What do course offerings reveal about university preferences? [JOB MARKET PAPER]

James Thomas*

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Abstract

This paper develops a method for inferring a university's preferences for the type of courses students choose and the utility students derive from these choices. The method is based on the idea that offering an additional course in a specific field presents a direct cost to a university, makes that field more attractive to students, and increases student utility. A university which only values student utility offers courses so that the marginal effect per dollar of offering an additional course is the same across all fields. I show that differences in these marginal effects per dollar can be used to quantify a university's willingness to sacrifice student utility in order to draw more students into certain fields. I apply my method to the introductory course offerings at University of Central Arkansas (UCA) and find that UCA is willing to sacrifice student utility to draw students out of humanities and arts courses and into STEM courses. To quantify the university's trade-off, I show that a 16.6% increase in the cost of offering a STEM course and a 13.2% decrease in the cost of offering a humanities or arts course would induce UCA to offer courses which maximize student utility.

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1 Introduction

Universities are very important social institutions—they allow students to acquire human capital which is valuable to them individually and to society more broadly. But universities

*E-mail: james.r.thomas@yale.edu. I am especially thankful to Joseph Altonji, Peter Arcidiacono, V. Joseph Hotz, Robert Garlick, Hugh Macartney, and Arnaud Maurel for ongoing advice on this project and to the Arkansas Research Center for access to and assistance with administrative data. This project has also benefited from comments from Benjamin Cowan, Lisa Kahn, and Kevin Stange and from presentations at Duke University, University of South Carolina, Yale University, the 2016 SEA Annual Meeting, and the 2017 SOLE Annual Meeting. All remaining errors are my own.

are not passive parties in the production of human capital, they are active entities which allocate their resources to maximize their payoffs subject to constraints. As recent literature shows, the inputs universities choose play important roles in the production of human capital.[1]

Given the importance of human capital production and the role of institutional inputs in this production, it is surprising that very little research attempts to understand how universities choose their institutional inputs.[2] A better understanding of these decisions is interesting in its own right but would also be useful for choosing smart policies which correctly anticipate how universities will adjust their inputs in response to reforms.

To contribute to our understanding of how universities make decisions, this paper develops a method which uses observed course offerings to reveal a university's relative preferences for total student choice utility and the type of courses students choose. This tests whether course offerings maximize student utility; if they do not, it quantifies how much student utility the university is willing to sacrifice to change the type of courses students choose. To my knowledge, this is the first attempt to understand how universities decide which courses to offer and the implications of these choices for students.

My method for inferring university preferences is built on the idea that course offerings influence the type of courses students choose and the utility students derive from these choices. While a large portion of a university's semester specific instruction budget is already earmarked to pay instructors who are on long term contracts, there is a smaller portion of the semester specific budget which is used to make marginal hiring decisions. If a university reallocates its discretionary instruction budget in a way that increases variety in one field but decreases variety in another, students will be more likely to choose courses in the first field and less likely to choose courses in the latter. The compositional change in available choices may also increase or decrease any given student's expected utility.

This framework provides an intuitive method for identifying a university's relative preferences for total student utility and the type of courses students choose: If a university's

[1] For studies of the effects of aggregate institutional spending on student outcomes see Bound and Turner (2007); Bound et al. (2010, 2012); Dynarski (2008); Turner (2004). For studies of the effects of tuition on student outcomes see Deming and Walters (2017); Hemelt and Marcotte (2011); Kane (1995). For studies of the effects of instructor characteristics on student outcomes see Bettinger and Long (2005, 2010); De Vlieger et al. (2017); Figlio et al. (2015).

[2] Two notable exceptions are Epple et al. (2006) and Epple et al. (2013). These papers develop general equilibrium models of the higher education market which explain observed variation in tuition, admission rates, student characteristics, and other measures across schools. While these papers use a macroeconomic approach to understand higher education market as a whole, my paper uses a microeconomic approach to understand the choices of one specific university. While the approach of Epple et al. (2006) and Epple et al. (2013) is better suited for policy counterfactual analysis, my approach is better suited for recovering the preference parameters which underlie university decisions.

choices maximize total student utility then offering an additional course in one field must have the same effect per dollar on total student utility as offering an additional course in another field—otherwise, a utility maximizing university could increase total utility by reallocating its discretionary budget. If marginal dollars of discretionary spending do not have the same effects on student utility across fields, the university's course offerings are not maximizing student utility. Moreover, if the marginal effect per dollar is lower in one field relative to others, this implies the university is offering too many courses in this field relative to the student-preferred allocation. This results in more students choosing courses in this field and less total student utility relative to the student-preferred setting. As such, differences in these marginal effects per dollar can be used to identify how the university trades off increasing student utility and changing the type of courses students choose.

