields with greater frequencies of outside offers are more sensitive to changes in appropriations when moving from period $t = 0$ to $t = 1$. However, in these same fields, wages approach W at a greater rate than others (see equation (9)). As offered wages approach the competitive wage, the effect of an increasing budget on salary levels weakens.

So, in fields with high values of γ_{sft}, faculty who earn below their competitive salary will approach W_{isf} quickly. In the long run, faculty in these fields will have relatively low values of $\frac{W_{isf}-w_{isf[t-1]}}{w_{isf[t-1]}}$, which diminishes the effect of appropriations shocks on salary. In general, faculty salaries in these fields will be less sensitive to changes in their department's budget, due to the fact that their wages are more likely to closely match their productivity.

Within departments, faculty vary by rank and productivity level. The theoretical framework explains how expected research and teaching productivity is a key component in the level of responses of faculty salaries to appropriations shocks. While productivity levels are often unobservable, universities attempt to estimate expected productivity by measuring factors such as publications, citations, perceived research quality, and even baseline income. Higher expected productivity leads to more outside offers, which is captured through η_{isf}. By having a positive impact on offered wages, η_{isf} dictates the extent to which salaries approximate one's competitive wage. Through equation (9), the closeness of offered wages to competitive wages leads to appropriations having a weaker impact on faculty with higher productivity levels. On the flip side, those with lower productivity who fall in the lower regions of the income distribution will experience stronger responses to appropriations due to the gap between their salary and their competitive wage, and a higher probability of accepting a wage offer below W_{isf}. As a result, this framework predicts that the salary variance within a given department is negatively correlated to appropriations.

Even if productivity, field, and rank are held constant, gender-based frictions in the labor market may impact the level of a university's monopsony power over certain faculty. If frictional factors that stem from geographical mobility and family constraints are stronger for women, then compared to men, women will be less likely to command a raise to match any increases market value.

Factors that impact geographic mobility for women include motherhood, family ties, and societal norms regarding a woman's household role. Because women are expected to be more restricted than men in terms of in geographical mobility, this framework hypothesizes that salaries for female faculty are more sensitive to appropriations shocks. In the proposed model, this effect is captured through differences in m_{isf}. If a given faculty member has a greater value of m_{isf} than others, their difference between w_{isf0} and W_{isf} will be greater, all else equal. Therefore, given the result in equation (7), salaries for women are predicted to be more sensitive to appropriations than salaries for men in the short-run. If women do face more earnings cyclicality than men, then the wage gap between men and women should widen in a recession with negative appropriations shocks. However, the difference in level response between men and women may vary along the income distribution or across fields due to the other mechanisms that impact responses to appropriations.

4 Data and Descriptive Statistics

In this analysis, I use data from 12 public research universities that were able to provide information on individual faculty salaries, field, and rank for the years of 2010-2017.

4.1 Data Sources

To provide an empirical test of the theoretical prediction, this paper uses individual-level salary data accessed from public universities through Freedom of Information Act (FOIA) requests.[13] The data used were obtained either through direct correspondence with public university personnel, or through previously published data sets.[14] The individual-level data, with fields for name, job title, school, field, salary, and year were used to generate a set of outcome variables for individual i in field f at school s in year t. I also utilize a name-to-gender algorithm to predict gender for each individual name. This process is done for all schools in my data set except for the University of Connecticut, who did not provide faculty names. Details of this process are provided in Appendix A. This project also makes use of data on state appropriations over time, made available by the Integrated Post-secondary Education Data System (IPEDS).

Tenure-track faculty - those with ranks of assistant, associate, and full professor - are the primary focus of this analysis. This research focuses on data between 2010 and 2017, as those are the years captured in both the institution-level salary data and the IPEDS measures of state appropriations. Moreover, the data is limited in scope to four-year public institutions, as the model of labor market competition in four-year colleges is of primary interest.

[13] The FOIA requires the full or partial disclosure of previously unreleased information and documents controlled by United States governments upon request

[14] Data collection was a byproduct of research assistant work for Sarah Turner on "Postdoctoral Researchers: The Impact of Labor Regulations and Visa Policy" (with John Bound, University of Michigan).

Table 2: *School characteristics, 2010-2017.*

School	Observations	Mean Salary	Median Salary	US News 2020
University of Connecticut	2,559	113,263	101,320	64
Florida State	7,258	96,298	91,227	57
University of Georgia	2,311	97,066	90,311	50
Univerisity of Iowa	2,622	96,767	91,145	84
Univerisity of Maryland	2,877	133,689	125,060	64
Univerisity of Michigan	4,362	123,356	120,496	25
Univerisity of Nebraska	2,406	96,266	87,512	139
Ohio State	3,544	107,577	97,598	54
Texas A&M	4,218	109,618	100,043	70
University of North Carolina	3,910	123,162	113,913	29
Virgnia Tech	2,647	98,772	90,107	74
Univerisity of Wisconsin	3,081	120,322	110,324	46

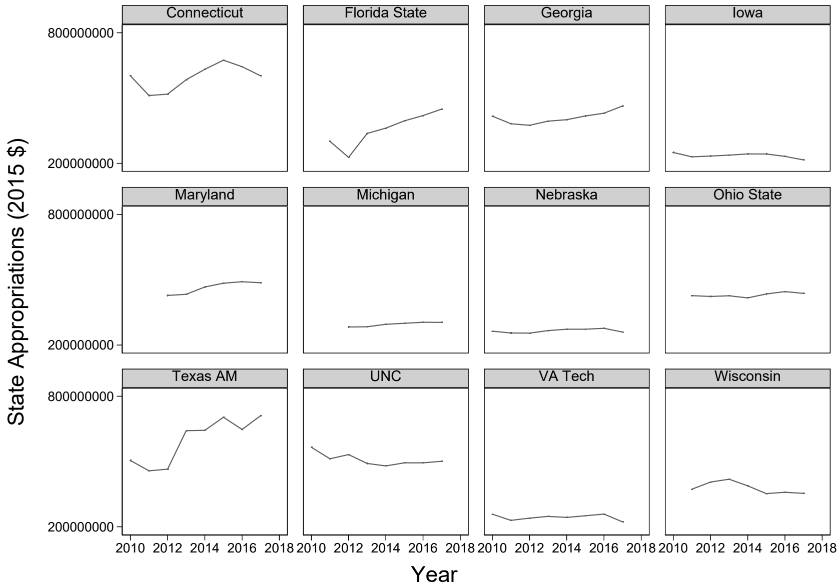
Note: Observations refer to the total number of observations for the years 2010-2017. Salaries are adjusted to 2015 dollars. US news rankings refer to the US News and World Report's "Best National Universities" ranking, which includes both public and private colleges. Note that the data from Michigan and Maryland only span 2012-2017, rather than 2010-2017.

4.2 Descriptive Statistics

Given the availability of data, in addition to the need to restrict the analysis to schools that provided data sets containing each of the the necessary variables, the complete data set used for this paper consists of 12 universities. Each of these universities are large public universities, and are either their state's flagship institution or one of the largest research universities in their state. While each of these schools function as public research universities, the institutions in the data are heterogeneous at a multitude of levels, including size, prestige, and average salary levels. Table 2 displays the schools included in the data, along with the number of observations, the mean and median faculty salary for all faculty in all academic fields in the data set, and their U.S. News and World Report Ranking in 2020. Clearly, there are large differences between the schools in this data, with average salaries ranging from $96,2018 to $133,689, and ranks ranging from 25 to 139.

In order to analyze the impact of state appropriations on faculty salary and other variables, it is important that among selected schools, state appropriations vary in both magnitude and direction of growth. Figure 1 documents this heterogeneity. Real values of appropriations can

Figure 1: *State appropriations by school, 2010-2017.*



Note: State appropriations are reported in 2015 dollars. The full IPEDS data set includes appropriations from 2010-2017. This figure only includes appropriations from years in states where schools have the associated salary data.

have an increasing trend over time (i.e. Texas A&M), a decreasing trend over time (i.e. UNC), or a cyclical trend (i.e. Connecticut).

Raw salary data are used to generate the set of variables that are necessary to empirically test the theoretical model. The means for salary pool, department size, and salary are presented by field in Table 3, along with a measure of salary pool that includes lecturers. Furthermore, Table 4 presents the mean, median, and standard deviation of salary, by both field and faculty rank.[15]

Table 3 and Table 4 demonstrate the field-level heterogeneity of the level and distribution of salaries. Fields vary in average salary pool, size, and salary level. Some fields, such as economics, have departments with small average sizes and large salary levels. Others, such as English, have large numbers of faculty and small salary levels. Furthermore, Table 4 exhibits differences in

[15] The variable for rank contains one of three values: "Assistant Professor", "Associate Professor", or "Professor". A faculty's assignment to one of these ranks was based on their job title in the raw data.

Table 3: *Mean salary pool, mean department size, and mean salary by department, 2010-2018.*

Department	Salary Pool (w/Lecturers)	Salary Pool (w/o Lecturers)	Num in Dept	Mean Salary
Biology	6,932,940	6,677,407	66	105,218
Chemistry	6,452,593	6,103,204	51	121,214
Computer Science	5,763,017	5,252,604	40	130,779
Economics	5,742,676	5,347,060	37	147,768
English	7,452,977	6,531,056	70	93,633
History	5,041,730	4,887,730	51	94,353
Mathematics	8,270,036	7,461,696	74	102,224
Philosophy	2,272,394	2,183,456	22	98,871
Physics	7,707,357	7,531,359	67	116,319
Political Science	4,290,789	4,146,977	37	110,486
Psychology	7,296,692	6,933,930	61	112,029
Sociology	3,275,755	3,105,293	30	105,207

Note: Salaries are adjusted to 2015 dollars. The columns for number in department and salary do not include lecturers.

salary variation by rank. Notably, salary standard deviations tend to increase as rank increases. While there is relatively little variation in salary for assistant professors, there is much higher salary variation between full professors. The nature of academic employment contributes to the relatively high variation in compensation among full professors. Differences in research productivity are most incident at this career stage, and the tenure system makes it difficult for employers to terminate underperformers. At the professor rank, there are a small number of high performing faculty that earn the highest salaries. These high salaries increase the total variation of salary within rank. Overall, the magnitudes of the coefficients of variation help reveal that some fields have more variance than others, and that much of this variation is concentrated at the professor rank.

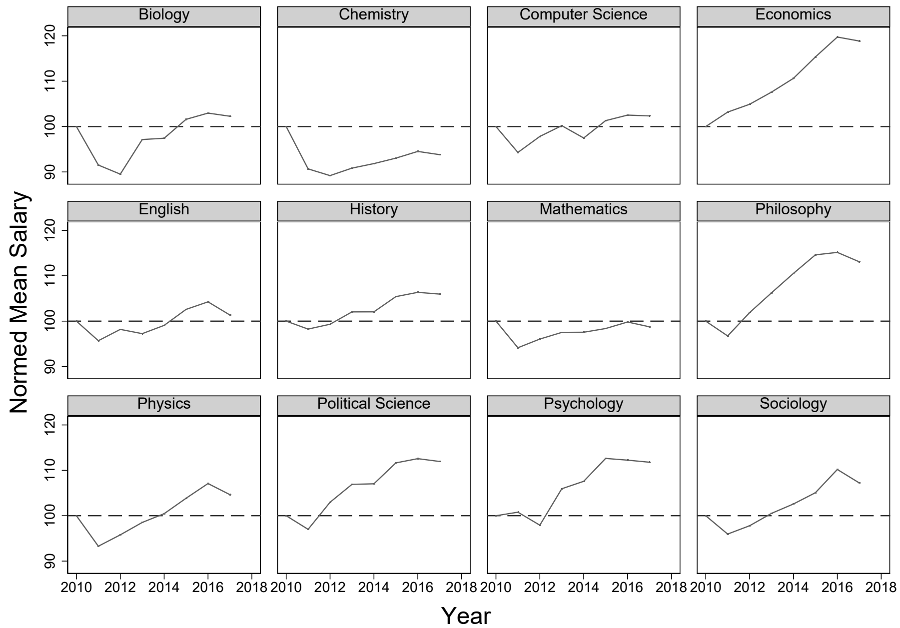
In addition to the heterogeneity of mean salary by field, salary growth levels vary as well. Figure 2 plots a normed measure of mean salary, which equals 100 for each department in 2010, versus time. Salary levels are adjusted to 2015 dollars. This plot allows for the comparison of growth rates over time. Some fields, such as economics, philosophy, and psychology have had significant positive growth rates compared to the base year, 2010. Others, such as chemistry and