To be clear, my method is best suited for a positive analysis of university choices. The method is designed to understand how a university allocates its instruction budget across academic fields but cannot be used to evaluate whether this process is socially optimal. While the method can establish whether observed course offerings maximize student choice utility, there are many reasons why maximizing student choice utility might not be the socially optimal goal. At the end of this paper, I discuss literature and provide suggestive evidence on the mechanisms underlying university preferences and the normative implications associated with potential mechanisms. However, a full analysis of mechanisms and normative implications is beyond the scope of this paper.

For the empirical application, I analyze the introductory course offerings of the University of Central Arkansas in Fall and Spring academic semesters of academic years 2006-07 through 2009-10. University of Central Arkansas (UCA) is a large public university in central Arkansas whose primary focus is teaching.[3] For the analysis, I use administrative data which include full student transcripts and detailed information on all offered courses. These data allow me to analyze the relationship between the characteristics of offered courses and the choices of students. This allows me to obtain estimates of the effects of offering additional courses on student choices and utility. Furthermore, detailed course information allows me to estimate the cost of offering courses with different characteristics. Together, the data allow me to analyze both the costs and benefits of offering additional courses in each academic field—it is differences in these costs and benefits across fields which will be crucial

[3]UCA's teaching focus is apparent in their vision statement:

> The University of Central Arkansas aspires to be a premier learner-focused public university, a nationally recognized leader for its continuous record of excellence in undergraduate and graduate education, scholarly and creative endeavors, and engagement with local, national, and global communities. (Board, 2011)

for inferring university preferences over total student choice utility and the type of courses students choose.

To estimate a university's relative preferences for total student utility and the number of students choosing courses in each field I employ a two step procedure: First, I analyze observed student choices taking the set of offered courses as given; second, I analyze the university's decision of which courses to offer given the anticipated responses of students. The primary goal of the first step is to estimate marginal effects per dollar of offering additional courses in each academic field on total student utility and the number of students choosing courses in each field. To do this, I use a static nested logit model of course choices where nests are determined by the academic field of a course. A crucial feature of this model is that the nesting parameter allows marginal effects of offering additional courses to reflect empirical variation in the relationship between course offerings and course choices.

Results of this first step show that adding one introductory humanities or arts course increases total student utility by 37.0% more per dollar than adding one introductory STEM course, adding one introductory social science course increases total student utility by 23.9% more per dollar than one introductory STEM course, and adding one introductory business or occupational course increases total student utility by 16.7% more per dollar than one introductory STEM course. These differences imply UCA is sacrificing some student utility to draw students out of introductory humanities and arts courses and into introductory STEM courses.

The second step uses these differences in marginal effects per dollar to quantify exactly how much student utility UCA is willing to sacrifice to draw students away from introductory humanities and arts courses and into introductory STEM courses. To do this, I derive first order conditions describing the optimal field composition of offered courses for a university which values total student utility and the number of students choosing courses in each field and faces budget and contract constraints. These first order conditions depend on university preference parameters and the marginal effects per dollar of offering additional courses obtained in the first step. Inverting the system of first order conditions yields an expression for university preference parameters as a function of marginal effects and costs obtained previously. Substituting yields estimates of university preference parameters which rationalize why the observed field composition was optimal for the university given its constraints.

To quantify the importance of these university preferences, I solve for counterfactual costs which would induce University of Central Arkansas to offer the student-preferred allocation while maintaining the same level of total expenditures. I find that it would take a 16.6% increase in the cost of offering an introductory STEM course, a 0.7% increase in the cost of offering an introductory business or occupational course, a 5.5% decrease in the cost of offering an introductory social science course, and a 13.2% decrease in the cost of offering an introductory humanities or arts course to price out institutional preferences and induce the university to offer courses which maximize student utility.

Finally, I conclude with a brief discussion of why UCA might be willing to sacrifice student utility to draw students out of introductory humanities and arts courses and into introductory STEM courses. Existing literature shows—and naïve regressions in my data suggest—that STEM courses have higher labor market returns but involve more student effort than other courses. If students are myopic or have incomplete information about heterogeneous labor market returns, UCA's preference for STEM enrollment may reflect paternalistic behavior which maximizes student welfare in the long run. Alternatively, if higher labor market returns also imply larger social externalities, UCA's preference for STEM enrollment may reflect a desire to maximize social welfare more broadly.