Table 4: *Salary mean, median, and variation, by department and rank, 2010-2018.*

Department	Rank	Mean	Median	Coefficient of Variation
Biology	Assistant	77,882	77,462	0.254
Biology	Associate	88,809	87,666	0.23
Biology	Professor	130,454	121,998	0.349
Chemistry	Assistant	78,698	82,291	0.227
Chemistry	Associate	91,954	92,289	0.192
Chemistry	Professor	146,539	137,316	0.363
Computer Science	Assistant	99,110	98,909	0.232
Computer Science	Associate	113,832	112,460	0.268
Computer Science	Professor	155,004	149,562	0.305
Economics	Assistant	112,546	115,194	0.212
Economics	Associate	128,482	127,952	0.344
Economics	Professor	184,070	175,383	0.417
English	Assistant	63,251	66,307	0.231
English	Associate	77,756	78,427	0.21
English	Professor	114,099	108,058	0.299
History	Assistant	65,551	67,686	0.213
History	Associate	81,444	80,486	0.215
History	Professor	117,799	112,867	0.301
Mathematics	Assistant	66,014	58,702	0.3
Mathematics	Associate	87,883	88,917	0.23
Mathematics	Professor	127,295	121,215	0.319
Philosophy	Assistant	61,920	63,818	0.262
Philosophy	Associate	81,027	77,304	0.257
Philosophy	Professor	123,307	119,718	0.321
Physics	Assistant	83,396	83,357	0.24
Physics	Associate	92,305	89,829	0.234
Physics	Professor	130,796	120,952	0.357
Political Science	Assistant	76,970	78,272	0.199
Political Science	Associate	94,313	91,848	0.23
Political Science	Professor	146,796	139,882	0.374
Psychology	Assistant	74,375	78,111	0.24
Psychology	Associate	86,734	87,295	0.24
Psychology	Professor	140,753	136,726	0.347
Sociology	Assistant	72,546	73,988	0.227
Sociology	Associate	87,904	87,003	0.224
Sociology	Professor	131,136	120,828	0.384

Note: Salaries are adjusted to 2015 dollars. Coefficient of variation equals standard deviation divided by mean salary.

Figure 2: *Mean salary growth rates by field, 2010-2018.*



Note: Salaries are adjusted to 2015 dollars. For this figure, mean real salaries in each department are normed to 100 in 2010 to compare growth rates. Horizontal line at the normed value of 100.

mathematics, have experienced stagnant or declining real salary levels.

Table 5 exhibits the means of a set of variables related to the extensive margin of faculty employment - new hires and departures. The variables in this table are measured in terms of proportion of department. For example, one may interpret row 1 column 1 as "on average, 3.2 percent of faculty in a representative English department in a given year are new hires."

There are two notable findings from this table. First, some fields are more active in the hiring market than others. Departments in the fields of economics, computer science, and mathematics hire a relatively higher proportion of their department from year to year, compared to fields in English, biology, and physics. Departments in these fields also experience exits much more frequently. This is consistent with the hypothesis that in relatively competitive fields like economics, there is much more turnover due to competition between universities. Second, this table demonstrates that the majority of hiring takes place at the assistant level, which is expected

Table 5: *Means of hiring variables, 2010-2018.*

Department	Hired	Stay	Leave	Asst Prof Hired	Assoc Prof Hired	Prof Hired
Biology	0.032	0.981	0.050	0.026	0.002	0.003
Chemistry	0.039	0.973	0.041	0.031	0.004	0.004
Computer Science	0.061	0.954	0.050	0.046	0.009	0.006
Economics	0.081	0.923	0.081	0.058	0.011	0.011
English	0.035	0.992	0.065	0.028	0.003	0.005
History	0.047	0.959	0.063	0.036	0.005	0.006
Mathematics	0.118	0.988	0.094	0.109	0.003	0.006
Philosophy	0.063	0.908	0.064	0.048	0.005	0.010
Physics	0.032	0.988	0.041	0.024	0.003	0.005
Political Science	0.059	0.934	0.061	0.046	0.005	0.007
Psychology	0.044	0.983	0.082	0.036	0.004	0.004
Sociology	0.058	0.930	0.057	0.039	0.009	0.010

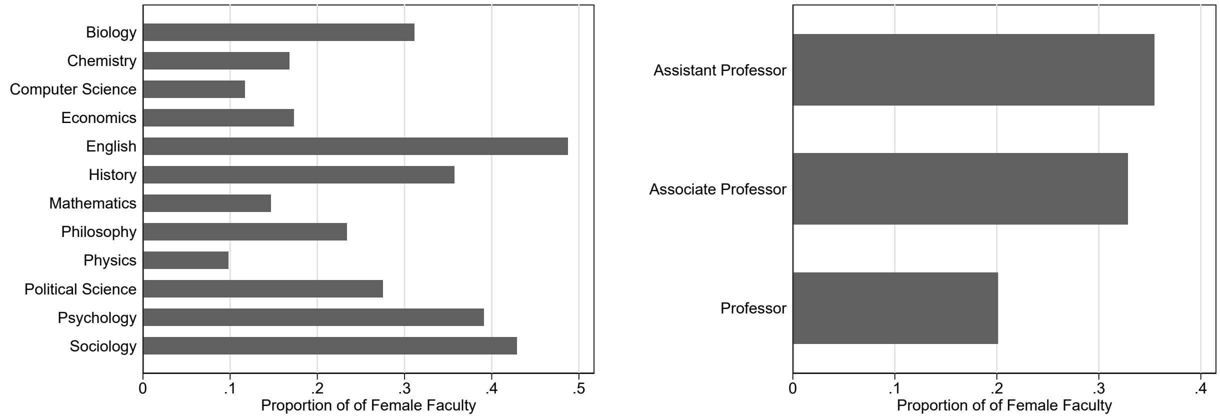
Note: For hired, stay, leave, assistant professor hired, associate professor hired, and professor hired, the denominator of the proportion is the number of faculty at school s, in field f, in year t.

given that this is the entry level for tenure-track faculty. Some fields are more active in hiring full professors than others, such as economics, philosophy, and sociology.

It is important to note that women behave differently than men in faculty labor markets. The heterogeneity of gender makeup by department contributes to a large portion of the gender wage gap. Figure 3a documents this heterogeneity. Women are disproportionately likely to work in fields like English, sociology, psychology, history, and biology, while men are much more likely to work in computer science, economics and physics. In general, the fields that have a greater proportion of female employment are those with lower average salary levels (see table 3.). Because academic field is a key explanatory variable for salary levels, this selection into lower-paying fields plays a significant role in the wage-gap. In addition, women are more likely to be associate or assistant professors than full professors, as shown in figure 3b. The declining proportion of women as rank increases may be explained by either (i) less women persisting long enough with their employment to achieve professor rank, or (ii) women experiencing declines in research productivity that make them less likely to achieve promotion to professor.[16] Again, differences in

[16] As mentioned previously, this decline in research productivity has been documented by Blackaby et al. (2005)

Figure 3: *Proportion of female faculty by field and by rank, 2010-2017.*



(a) Departments

(b) Ranks

Note: Values represent the proportion of female faculty over the entire time range 2010-2017. There are no large differences in the proportion of female faculty over this period.

gender make-up by rank are a key factor in the gap between average wages of men and women. These figures show that in order to isolate the effects of appropriations on gender, one must first control for field- and rank-level differences.

5 Empirical Strategy

Using the available salary and appropriations data, I seek to test the hypotheses presented in the theoretical model of salary determination through a series of empirical specifications. This paper utilizes three main specifications to test the effect of state appropriations on the set of outcome variables discussed in the theoretical model. The identifying assumption for each of these specifications is that the level of state appropriations is exogenous to the set of outcome variables.

I use ordinary least squares (OLS) regressions to model the impacts of appropriations on faculty labor market outcomes. For individual-level outcome variables, such as salary and raises, I regress the given outcome variable Y on log appropriations, an interaction of log appropriations and academic field, an interaction of log appropriations on faculty rank, and school and field fixed effects. The following specification is for individual i, school s, field f, and year t.

$$Y_{isft} = \alpha_s + \sigma_f + \beta_1 lnA_{st} + \beta_2(lnA_{st} \times Field_{if}) + \beta_3(lnA_{st} \times Rank_{it}) + \epsilon_{isft}$$

This analysis is particularly interested in β_1 along with β_2 and β_3, which are the vectors of coefficients on the field and rank interactions. These coefficients capture the differential impact of appropriations on the outcome variable, by field or rank. Rather than employing a full-interaction term (i.e. $lnA_{st} \times Field_{if} \times Rank_{it}$), I only utilize the separate field and rank interactions. The full-interaction term does not provide information with regards to the efficacy of the theoretical model that the separate interaction terms do not provide themselves. The field interactions provide insight on how the level of outside offers (γ) interacts with appropriations, while the rank interactions provide insight on the relationship between appropriations and productivity/value. The full-interaction clutters the results while also explaining little-to-none of the variation when implemented in tandem with the separate interaction terms.

For department-level variables, such as salary pool and department size, I regress the outcome variables on log appropriations, an interaction of log appropriations and academic field and school and field fixed effects. The main difference in this model is the absence of the rank variable, which can only be included in the individual-level specification.

$$Y_{s,f,t} = \alpha_s + \sigma_f + \beta_1 lnA_{st} + \beta_2(lnA_{st} \times Field_f) + \epsilon_{sft}$$

To examine the effects of salary along the income distribution, I employ quantile regressions of salary on on log appropriations, an interaction of log appropriations and academic field, an interaction of log appropriations on faculty rank, and school and field fixed effects.

$$Y_{isft}^{QR(\tau)} = \alpha_s^\tau + \sigma_f^\tau + \beta_1^\tau lnA_{st} + \beta_2^\tau (lnA_{st} \times Field_{if}) + \beta_3^\tau (lnA_{st} \times Rank_{it}) + \epsilon_{isft}^\tau$$

The beta-coefficients in the quantile regressions capture the impacts of appropriations on salary at a specific income quantile τ. Baseline income is used as an approximation for productivity, and the quantile regressions seek to examine the impacts of appropriations on faculty at various productivity levels. In my analysis of the differential effects of appropriations by gender, I utilize these same quantile regressions with the inclusion of interactions between log appropriations and gender.

Because appropriations are allocated on a state-by-state basis and each university in the data set resides in a different state, serial correlation likely exists at the university-level. However, there may also exist field-level differences in the allocation of the total budget to each department. If universities recognize that faculty labor markets differ by field, they will adjust allocation methods based on these field-level differences. If budget distribution policies do in fact differ by field, then clustering standard errors at the university-level will not suffice, because field-level correlation of residuals would bias standard errors (Barrios, Diamond, Imbens, & Kolesar, 2012). I cluster standard errors at the department-level (i.e. Michigan Economics) to account for this serial correlation. Abadie, Athey, Imbens, and Wooldridge (2017) show that the number of clusters and the number units per cluster must be sufficient in order to obtain causal inference, and argue that $n > 100$ is more than a sufficient amount of clusters.[17] In this analysis, department clusters leave us with an appropriately large number of clusters, 144 (12 schools and 12 academic fields), in addition to having hundreds of observations per cluster.

[17] A sufficient number of clusters is required to avoid the small sample problems presented in Donald and Lang (2007).

Due to sticky wages and slow labor market response, departments may not respond to year-to-year changes in appropriations as strongly as they respond to trends. To address the issue of lagged responses, I test each specification using a three-year moving average measure of state appropriations, in addition to the year-to-year measurement. The goal of using the moving average measurement is to capture (i) delayed responses to appropriations shocks in year $t-1$, and (ii) the effects of future expectations of appropriations in year $t+1$. While the results presented in the paper focus on the year-to-year measure of appropriations, moving average results are presented in the appendix.

6 Results

Using the salary and appropriations data from 2010-2017, the proposed empirical specifications confirm the general expectations of the theoretical framework.

6.1 General Findings

Regressions of the first set of outcome variables (log salary pool, log salary, log number in department, and the coefficient of variation) on log state appropriations interacted with field indicators are presented throughout table 6 and figure 4. Table 6 presents the regression outputs, and figures 4a through 4d plot the predicted marginal effects and the associated 95% confidence intervals for each academic field. Effects that are greater than zero imply a significant impact of appropriations on the given outcome in the given academic field.

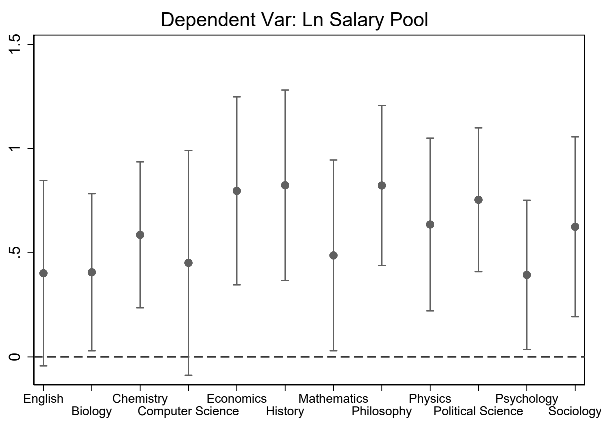
As expected, the effects of log state appropriations on salary pool, number in department, and salary are generally positive and significant, which confirms (i) that appropriations do in fact impact a department's budget for faculty salaries, (ii) that salaries and raises increase in response

Table 6: *The effect of log state appropriations on log salary pool, log department size, log salary, and salary variance by department, 2010-2017.*

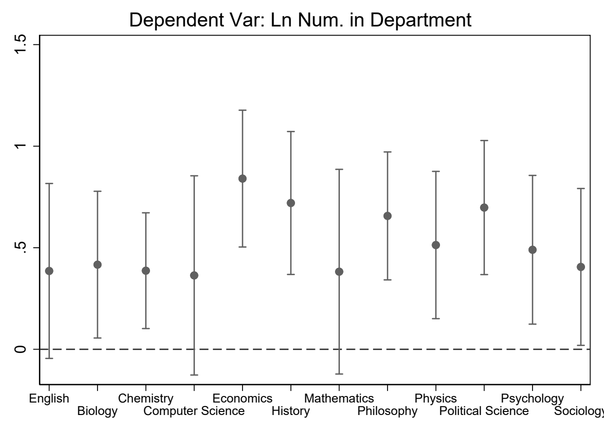
	(1) Ln Salary Pool	(2) Ln Num. in Department	(3) Ln Salary	(4) Var. Salary
Ln State Appropriations	0.402*	0.386*	0.151**	-0.085
	(0.225)	(0.218)	(0.065)	(0.053)
Biology	-0.198	-0.864	1.537	-0.549
	(4.205)	(4.403)	(1.215)	(1.219)
Chemistry	-3.708	-0.345	-2.210	-2.667**
	(4.172)	(3.783)	(1.873)	(1.067)
Computer Science	-1.162	-0.057	-0.790	-2.652**
	(6.017)	(5.675)	(1.669)	(1.143)
Economics	-8.123	-9.715**	4.651*	-3.605**
	(5.271)	(4.326)	(2.582)	(1.620)
History	-8.610*	-6.854	-0.848	-1.310
	(4.814)	(4.178)	(1.874)	(1.130)
Mathematics	-1.559	0.097	-0.894	-1.595
	(5.338)	(6.057)	(2.239)	(1.176)
Philosophy	-9.404**	-6.449*	-0.070	-2.008
	(4.069)	(3.813)	(2.500)	(1.375)
Physics	-4.639	-2.749	-1.066	-1.651
	(4.868)	(4.608)	(1.708)	(1.284)
Political Science	-7.400*	-6.722	1.027	-0.687
	(3.963)	(4.083)	(2.159)	(1.696)
Psychology	0.053	-2.309	3.075*	-0.921
	(4.457)	(4.543)	(1.578)	(1.170)
Sociology	-5.042	-1.127	-2.218*	-2.162*
	(4.767)	(4.615)	(1.246)	(1.198)
Biology X Ln Appropriations	0.005	0.031	-0.071	0.029
	(0.214)	(0.224)	(0.061)	(0.062)
Chemistry X Ln Appropriations	0.184	0.001	0.124	0.138**
	(0.213)	(0.192)	(0.095)	(0.054)
Computer Science X Ln Appropriations	0.050	-0.022	0.056	0.131**
	(0.304)	(0.286)	(0.084)	(0.058)
Economics X Ln Appropriations	0.395	0.455**	-0.215	0.183**
	(0.266)	(0.220)	(0.130)	(0.082)
History X Ln Appropriations	0.422*	0.335	0.042	0.065
	(0.245)	(0.212)	(0.095)	(0.057)
Mathematics X Ln Appropriations	0.086	-0.004	0.048	0.082
	(0.273)	(0.310)	(0.113)	(0.059)
Philosophy X Ln Appropriations	0.421**	0.271	0.004	0.102
	(0.208)	(0.194)	(0.126)	(0.069)
Physics X Ln Appropriations	0.234	0.128	0.065	0.083
	(0.248)	(0.235)	(0.086)	(0.065)
Political Science X Ln Appropriations	0.352*	0.312	-0.046	0.038
	(0.201)	(0.208)	(0.108)	(0.085)
Psychology X Ln Appropriations	-0.008	0.104	-0.148*	0.049
	(0.227)	(0.230)	(0.080)	(0.059)
Sociology X Ln Appropriations	0.223	0.020	0.117*	0.110*
	(0.241)	(0.233)	(0.063)	(0.060)
Constant	7.021	-4.112	8.403***	1.977*
	(4.459)	(4.321)	(1.295)	(1.056)
N	1088	1088	43241	1088
R^2	0.811	0.821	0.143	0.410

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

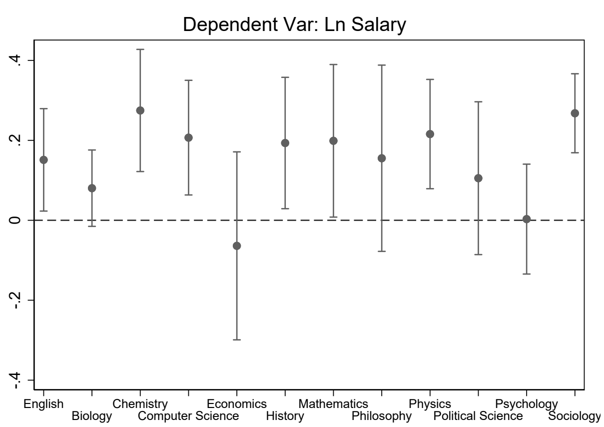
Figure 4: *95% Confidence intervals of the field-level marginal effects of log appropriations on log salary pool, log department size, log salary, and salary variance by department, 2010-2017, corresponding to table 6.*



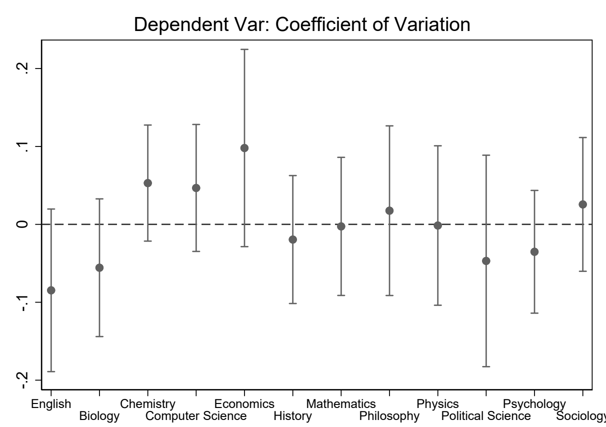
(a) Ln Salary Pool



(b) Ln Department Size



(c) Ln Salary



(d) Coefficient of Variation

to appropriations, and (iii) that department size is positively related with appropriations. For the omitted field, English, a 10 percent increase in appropriations leads to a 4.02 percent increase in salary pool, a 3.86 percent increase in department size, and a 1.51 percent increase in salary levels. In most fields, the results are consistent with the idea that appropriations have a positive impact on a department's salary pool, faculty salaries, and department size.

Figure 4a confirms that appropriations shocks to a university do in fact impact a department's budget. As per the theoretical framework, universities distribute a fraction of their total budget to departments, which they may use on labor or other forms of capital. In each academic field, there is evidence of a positive correlation between appropriations and salary pool. This relationship is weaker than one-to-one, which is expected for two reasons. First, appropriations are only a portion of a university's budget (see equation (2)). Universities may find ways to dampen the effects of appropriations declines by attempting to increase their budget through tuition revenue, grants, or donations. Second, a department's budget is not used entirely on labor, and thus the measure of salary pool does not capture total departmental spending. While there is some variation in the effect of appropriations on salary pool, there are little significant differences by field. Any variation that does exist is likely driven by either universities distributing different proportions of their budget to different departments or through disparities in the proportion of department budgets that are allocated to labor resources.

There is greater variation by field when it comes to department size, as shown in figure 4b. Some fields exhibit little-to-no response to appropriations shocks on the extensive margin. However, some fields, notably economics, history, philosophy, and political science, experience considerable increases in their department size when appropriations levels increase. The number of faculty in a department may increase through (i) new hires or (ii) more faculty continuing their employment from year to year.[18]

The same fields with large responses on the extensive margin exhibit relatively low responses via salary level, as shown in figure 4c. Most notably, there is no evidence of any positive impact of appropriations on salary in the economics field. Further, the effects of appropriations on faculty salaries in the fields of philosophy and political science, two fields with large responses through department size, are not significantly different from zero. These findings indicate that universities face an important trade off when dealing with budget shocks, and must decide whether to adjust through size, through salary, or some combination of both. With an impending budget decrease, this finding has important implications on research output and teaching quality in certain fields. Economics departments have demonstrated that given a budget decrease, they prefer to sacrifice student-teacher ratios and the number of publications in favor of ensuring that they retain their top researchers. Departments in other fields, such as sociology, may sacrifice paying competitive wages to their faculty in favor of maintaining their department size.

The theoretical framework hypothesizes that the differences in type of response to appropriations are largely driven through variation in monopsony power by field. This is due to differences in γ_{sft}, the framework's measure of the frequency of outside offers. High levels of outside offers prompt salaries for faculty in the economics field, for example, to approach competitive levels. Through equation (9), as the percentage difference between one's wage and their competitive wage approaches zero, their response to any appropriations shocks weakens. Because economics departments generally must avoid decreasing faculty salaries relative to their competitors, they will sacrifice hiring levels (or non-personnel resources) as appropriations decline. Given that among all fields, economics salaries have the highest levels and highest growth rates, it is safe to characterize the economics field as having a greater frequency of outside offers.

[18] The results in table 7 will address how departments respond through both of these mechanisms.

Thus, these results suggest that γ_{sft} and the proportion of response though salary adjustment are negatively related.

Figure 4d shows no significant impacts on the level of variation of faculty salaries within a department. However, appendix table B.1, which uses a three year moving average measure of state appropriations rather than the year-to-year measure, exhibits some significant effects of appropriations on salary variation. Column (4) of table B.1 shows that in certain fields, salary variance decreases as appropriations trend upward, and vice versa. This is consistent with the theoretical framework. When appropriations are low, the highest ranking faculty get paid while others do not, which exacerbates salary variance. When appropriations are higher, departments can distribute raises to others, providing faculty with a smaller level of outside offers with a greater likelihood of receiving a raise. Appropriations increases allow departments to increase the salaries of those at the bottom of the income distribution, closer to the level of the highest earners. This effect is least apparent in computer science and economics, the two fields which have been shown to be most active in the hiring market, implying high values of γ_{sft}. Greater field-level labor market activity leads to offered wages that approach competitive wages, which results in appropriations having a limited impact on within-department salary variation.

To test the effects of appropriations on hiring activity, Table 7 regresses new hires, continuation, and leaving, which are measured as proportions of the total department in a given year, on appropriations with interactions by field. This table exhibits little significant evidence of an effect of appropriations on overall hiring levels and exits, although there is evidence of an impact on the proportion of faculty who continue their employment from the previous year. This mechanism is apparent in all academic fields in the data except for psychology.

The positive impact on staying is motivated through changes in $p()$, the probability of an individual faculty member accepting a given wage offer, w_{isft}. This probability increases as the

Table 7: *The effect of log state appropriations on hiring, continuation, and exit, by field, 2010-2017.*

	(1) Hire	(2) Stay	(3) Leave	(4) Hire Asst.	(5) Hire Assoc.	(6) Hire Prof.
Ln State Appropriations	0.026	0.149*	0.058	0.040**	-0.004	-0.010
	(0.021)	(0.079)	(0.046)	(0.019)	(0.006)	(0.007)
Biology	-0.049	0.382	0.881	0.035	0.070	-0.154
	(0.387)	(1.269)	(0.895)	(0.379)	(0.078)	(0.113)
Chemistry	-0.118	1.220	0.242	0.081	-0.028	-0.171
	(0.303)	(1.158)	(0.832)	(0.240)	(0.095)	(0.124)
Computer Science	-0.123	0.813	-0.140	0.137	0.075	-0.335**
	(0.372)	(1.791)	(0.866)	(0.266)	(0.171)	(0.129)
Economics	0.077	0.064	0.918	0.039	-0.004	0.042
	(0.394)	(2.061)	(1.208)	(0.298)	(0.113)	(0.144)
History	0.119	-0.094	0.919	0.419*	0.042	-0.341***
	(0.328)	(1.245)	(0.839)	(0.230)	(0.112)	(0.115)
Mathematics	0.147	0.518	0.753	0.362	-0.045	-0.170
	(0.693)	(1.436)	(1.062)	(0.664)	(0.067)	(0.111)
Philosophy	0.060	-1.418	1.053	0.739	-0.161	-0.518**
	(0.530)	(2.570)	(1.293)	(0.451)	(0.108)	(0.212)
Physics	-0.146	1.254	0.246	0.147	-0.068	-0.225**
	(0.295)	(1.287)	(0.877)	(0.284)	(0.069)	(0.100)
Political Science	0.588	1.273	1.101	0.787**	-0.030	-0.170*
	(0.364)	(1.089)	(0.879)	(0.374)	(0.069)	(0.101)
Psychology	-0.322	3.655**	-1.508	-0.109	0.028	-0.242**
	(0.325)	(1.794)	(1.599)	(0.280)	(0.073)	(0.104)
Sociology	0.410	0.720	0.582	0.671***	-0.041	-0.220
	(0.255)	(1.222)	(0.806)	(0.230)	(0.144)	(0.146)
Biology X Ln Appropriations	0.003	-0.020	-0.046	-0.002	-0.003	0.008
	(0.019)	(0.065)	(0.046)	(0.019)	(0.004)	(0.006)
Chemistry X Ln Appropriations	0.006	-0.061	-0.014	-0.004	0.001	0.009
	(0.015)	(0.059)	(0.043)	(0.012)	(0.005)	(0.006)
Computer Science X Ln Appropriations	0.007	-0.040	0.006	-0.006	-0.004	0.017**
	(0.019)	(0.092)	(0.044)	(0.014)	(0.009)	(0.007)
Economics X Ln Appropriations	-0.002	-0.007	-0.046	-0.000	0.000	-0.002
	(0.020)	(0.104)	(0.061)	(0.015)	(0.006)	(0.007)
History X Ln Appropriations	-0.005	0.004	-0.047	-0.021*	-0.002	0.017***
	(0.016)	(0.063)	(0.043)	(0.012)	(0.006)	(0.006)
Mathematics X Ln Appropriations	-0.005	-0.027	-0.037	-0.015	0.002	0.009
	(0.035)	(0.074)	(0.054)	(0.033)	(0.003)	(0.006)
Philosophy X Ln Appropriations	-0.002	0.067	-0.053	-0.036	0.008	0.026**
	(0.027)	(0.129)	(0.065)	(0.023)	(0.005)	(0.011)
Physics X Ln Appropriations	0.007	-0.063	-0.014	-0.007	0.003	0.011**
	(0.015)	(0.066)	(0.045)	(0.014)	(0.004)	(0.005)
Political Science X Ln Appropriations	-0.028	-0.065	-0.056	-0.038**	0.002	0.009*
	(0.018)	(0.056)	(0.045)	(0.019)	(0.004)	(0.005)
Psychology X Ln Appropriations	0.017	-0.185**	0.077	0.006	-0.001	0.012**
	(0.016)	(0.091)	(0.082)	(0.014)	(0.004)	(0.005)
Sociology X Ln Appropriations	-0.019	-0.038	-0.030	-0.033***	0.002	0.011
	(0.013)	(0.062)	(0.041)	(0.012)	(0.007)	(0.007)
Constant	-0.468	-2.087	-1.083	-0.791**	0.098	0.226
	(0.429)	(1.580)	(0.910)	(0.377)	(0.111)	(0.148)
N	946	946	1088	946	946	946
R^2	0.201	0.077	0.109	0.196	0.083	0.109

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

offered wage increases, which is shown to be positively related to a department's budget. The positive impact on stayers is a relevant economic finding. Hiring market activity is inefficient and costly for departments, both in terms of search costs and in terms of the potential salary increases given to replacements. This serves to show that state appropriations do have an impact on efficiency, along with the level of resources.

There is evidence of appropriations resulting in an increase in the hiring of assistant professors, but not the hiring of higher ranking faculty.[19] This evidence is significant in all academic fields save for history, political science, and sociology. While this effect is modest in magnitude, it does suggest that positive appropriations shocks allow departments to increase their level of tenure-track hires. This finding is particularly interesting in the context of the results from table 6, which show that changes in a department's salary pool positively impact department size. Table 7 sheds light on the two ways through which department size is impacted by appropriations. In most departments, higher appropriations induce more faculty to stay, which increases the number of faculty employed in a department. At the same time, most departments use some portion of any budget increases to hire assistant professors, which also increases department size. As a result, it is clear that appropriations do have an influence on the number of academics at a given university, which has a direct impact on a university's research output and teaching quality.

The regressions presented table 8 and figure 5 confirm that raises are positively related to state appropriations. Note that the raise regressions exclude observations in years where an individual was promoted. Promotions are unrelated to appropriations and generally lead to significant raises.[20] In the model, a key assumption is that each faculty member's productivity

[19] The data exhibits no significant impact of state appropriations on the number of lecturers hired or the proportion of a department composed of lecturers. This was testing using the year-to-year measure and the moving average measure.

[20] Using this data, regressions of a promotions indicator on log appropriations, controlling for field, rank, school and year, show no impact of appropriations on the likelihood of a a promotion.

Table 8: *The effect of log state appropriations on log salary and raises by department and rank, 2010-2017.*

	(1) Ln Salary	(2) Raise	(3) Raise > 10%	(4) Raise > 20%
Ln State Appropriations	0.148*	0.203***	-0.122***	-0.120***
	(0.081)	(0.074)	(0.030)	(0.029)
Associate	-0.122	0.138	0.943***	1.148***
	(0.942)	(0.578)	(0.335)	(0.287)
Professor	0.669	-0.060	0.868**	0.934***
	(1.113)	(0.648)	(0.333)	(0.301)
Associate X Ln Appropriations	0.016	-0.007	-0.047***	-0.058***
	(0.048)	(0.029)	(0.017)	(0.015)
Professor X Ln Appropriations	-0.006	0.002	-0.044**	-0.048***
	(0.056)	(0.033)	(0.017)	(0.015)
Constant	8.162***	-3.343**	2.522***	2.453***
	(1.616)	(1.488)	(0.603)	(0.589)
N	43241	33809	33809	33809
R^2	0.415	0.170	0.029	0.026

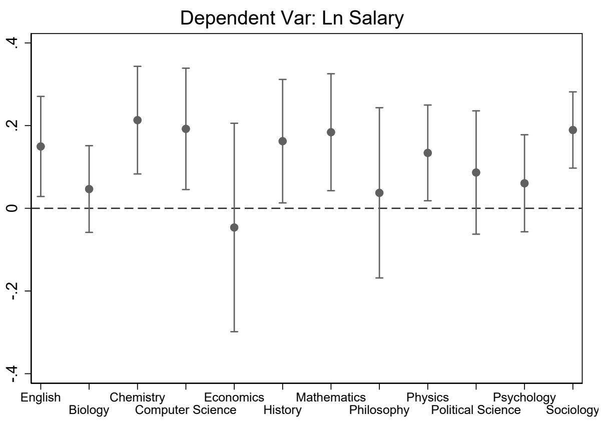
Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English and Assistant Professor Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Raises are defined in real terms. The full output of these regressions, including field and rank intercept terms, field/appropriations interactions, and rank/appropriations interactions, are provided in appendix table B.2. Point and confidence intervals of the marginal effects by department are presented in figures 5a through 5d. Note that the result for the regression of log salary is slightly different than the result in table 6, because unlike in that table, these specifications include a rank/appropriations interaction.

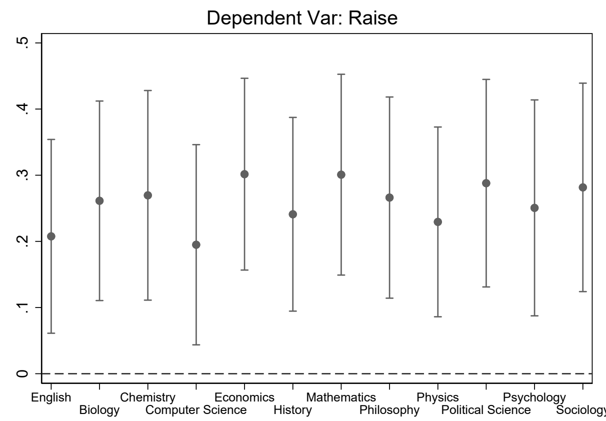
and rank is constant throughout $t = 0, 1, 2, ..., n$. Excluding cases of promotion allows these regressions to capture the effect of appropriations on standard year-to-year raises.

Raises are positively correlated with appropriations in all fields. Predicted effects of appropriations on the likelihood of an individual faculty member receiving a raise vary around 0.25, which indicates that a 10 percent increase in state appropriations increases the likelihood of receiving a raise by 2.5 percentage points, on average. Raises should translate to higher salary levels, although if appropriations also lead to increases in tenure-track hiring, then the effect of appropriations on overall salary levels may be dampened by the lower salaries of young professors at the onset of their career. Therefore, the salary results in figure 4c may not cupture the full effect of appropriations on individual salary levels, making the raise results in figure 5b the best

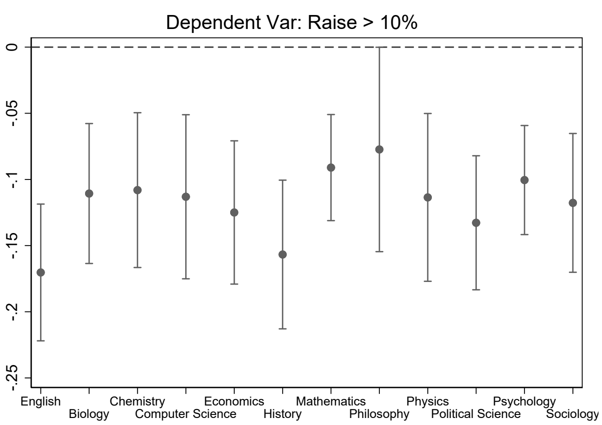
Figure 5: *95% Confidence intervals of the field-level marginal effects of log appropriations on log salary and raises by department, 2010-2017, corresponding to table 8.*



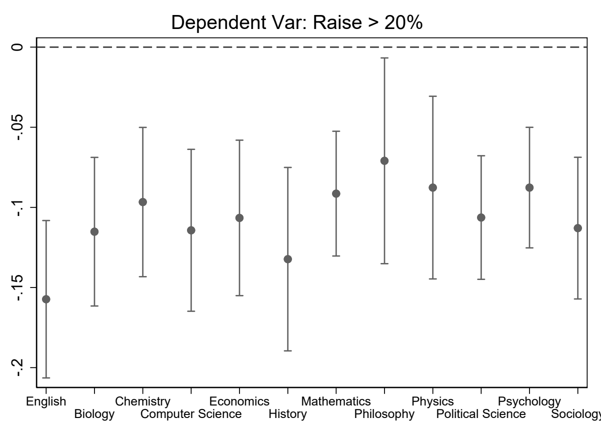
(a) Ln Salary



(b) Raise



(c) Raise > 10%



(d) Raise > 20%

evidence that appropriations shocks have an impact on faculty wages. There are very limited differences in the impact of appropriations shocks on raises by both field and rank.

Given the nature of the data, retention cases are unobservable.[21] However, I approximate retention cases through the presence of large raises, measured as raises greater than 10 percent, along with raises greater than 20 percent. Raises of these magnitudes are atypical of standard year-to-year raises in response to productivity increases. Such large raises are generally only granted in order to compete with outside offers. Therefore, large raises should be representative of cases where faculty receive outside offers but are induced to stay. Figures 5c and 5d exhibit a negative relationship between appropriations and retention cases in all academic fields. This finding is consistent with the hypothesis that retention cases decrease as appropriations increase, and vice versa. As appropriations increase, offered wages increase. This decreases the value of $1 - p()$, which is the probability of the university needing to increase offered wages to competitive wages to retain their employee (see equation (10)).

While there is little evidence of field-level differences in retention cases, there do exist differential impacts of appropriations on retention cases by rank. There are not necessarily inherent differences in productivity between assistant professors and associate/full professors; assistant professors may be as highly productive in terms of research. However, because assistant professors are at the incipiency of their career, much of their research productivity is unknown. Because of this lack of knowledge, the expected value of an assistant professor's productivity may be low relative to a professor whose research and teaching abilities are known quantities. Given that outside offers and retention cases should be the most common for highly productive faculty with a greater expected productivity (η_{isf} in the theoretical framework), one should expect that the effect of appropriations on large raises is greater for higher ranking faculty. Indeed, the

[21] Retention cases are defined as cases where an individual is offered a wage w, receives an outside offer, which prompts the university to increase their offer to W to avoid their departure.

significant negative values on the rank interaction terms in table 8 indicate that the negative impact of appropriations on retention cases is strongest for associate professors and full professors. This result illustrates how declining appropriations may exacerbate inequality in faculty salaries. As appropriations decline, most faculty become less likely to receive a raise and earn lower relative salaries as a result; yet at the same time, retention cases and their associated salary increases become more likely for the most productive professors, which increases their earnings. Put together, this intensifies the gap between the average faculty member and the higher ranking superstars.

6.2 Effects of Appropriations, by Income Level

A large portion of the theoretical framework focuses on the differential impacts of appropriations on faculty of different productivity levels. Research output and teaching skill dictate one's competitive wage. Top performers ("superstars") earn the highest wages, and generally earn close to their competitive wage, W_{isf}. Due to their immense importance to a university's research output and educational outcomes (as per the utility function in equation 1), departments will attempt to maximize the probability of a superstar accepting their wage offer, denoted as $p()$. This entails increasing their offered wage to approach competitive levels. For this reason, salaries for a department's most crucial professors will approach W_{isf}, which results in their salaries being relatively unresponsive to appropriations shocks. The theoretical framework predicts that appropriations have greater impacts on faculty salaries at the lower end of the income distribution, who face larger gaps between their offered wages and their market value. If this is the case, then increasing appropriations may be a viable method of reducing income inequality among faculty.

Ideally, a measure of productivity, either through research breakthroughs or publication numbers, would be used in order to examine how superstars and higher performing faculty respond to appropriations shocks in comparison to the average or below-average professor. However, given the latency of a productivity measure in the data, I approximate productivity using baseline compensation. By employing quantile regressions at the individual level, I examine the effect of appropriations on salary at different levels of the income distribution, which approximates productivity. Table 9 displays the results of the individual-level quantile regressions at the 10th, 25th, 50th, 75th, and 90th income percentiles, and compares these to the OLS results.[22] Plots of the marginal effects by field in each of these quantile regressions are presented in appendix tables B.2 through B.6. In each of these specifications, log appropriations is interacted with rank and field categorical variables.

Appropriations have a significant impact on salary for faculty at the bottom 10 percent of the income distribution in all fields, including those where the OLS estimates are insignificant. In many fields, the predicted effect at the 10th quantile is at least three times greater than the predicted OLS effect. In this portion of the income distribution, the effect of appropriations on salary is strongest for assistant professors, which is demonstrated by the significant negative values on the rank interaction terms in column (2). Given that assistant professors at the lowest end of the income distribution likely have the lowest expected productivity in terms of research output and teaching quality, it is not surprising that the effect of appropriations is strongest for the these individuals. At this income level, English salaries exhibit the largest response, which indicates that those with the largest percentage gap between their wages and their competitive wages are entry-level English faculty.

The strength of the response to appropriations weakens as individuals move up the income distribution, in all fields. These declines are apparent in the set of figures B.2 through B.6. By the 75th percentile, the effects of appropriations on salary are not significantly different from zero

[22]The three year moving average version of this table is presented in appendix table B.3.

Table 9: *Quantile regressions of the effect of state appropriations on log salary with interactions of department and rank, 2010-2017.*

	(1) OLS	(2) 10%	(3) 25%	(4) 50%	(5) 75%	(6) 90%
Ln State Appropriations	0.148***	0.459***	0.207***	0.093***	0.024	-0.040**
	(0.025)	(0.040)	(0.021)	(0.017)	(0.017)	(0.018)
Biology	2.202***	4.496***	2.342***	1.159***	0.788**	0.674
	(0.395)	(0.680)	(0.299)	(0.267)	(0.309)	(0.568)
Chemistry	-1.046**	1.642**	0.139	-0.944***	-2.107***	-4.120***
	(0.461)	(0.664)	(0.272)	(0.294)	(0.374)	(0.465)
Computer Science	-0.521	4.806***	2.228***	-0.687**	-1.773***	-3.656***
	(0.464)	(0.848)	(0.301)	(0.267)	(0.405)	(0.412)
Economics	4.327***	4.752***	2.933***	1.212***	0.729*	-0.002
	(0.613)	(0.796)	(0.799)	(0.443)	(0.404)	(0.455)
History	-0.239	2.752***	0.344	-0.828***	-1.238***	-2.106***
	(0.404)	(0.677)	(0.277)	(0.226)	(0.304)	(0.373)
Mathematics	-0.620	1.264**	-0.734	-1.675***	-1.668***	-2.021***
	(0.414)	(0.618)	(0.553)	(0.322)	(0.321)	(0.354)
Philosophy	2.236***	5.559***	1.979***	-0.974**	-0.338	-0.768
	(0.584)	(0.945)	(0.538)	(0.416)	(0.396)	(0.616)
Physics	0.464	3.155***	0.484	-0.560**	-2.377***	-2.775***
	(0.405)	(0.661)	(0.297)	(0.261)	(0.313)	(0.481)
Political Science	1.427***	2.447***	0.303	0.094	0.563*	1.111*
	(0.460)	(0.835)	(0.355)	(0.337)	(0.338)	(0.636)
Psychology	1.919***	3.330***	1.344***	-0.166	-0.085	-0.405
	(0.461)	(0.758)	(0.409)	(0.281)	(0.359)	(0.364)
Sociology	-0.681	1.678**	0.300	-1.667***	-2.458***	-2.794***
	(0.473)	(0.717)	(0.346)	(0.323)	(0.387)	(0.577)
Biology X Ln Appropriations	-0.103***	-0.221***	-0.112***	-0.051***	-0.032**	-0.026
	(0.020)	(0.034)	(0.015)	(0.013)	(0.016)	(0.029)
Chemistry X Ln Appropriations	0.064***	-0.075**	0.002	0.058***	0.117***	0.219***
	(0.023)	(0.033)	(0.014)	(0.015)	(0.019)	(0.024)
Computer Science X Ln Appropriations	0.043*	-0.227***	-0.096***	0.053***	0.108***	0.203***
	(0.023)	(0.043)	(0.015)	(0.014)	(0.021)	(0.021)
Economics X Ln Appropriations	-0.196***	-0.224***	-0.128***	-0.036	-0.010	0.029
	(0.031)	(0.040)	(0.040)	(0.022)	(0.020)	(0.023)
History X Ln Appropriations	0.013	-0.139***	-0.016	0.043***	0.063***	0.106***
	(0.020)	(0.034)	(0.014)	(0.011)	(0.015)	(0.019)
Mathematics X Ln Appropriations	0.034	-0.065**	0.038	0.090***	0.091***	0.107***
	(0.021)	(0.031)	(0.028)	(0.016)	(0.016)	(0.018)
Philosophy X Ln Appropriations	-0.112***	-0.282***	-0.101***	0.051**	0.019	0.039
	(0.030)	(0.048)	(0.028)	(0.021)	(0.020)	(0.031)
Physics X Ln Appropriations	-0.016	-0.152***	-0.018	0.036***	0.128***	0.148***
	(0.021)	(0.033)	(0.015)	(0.013)	(0.016)	(0.024)
Political Science X Ln Appropriations	-0.063***	-0.117***	-0.009	0.004	-0.019	-0.046
	(0.023)	(0.042)	(0.018)	(0.017)	(0.017)	(0.032)
Psychology X Ln Appropriations	-0.089***	-0.163***	-0.062***	0.016	0.013	0.028
	(0.023)	(0.038)	(0.021)	(0.014)	(0.018)	(0.018)
Sociology X Ln Appropriations	0.040*	-0.080**	-0.010	0.090***	0.130***	0.148***
	(0.024)	(0.036)	(0.017)	(0.016)	(0.020)	(0.030)
Associate	-0.122	1.530***	0.426*	0.006	0.106	-0.186
	(0.248)	(0.285)	(0.252)	(0.135)	(0.128)	(0.171)
Professor	0.669**	1.938***	0.529**	-0.013	0.043	0.577**
	(0.260)	(0.278)	(0.268)	(0.171)	(0.198)	(0.242)
Associate X Ln Appropriations	0.016	-0.063***	-0.013	0.007	0.002	0.018**
	(0.013)	(0.014)	(0.013)	(0.007)	(0.007)	(0.009)
Professor X Ln Appropriations	-0.006	-0.071***	-0.005	0.024***	0.026***	0.006
	(0.013)	(0.014)	(0.014)	(0.009)	(0.010)	(0.012)
Constant	8.162***	1.708**	6.917***	9.254***	10.728***	12.151***
	(0.506)	(0.796)	(0.415)	(0.336)	(0.348)	(0.368)
N	43241	43241	43241	43241	43241	43241

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English and Assistant Professor Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

in biology, economics, and political science. In all other fields, the strength of response approaches zero, but remains significant. At the 90th percentile, the predicted marginal effects in English, biology, and politics become negative. This phenomenon may potentially be caused by the negative relationship between appropriations and retention cases. If the overall effect of having fewer "large raises" outweighs the effect of having more standard raises, then it is plausible that average salary levels decline in response to appropriations increases for highly-productive faculty in these fields.

Appropriations impact the lowest earning faculty at a far greater magnitude than the highest earning faculty, which bears important implications in the understanding of faculty labor markets. The fact that the top 10 percent of earners, superstars, do not respond to appropriations changes implies that their salaries are already at competitive levels. The same cannot be said for those below them on the distribution, where universities are able to exert their monopsony power. Because of the presence of monopsony power, these faculty rely on budgetary factors to receive raises, and thus experience far more variation in their earnings levels. Therefore, a key takeaway from these results is that in faculty labor markets, wage gaps are cyclical.

6.3 Effects of Appropriations, by Gender

Appropriations may impact men and women differently due to variation in the level of labor market frictions between genders. The theoretical setup presents the hypothesis that that women may be more likely than men to earn below their competitive wage, because social factors and family constraints are more likely to inhibit their mobility. If this is the case, then it would grant universities a certain level of differential monopsony power over women. By adding an interaction of gender and log appropriations to the set of quantile regressions, these results aim to isolate the differential impacts of appropriations on salary by gender. Table 10 presents the results of the quantile regressions with gender/appropriations interactions, in addition to full interactions of gender/appropriations/field. These specifications also control for field, rank, year, and school.[23]

These results show that the wedge that mobility-based market frictions creates between productivity and income varies significantly by field. Notably, the gender gap in the response of faculty salary to appropriations is by far the largest in the economics field; in all other fields, the gap is modest or insignificant. At the 10th income percentile in response to a 10 percent increase in appropriations, salaries for female economists increase by increase by 5.37 percentage points, on average.[24] This is 4.57 percentage points more than the increase for male economists. In the OLS specification, this difference is 3.39 percentage points. This difference is weaker for faculty in higher portions of the income distribution, yet remains statistically and economically significant.

The fact that the gender gap in income cyclicality is by far the largest in the economics field makes sense given that raises in faculty labor markets are tied to outside offers through the "implicit peer review" strategy, and that among the fields in the data, the economics field is the most active field in the data with regards to hiring and exit. Because of the frequency of outside offers, faculty who are fully mobile have greater opportunity to realize increases in salary. At the same time, faculty who are constrained to local labor markets lack the ability to take advantage of outside offers to induce merit-based raises. As a result, if women are expected to be more likely to have mobility limitations, there will be gender gap in salary, conditional on rank and field. Because of these mobility limitations and the gap between wages and market competitive wages for women, the theoretical framework suggests that responses to appropriations will be strongest for women.

[23] Note that not all coefficients from these specifications are presented in table 10. Field intercepts, field x gender interactions, rank interactions and intercepts, and school and year controls are left out of this table.

[24] This is the total marginal effect for female economists, which is the sum of the terms on "Ln State Appropriations", "Female X Ln Appropriations", "Econ X Ln Appropriations", and "Econ X Female X Ln Appropriations".

Table 10: *Quantile regressions of the effect of log state appropriations on log salary, by gender, 2010-2017.*

	(1) OLS	(2) 10%	(3) 25%	(4) 50%	(5) 75%	(6) 90%
Ln State Appropriations	0.119***	0.315***	0.171***	0.069***	0.015	-0.024
	(0.031)	(0.039)	(0.022)	(0.018)	(0.022)	(0.028)
Female	-0.263	-1.593	-0.634	-0.491	-0.247	1.751**
	(0.620)	(1.146)	(0.446)	(0.352)	(0.464)	(0.733)
Female X Ln Appropriations	0.010	0.077	0.030	0.023	0.009	-0.092**
	(0.031)	(0.058)	(0.023)	(0.018)	(0.024)	(0.037)
Biology X Ln Appropriations	-0.055*	-0.118***	-0.054***	-0.026	-0.011	-0.057*
	(0.029)	(0.029)	(0.019)	(0.019)	(0.022)	(0.033)
Chemistry X Ln Appropriations	0.076**	-0.088**	0.026	0.101***	0.151***	0.219***
	(0.032)	(0.036)	(0.017)	(0.019)	(0.025)	(0.035)
CS X Ln Appropriations	0.102***	-0.064	-0.007	0.115***	0.137***	0.206***
	(0.032)	(0.061)	(0.019)	(0.017)	(0.024)	(0.032)
Econ X Ln Appropriations	-0.247***	-0.312***	-0.124**	0.107***	0.036	-0.010
	(0.048)	(0.075)	(0.059)	(0.028)	(0.026)	(0.033)
History X Ln Appropriations	-0.008	-0.181***	-0.058***	0.044**	-0.001	-0.035
	(0.030)	(0.038)	(0.019)	(0.017)	(0.023)	(0.035)
Math X Ln Appropriations	0.045	-0.005	-0.029	0.097***	0.109***	0.084***
	(0.028)	(0.033)	(0.029)	(0.021)	(0.021)	(0.028)
Philosophy X Ln Appropriations	-0.182***	-0.328***	-0.216***	-0.034	-0.034	-0.066**
	(0.042)	(0.098)	(0.033)	(0.028)	(0.026)	(0.030)
Physics X Ln Appropriations	0.024	-0.075**	0.023	0.057***	0.154***	0.155***
	(0.027)	(0.035)	(0.016)	(0.017)	(0.022)	(0.033)
Politics X Ln Appropriations	-0.008	0.059	0.107***	0.094***	0.030	-0.051
	(0.035)	(0.046)	(0.022)	(0.029)	(0.027)	(0.042)
Psychology X Ln Appropriations	-0.026	-0.120**	0.025	0.091***	-0.031	0.045
	(0.034)	(0.049)	(0.020)	(0.022)	(0.033)	(0.028)
Sociology X Ln Appropriations	0.079**	-0.024	0.036	0.100***	0.105***	0.228***
	(0.039)	(0.039)	(0.029)	(0.030)	(0.036)	(0.036)
Biology X Female X Ln Appropriations	-0.070	-0.193***	-0.116***	-0.042	-0.038	0.148***
	(0.045)	(0.060)	(0.036)	(0.030)	(0.032)	(0.047)
Chemistry X Female X Ln Appropriations	0.120*	0.146*	-0.001	-0.054	-0.016	0.115
	(0.066)	(0.086)	(0.045)	(0.035)	(0.043)	(0.092)
CS X Female X Ln Appropriations	-0.142**	-0.366	-0.040	-0.052	0.015	0.089
	(0.071)	(0.236)	(0.071)	(0.048)	(0.051)	(0.069)
Econ X Female X Ln Appropriations	0.339***	0.457***	0.238**	0.021	0.147***	0.212***
	(0.066)	(0.093)	(0.102)	(0.046)	(0.032)	(0.052)
History X Female X Ln Appropriations	-0.039	0.001	0.002	-0.036	0.021	0.107**
	(0.046)	(0.068)	(0.035)	(0.026)	(0.031)	(0.051)
Math X Female X Ln Appropriations	-0.066	-0.104	-0.166	-0.121***	-0.094***	0.044
	(0.051)	(0.085)	(0.192)	(0.047)	(0.032)	(0.045)
Philosophy X Female X Ln Appropriations	0.089	-0.012	0.080*	0.140***	0.025	0.155
	(0.071)	(0.135)	(0.046)	(0.050)	(0.032)	(0.105)
Physics X Female X Ln Appropriations	-0.103	-0.040	-0.090***	-0.050	-0.100**	-0.029
	(0.071)	(0.086)	(0.034)	(0.030)	(0.045)	(0.064)
Politics X Female X Ln Appropriations	0.007	-0.075	-0.068*	-0.046	-0.046	0.104
	(0.052)	(0.108)	(0.038)	(0.034)	(0.036)	(0.064)
Psychology X Female X Ln Appropriations	-0.067	-0.139*	-0.142***	-0.103***	0.102***	0.116**
	(0.049)	(0.072)	(0.037)	(0.030)	(0.038)	(0.048)
Sociology X Female X Ln Appropriations	-0.024	-0.056	-0.077**	-0.038	0.032	-0.046
	(0.054)	(0.066)	(0.036)	(0.036)	(0.041)	(0.053)
Constant	8.607***	4.430***	7.530***	9.652***	10.830***	11.712***
	(0.603)	(0.767)	(0.442)	(0.356)	(0.427)	(0.555)
N	38446	38446	38446	38446	38446	38446

Standard errors in parentheses
Specifications control for year, school, field, and rank
Full set of interactions are included, but not shown. This includes field intercepts and and field/female interactions.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7 Discussion

Using data on faculty salaries at public universities, this analysis demonstrates that increases in state appropriations positively impact salary levels and department size, and negatively affect retention cases.[25] Moreover, this analysis establishes how the responses of faculty salaries to appropriations changes vary with field, expected productivity, rank, and expected mobility. Differences in response among each of these variables are tied to market frictions and the likelihood of outside offers.

In a perfectly competitive model, changes in levels of funding do not vary in their impact on faculty salaries because each employed individual earns their market competitive wage. However, the monopsony framework of the faculty labor market allows state appropriations to drive a wedge between compensation and productivity. The differential responses of faculty salary to appropriations by field, baseline compensation, and gender exacerbate inequality in multiple ways that are tied to market frictions, rather than research and teaching outcomes.

First, departments vary in how they respond to budget decreases, and face a trade off between adjusting through salary and adjusting through department size. The level of outside options in a given field is correlated with the proportion of response on the extensive margin. In fields where faculty have greater market options, departments are less successful in decreasing relative wages and concurrently retaining faculty. In fields where faculty have limited outside market options, limited faculty mobility grants departments with the ability to freeze raises while still retaining faculty. This mechanism widens the gap in average salaries between fields with lower market options and fields with higher market options where departments must keep salaries close to competitive levels. Second, conditional on rank and field, faculty at the bottom of the

[25] The symmetry assumed in this analysis unlikely entirely holds. The effects of appropriations increases and decreases are unlikely symmetric because one rarely records nominal decreases in wages.

income distribution experience the most cyclicality in their earnings, while the highest earning faculty experience the least. Because baseline income serves as an approximation of productivity, this implies that research and teaching productivity are key drivers in the response of salary to appropriations. In periods of declines to state appropriations, the salary variation between the highest earning faculty and the lowest earning faculty is likely to grow. This growth in income inequality is plausibly related to differences in monopsony power, rather fully attributable to individual differences productivity growth. Third, the differential impact of appropriations on gender is most notable in the economics field, where women earn less than men conditional on rank and field, and therefore experience greater salary response to appropriations shocks. This gender gap in income cyclicality in economics is a likely a product of gender-based market frictions.

The economic constraints that are already apparent with the COVID-19 pandemic will likely produce substantial contractions in state support for higher education in the coming years. In addition, the pandemic may prevent universities from smoothing appropriations declines by increasing funding from other sources. Declining demand for U.S. education from international students will limit the extent to which universities can increase tuition revenue, as will hesitance by students to pay full tuition for an "online-only" education. These factors will intensify the imminent appropriations declines. As they did in the 2008 recession, many universities are set to implement policies such as hiring freezes and salary freezes for the forthcoming academic year due to decreases in the university's total funding. Harvard University and the University of Virginia, among many others, have already adopted these policies in anticipation of budget cuts. This will not only affect faculty earnings but also have impacts on research and student outcomes through larger student/teacher ratios and diminishing resource levels.

The 2008 recession prompted a large and prolonged decrease in state appropriations; the average state now spends over 16 percent less per student than their pre-recession level (Mitchell, Leachman, Masterson, & Waxman, 2018). In the current pandemic, given the economic forecasts for the second half of 2020, appropriations will likely decrease by much more. In addition, similar to in 2008, certain states are experiencing greater financial hardships than others. This will create variation in budget cuts among public universities, with mobility-related inequality increasing at some institutions by more than others. This should also allow universities in states with smaller budget cuts to compete for faculty in the hiring market more so than universities with large and prolonged appropriations declines.

Public universities whose aim is to maximize an objective function which includes education quality may benefit from adjusting their policies in a recession and distributing budgets to departments according to an inverse relationship with monopsony power. Doing so would allow departments whose faculty have high levels of outside options to retain their top researchers and sacrifice less in terms of department size. This may hurt faculty salaries in other departments, but due to monopsony power, departments in these fields should face less exit, and therefore smaller declines in research output and teaching quality, which the university aims to maximize. Yet, strategic behavior which explicitly recognizes and rewards differences in the degree to which individuals have the personal latitude to seek outside offers may also increase inequities in compensation that are not related to productivity.

There is certainly more work to be done on this topic. For one, this research could be improved by expanding this analysis to a larger number of public universities and a wider range of time series data. Having data on research output would also improve the ability to measure faculty productivity. In addition, repeating this analysis in the future to capture the effects of the impending COVID-19 related budget contractions would allow for the analysis of a substantial negative appropriations shock and the effects of salary and hiring freezes.

One particularly salient next step in this research literature may be to tie the effect of appropriations shocks on the faculty labor market to available measures of research productivity including patents, publications and citations. This work speculates on how variables such as department size and the retention of top professors impact students and research, but the understanding of this relationship can be improved. While other work has documented that appropriations do impact student outcomes, the extent to which this is driven by changes in faculty composition is unknown. Do appropriations impact students and research via faculty, changes in resources available, or both? With educational funding set to decline in this recession, along with a potential increase in demand for higher education, negative shocks to teaching and research may have pertinent applications to innovation and the supply of skilled labor.

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Appendices

A Data Appendix: Assigning Genders

Genders were assigned to names using the service Gender-API.[26] This platform utilizes a historical database of names to predict one's gender based on first name. Santamaria and Mihaljevic (2018) argue for the efficacy of this platform relative to other services with a similar goal.

Gender-API produces a gender prediction along with an accuracy level for each prediction, which ranges from 0-100. An accuracy level of 100 indicates 100% certainty of the predicted gender. I denote a 'match' as any prediction with an accuracy level greater than or equal to 80.

Faculty from the University of Connecticut were unable to be genderized because they were reported via unique numerical identifiers, rather than by full names. However, I have full names for faculty from the remaining 11 schools in my data set. I feed all available names (7,635) into the algorithm and achieve a 94% match rate. After merging back to the original data set, I find that genderized entries account for 48,954 observations, which is 88.87% of the total sample. Among the matched sample, over 71.35% of faculty are male.

If unmatched faculty are inherently different from matched faculty, then there would be an endogeneity problem in the gender regressions. As a confirmation of robustness, I find that there is no statistically significant difference in the distribution of salary between matched and unmatched individuals.

[26] https://gender-api.com/

B Supplementary Tables and Figures

Figure B.1: *Median salary growth rates by field, 2010-2018.*

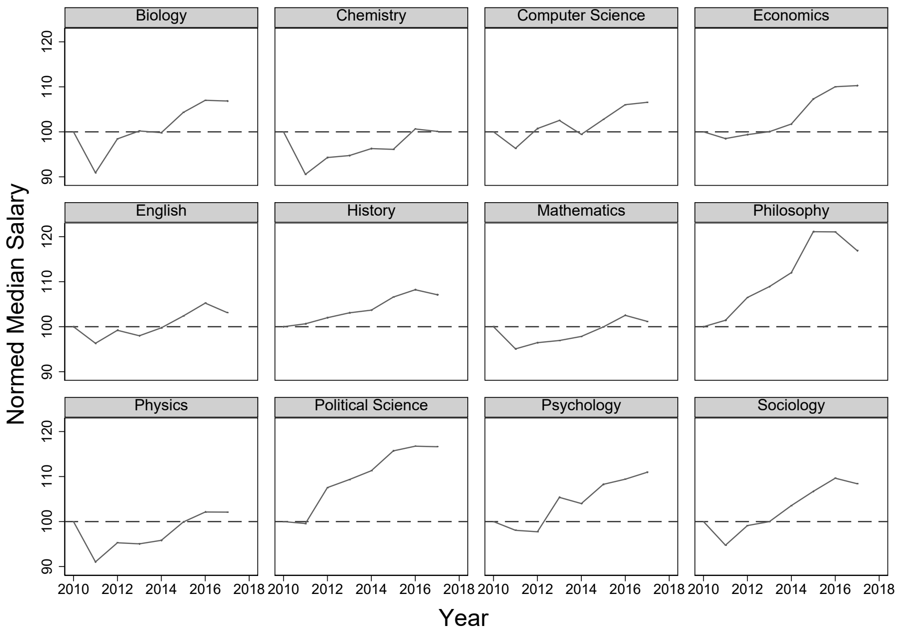

Table B.1: *Full results of the effect of the log of a three year moving average of state appropriations on log salary pool, log department size, log salary, and salary variance by department, 2010-2017.*

	(1) Ln Salary Pool	(2) Ln Num. in Department	(3) Ln Salary	(4) Var. Salary
Ln State Appropriations (MA-3)	0.524**	0.429*	0.266***	-0.149**
	(0.257)	(0.239)	(0.081)	(0.059)
Biology	-0.141	-0.841	1.623	-0.634
	(4.290)	(4.492)	(1.257)	(1.259)
Chemistry	-3.814	-0.375	-2.190	-2.803**
	(4.290)	(3.865)	(1.941)	(1.095)
Computer Science	-1.083	0.107	-1.021	-2.680**
	(6.135)	(5.765)	(1.846)	(1.194)
Economics	-8.325	-9.958**	4.823*	-3.759**
	(5.465)	(4.430)	(2.650)	(1.659)
History	-8.767*	-6.957	-0.837	-1.372
	(4.903)	(4.243)	(1.928)	(1.160)
Mathematics	-1.554	0.116	-0.831	-1.649
	(5.486)	(6.235)	(2.330)	(1.217)
Philosophy	-9.491**	-6.495*	0.080	-2.112
	(4.126)	(3.867)	(2.595)	(1.414)
Physics	-4.800	-2.869	-1.052	-1.724
	(5.022)	(4.738)	(1.777)	(1.318)
Political Science	-7.619*	-6.946*	1.126	-0.731
	(4.051)	(4.156)	(2.245)	(1.745)
Psychology	0.310	-2.188	3.338**	-0.981
	(4.625)	(4.677)	(1.645)	(1.199)
Sociology	-5.139	-1.138	-2.246*	-2.263*
	(4.846)	(4.682)	(1.304)	(1.228)
Biology X Ln Appropriations	0.002	0.030	-0.075	0.033
	(0.219)	(0.228)	(0.063)	(0.064)
Chemistry X Ln Appropriations	0.190	0.003	0.123	0.145***
	(0.218)	(0.196)	(0.098)	(0.055)
Computer Science X Ln Appropriations	0.046	-0.030	0.067	0.133**
	(0.310)	(0.290)	(0.093)	(0.060)
Economics X Ln Appropriations	0.405	0.467**	-0.224*	0.190**
	(0.276)	(0.225)	(0.134)	(0.084)
History X Ln Appropriations	0.430*	0.340	0.042	0.068
	(0.249)	(0.215)	(0.098)	(0.058)
Mathematics X Ln Appropriations	0.085	-0.005	0.044	0.085
	(0.281)	(0.319)	(0.117)	(0.061)
Philosophy X Ln Appropriations	0.426**	0.273	-0.004	0.108
	(0.210)	(0.197)	(0.131)	(0.071)
Physics X Ln Appropriations	0.242	0.134	0.064	0.087
	(0.256)	(0.241)	(0.089)	(0.066)
Political Science X Ln Appropriations	0.364*	0.323	-0.051	0.040
	(0.206)	(0.211)	(0.113)	(0.087)
Psychology X Ln Appropriations	-0.021	0.098	-0.162*	0.052
	(0.235)	(0.237)	(0.084)	(0.061)
Sociology X Ln Appropriations	0.228	0.020	0.118*	0.115*
	(0.245)	(0.237)	(0.066)	(0.062)
Constant	4.556	-4.983	6.069***	3.289***
	(5.114)	(4.743)	(1.628)	(1.178)
N	1088	1088	43241	1088
R^2	0.811	0.820	0.144	0.412

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.2: *Full results of the effect of log state appropriations on log salary, raises, and retention cases, 2010-2017.*

	(1) Ln Salary	(2) Raise	(3) Raise > 10%	(4) Raise > 20%
Ln State Appropriations	0.148*	0.203***	-0.122***	-0.120***
	(0.081)	(0.074)	(0.030)	(0.029)
Associate	-0.122	0.138	0.943***	1.148***
	(0.942)	(0.578)	(0.335)	(0.287)
Professor	0.669	-0.060	0.868**	0.934***
	(1.113)	(0.648)	(0.333)	(0.301)
Associate X Ln Appropriations	0.016	-0.007	-0.047***	-0.058***
	(0.048)	(0.029)	(0.017)	(0.015)
Professor X Ln Appropriations	-0.006	0.002	-0.044**	-0.048***
	(0.056)	(0.033)	(0.017)	(0.015)
Biology	2.202*	-1.119	-1.387***	-1.090**
	(1.280)	(1.137)	(0.503)	(0.446)
Chemistry	-1.046	-1.450	-1.252**	-1.200***
	(1.558)	(1.032)	(0.524)	(0.447)
Computer Science	-0.521	0.539	-0.859	-0.651
	(1.635)	(1.333)	(0.612)	(0.547)
Economics	4.327	-1.616	-0.581	-0.744
	(2.727)	(1.110)	(0.585)	(0.620)
History	-0.239	-0.541	-0.409	-0.657
	(1.622)	(0.992)	(0.427)	(0.464)
Mathematics	-0.620	-1.957**	-1.475***	-1.317***
	(1.544)	(0.974)	(0.352)	(0.345)
Philosophy	2.236	-0.932	-1.734**	-1.676***
	(2.171)	(1.154)	(0.770)	(0.629)
Physics	0.464	-0.250	-1.045*	-1.375***
	(1.361)	(0.972)	(0.566)	(0.493)
Political Science	1.427	-1.469	-0.611	-0.983***
	(1.696)	(1.105)	(0.466)	(0.373)
Psychology	1.919	-0.944	-1.323***	-1.400***
	(1.340)	(1.210)	(0.334)	(0.348)
Sociology	-0.681	-1.471	-0.888*	-0.749
	(1.107)	(1.107)	(0.496)	(0.479)
Biology X Ln Appropriations	-0.103	0.056	0.070***	0.055**
	(0.064)	(0.057)	(0.026)	(0.022)
Chemistry X Ln Appropriations	0.064	0.074	0.064**	0.060***
	(0.079)	(0.053)	(0.026)	(0.022)
Computer Science X Ln Appropriations	0.043	-0.025	0.043	0.033
	(0.082)	(0.067)	(0.031)	(0.028)
Economics X Ln Appropriations	-0.196	0.081	0.030	0.038
	(0.138)	(0.056)	(0.030)	(0.031)
History X Ln Appropriations	0.013	0.028	0.021	0.034
	(0.082)	(0.050)	(0.022)	(0.023)
Mathematics X Ln Appropriations	0.034	0.099**	0.074***	0.066***
	(0.078)	(0.049)	(0.018)	(0.017)
Philosophy X Ln Appropriations	-0.112	0.048	0.088**	0.086***
	(0.110)	(0.059)	(0.039)	(0.032)
Physics X Ln Appropriations	-0.016	0.013	0.052*	0.069***
	(0.068)	(0.049)	(0.029)	(0.025)
Political Science X Ln Appropriations	-0.063	0.075	0.031	0.050***
	(0.085)	(0.056)	(0.024)	(0.019)
Psychology X Ln Appropriations	-0.089	0.048	0.067***	0.071***
	(0.068)	(0.061)	(0.017)	(0.018)
Sociology X Ln Appropriations	0.040	0.075	0.045*	0.038
	(0.056)	(0.056)	(0.025)	(0.024)
Constant	8.162***	-3.343**	2.522***	2.453***
	(1.616)	(1.488)	(0.603)	(0.589)
N	43241	33809	33809	33809
R^2	0.415	0.170	0.029	0.026

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English and Assistant Professor Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.3: *Quantile regressions of the effect of the log of a three year moving average of state appropriations on log salary with interactions of department and rank, 2010-2017.*

	(1) OLS	(2) 10%	(3) 25%	(4) 50%	(5) 75%	(6) 90%
Ln State Appropriations (MA-3)	0.242***	0.670***	0.305***	0.148***	0.057***	-0.023
	(0.030)	(0.039)	(0.026)	(0.018)	(0.020)	(0.020)
Biology	2.300***	4.436***	2.591***	1.264***	0.896***	0.569
	(0.407)	(0.621)	(0.320)	(0.258)	(0.321)	(0.534)
Chemistry	-0.984**	1.532**	0.281	-0.937***	-2.206***	-4.617***
	(0.477)	(0.634)	(0.277)	(0.275)	(0.393)	(0.455)
Computer Science	-0.743	4.662***	2.426***	-0.650***	-1.839***	-4.002***
	(0.501)	(0.851)	(0.327)	(0.241)	(0.452)	(0.368)
Economics	4.474***	4.718***	2.964***	1.303***	0.821**	-0.196
	(0.630)	(0.782)	(0.754)	(0.428)	(0.416)	(0.406)
History	-0.198	2.759***	0.460*	-0.863***	-1.266***	-2.255***
	(0.412)	(0.637)	(0.270)	(0.205)	(0.311)	(0.370)
Mathematics	-0.560	1.520***	-0.785	-1.708***	-1.668***	-2.201***
	(0.428)	(0.534)	(0.553)	(0.315)	(0.328)	(0.299)
Philosophy	2.424***	5.372***	2.103***	-0.989**	-0.334	-0.946*
	(0.597)	(0.790)	(0.523)	(0.421)	(0.432)	(0.516)
Physics	0.537	3.163***	0.681**	-0.513*	-2.406***	-3.058***
	(0.415)	(0.595)	(0.272)	(0.262)	(0.315)	(0.462)
Political Science	1.498***	2.246***	0.426	0.201	0.693*	1.187*
	(0.471)	(0.832)	(0.345)	(0.332)	(0.362)	(0.619)
Psychology	2.105***	3.365***	1.599***	-0.084	0.066	-0.358
	(0.475)	(0.688)	(0.395)	(0.266)	(0.333)	(0.371)
Sociology	-0.719	1.615**	0.513	-1.783***	-2.481***	-3.255***
	(0.490)	(0.640)	(0.370)	(0.263)	(0.384)	(0.673)
Biology X Ln Appropriations	-0.108***	-0.218***	-0.124***	-0.056***	-0.037**	-0.021
	(0.021)	(0.031)	(0.016)	(0.013)	(0.016)	(0.027)
Chemistry X Ln Appropriations	0.061**	-0.069**	-0.005	0.058***	0.122***	0.244***
	(0.024)	(0.032)	(0.014)	(0.014)	(0.020)	(0.023)
Computer Science X Ln Appropriations	0.054**	-0.219***	-0.106***	0.051***	0.111***	0.220***
	(0.025)	(0.043)	(0.017)	(0.012)	(0.023)	(0.019)
Economics X Ln Appropriations	-0.203***	-0.222***	-0.130***	-0.040*	-0.014	0.038*
	(0.032)	(0.040)	(0.038)	(0.022)	(0.021)	(0.020)
History X Ln Appropriations	0.011	-0.139***	-0.022	0.044***	0.064***	0.113***
	(0.021)	(0.032)	(0.014)	(0.010)	(0.016)	(0.019)
Mathematics X Ln Appropriations	0.031	-0.078***	0.041	0.092***	0.091***	0.116***
	(0.022)	(0.027)	(0.028)	(0.016)	(0.017)	(0.015)
Philosophy X Ln Appropriations	-0.122***	-0.272***	-0.107***	0.052**	0.019	0.048*
	(0.030)	(0.040)	(0.027)	(0.021)	(0.022)	(0.026)
Physics X Ln Appropriations	-0.019	-0.153***	-0.028**	0.034**	0.130***	0.162***
	(0.021)	(0.030)	(0.014)	(0.013)	(0.016)	(0.023)
Political Science X Ln Appropriations	-0.067***	-0.107**	-0.015	-0.002	-0.025	-0.050
	(0.024)	(0.042)	(0.017)	(0.017)	(0.018)	(0.031)
Psychology X Ln Appropriations	-0.098***	-0.165***	-0.075***	0.012	0.005	0.026
	(0.024)	(0.035)	(0.020)	(0.014)	(0.017)	(0.019)
Sociology X Ln Appropriations	0.042*	-0.077**	-0.021	0.096***	0.132***	0.171***
	(0.025)	(0.032)	(0.019)	(0.013)	(0.019)	(0.035)
Associate	-0.198	1.694***	0.345	-0.046	0.070	-0.217
	(0.255)	(0.208)	(0.256)	(0.120)	(0.110)	(0.173)
Professor	0.640**	2.218***	0.491*	-0.076	-0.018	0.571**
	(0.266)	(0.208)	(0.267)	(0.163)	(0.197)	(0.241)
Associate X Ln Appropriations	0.020	-0.072***	-0.009	0.010	0.004	0.020**
	(0.013)	(0.011)	(0.013)	(0.006)	(0.006)	(0.009)
Professor X Ln Appropriations	-0.005	-0.086***	-0.003	0.027***	0.030***	0.006
	(0.014)	(0.011)	(0.014)	(0.008)	(0.010)	(0.012)
Constant	6.273***	-2.555***	4.929***	8.140***	10.072***	11.812***
	(0.603)	(0.789)	(0.513)	(0.360)	(0.398)	(0.403)
N	43241	43241	43241	43241	43241	43241

Standard errors in parentheses
Specifications include school and field fixed effects
Standard errors are clustered by department
English and Assistant Professor Omitted
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure B.2: *Marginal effects of log appropriations on log salary at the 10th income percentile, corresponding to column (2) in table 9, 2010-2017.*

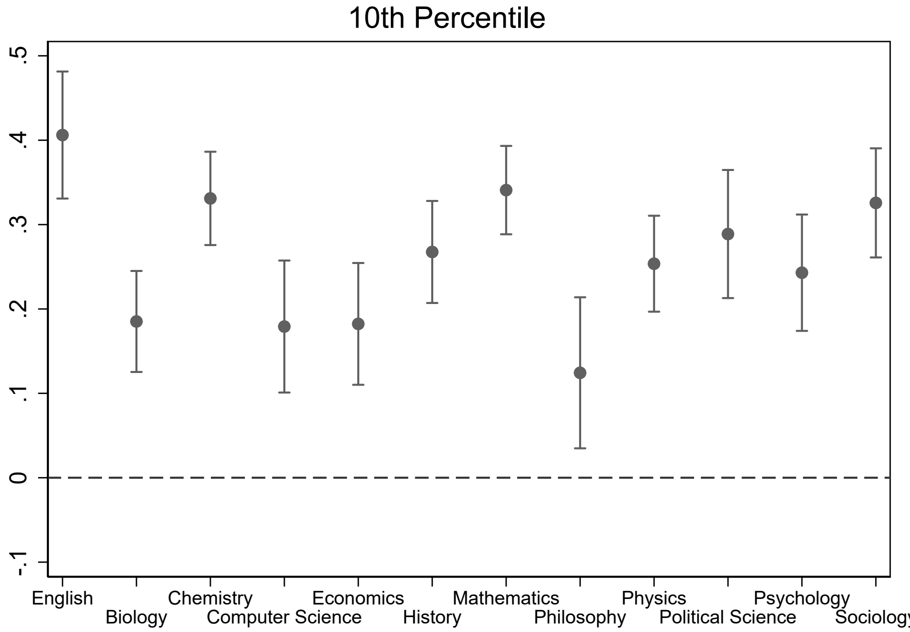

Figure B.3: *Marginal effects of log appropriations on log salary at the 25th income percentile, corresponding to column (3) in table 9, 2010-2017.*

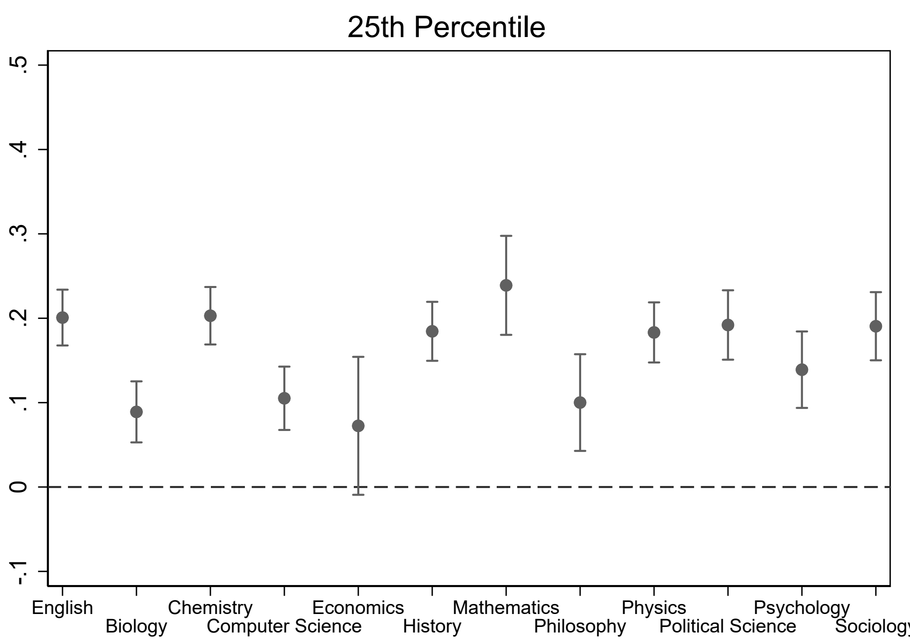

Figure B.4: *Marginal effects of log appropriations on log salary at the 50th income percentile, corresponding to column (4) in table 9, 2010-2017.*

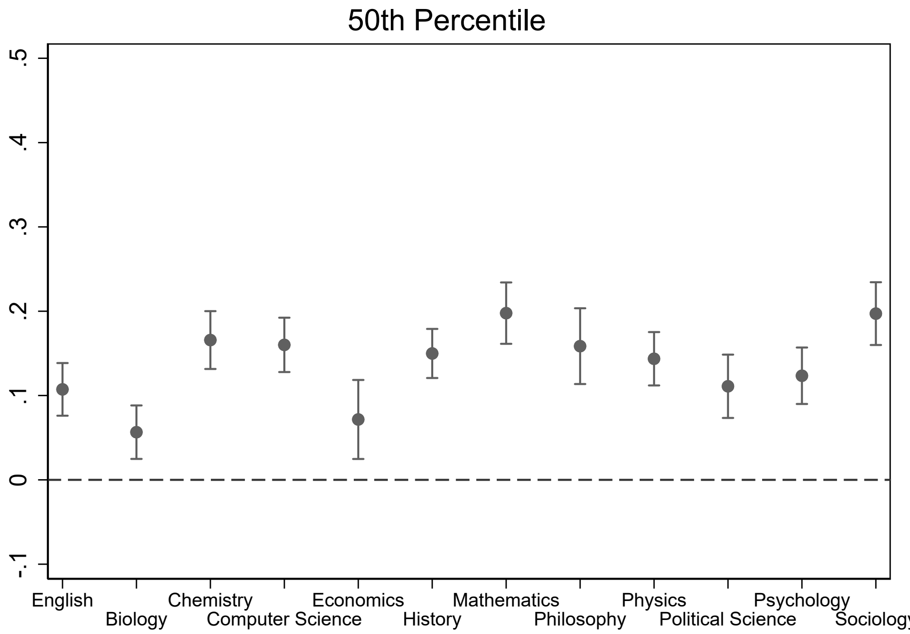

Figure B.5: *Marginal effects of log appropriations on log salary at the 75th income percentile, corresponding to column (5) in table 9, 2010-2017.*

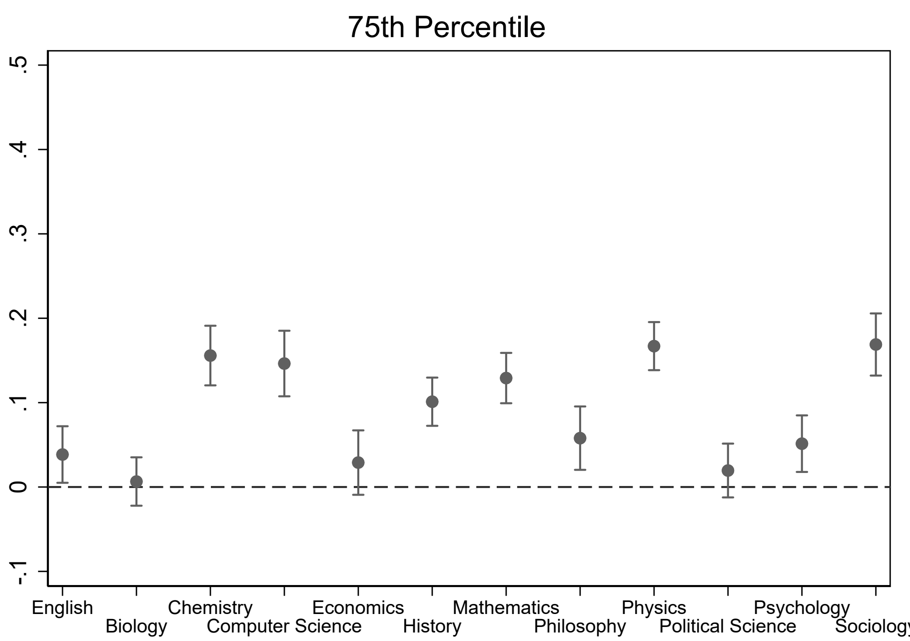

Figure B.6: *Marginal effects of log appropriations on log salary at the 90th income percentile, corresponding to column (6) in table 9, 2010-2017.*