This paper relates to a growing literature on the supply side of higher education which analyzes the role of universities in education production.[4] One branch of this literature focuses on estimating the effects of university choices and inputs on student outcomes. This includes studies of 'cohort crowding' effects which estimate the effects of aggregate institutional spending on student outcomes (Bound and Turner, 2007; Bound et al., 2010, 2012; Dynarski, 2008; Turner, 2004) and complementary work which estimates the effects of university tuition on student outcomes (Deming and Walters, 2017; Hemelt and Marcotte, 2011; Kane, 1995). Other studies in this branch of supply side higher education literature estimate the effects of instructor characteristics on student outcomes (Bettinger and Long, 2005, 2010; De Vlieger et al., 2017; Figlio et al., 2015). A second branch of this literature aims to form a better understanding of how universities make decisions. This includes studies which develop general equilibrium models of competition in the higher education market (Epple et al., 2006, 2013; Rothschild and White, 1995) as well as tests of the 'Bennett hypothesis' which predicts that universities will respond to increases in government student aid by increasing tuition (Cellini and Goldin, 2014; Long, 2004; Singell and Stone, 2007; Turner, 2017).

To my knowledge, the present paper is the first study to analyze how universities decide which courses to offer and the implications for students. Because the main objective of this analysis is to better understand university behavior, this study primarily complements the second branch of supply side higher education literature described above. However, because this paper also considers the effects of course offerings on student choices and utility, it also relates to the first branch of supply side higher education literature which estimates the

[4] Notable contributions not mentioned in the body include but are not limited to: Andrews and Stange (2016); Bhattacharya et al. (2016); Carrell and West (2010); Cellini (2009, 2010); Dinerstein et al. (2014); Hoffmann and Oreopoulos (2009); Hoxby (1997); Jacob et al. (2015); Pope and Pope (2009, 2014)

effects of university choices and inputs on student outcomes.

The remainder of this paper proceeds as follows: Section 2 describes the administrative data and gives background information about the University of Central Arkansas, Section 3 presents the method for inferring university preferences from observed course offerings, Section 4 presents main results, Section 5 performs a counterfactual analysis to quantify the importance of university preferences and provides a brief discussion of mechanisms underlying university preferences, and Section 6 concludes.

2 Data, Descriptive Statistics, and Institutional Setting

To estimate a university's relative preferences for total student utility and the number of students choosing introductory courses in each field I use detailed administrative data from the University of Central Arkansas (UCA). UCA is a large public teaching focused university located in central Arkansas. Table 1 provides background statistics on UCA. The statistics show UCA is a less selective mid-sized university with a six year graduation rate which is below the national average.[5] Furthermore, almost all students at UCA are full-time, 24 and under, and from the state of Arkansas.

These administrative data include demographic information, admissions information, and full academic transcripts for all students who were enrolled between the 2004-05 and 2011-12 academic years and information on all offered courses and the instructors teaching these courses for all courses offered between the 1994-95 and 2011-12 academic years. I combine these to create a sub-sample of student information and course information from the 2006-07 to the 2009-10 academic years. After excluding required writing courses, required oral communication courses, required health courses, and other special courses, the sample includes 19,346 unique UCA undergraduates and 176,509 observations of students choosing introductory courses.[6]

[5] The national average six year graduation rate is 59.4% (Ginder et al., 2017).

[6] Required writing, oral communication, and health courses are specific courses which almost all students take during their Freshmen year. I exclude these courses because students are choosing these courses to satisfy a requirement rather than to maximize utility. Including these courses would lead me to overstate the desirability of fields associated with these courses. I also exclude first year seminar courses (which are only available to freshmen and can only be taken once), English as a second language courses, military science courses, and courses worth fewer than three credit hours (which are predominantly labs associated with other courses, music lessons, and exercise classes). In addition to writing, oral communication, and health courses, UCA also has general education requirements in fine arts, American history and government, humanities, mathematics, natural sciences, behavioral and social sciences, and world cultural traditions. These requirements can be satisfied with many different courses and are often completed in later years. Furthermore, many of these courses also satisfy major specific requirements. I include these courses because many students are choosing these courses to maximize utility. For more information, please see the UCA course bulletin (UCA, 2006).

These administrative data are ideal for this study for two reasons: First, the transcript data, together with data on student characteristics and course offerings, allow me to analyze how student characteristics and the set of offered courses influence course choices. This allows me to obtain estimates of the effects of offering additional courses on student choices and utility. Second, the data include information on instructor salaries and contracts which allows me to estimate the cost of offering course sections with different characteristics and to identify which instructors must be paid to honor existing contracts and which instructors were hired for this semester only. This detailed instructor information is essential for understanding the cost side of course offering decisions and to correctly identify which budgeting decisions were truly discretionary and which decisions were predetermined.

Briefly, the empirical methodology presented in Section 3 involves analyzing how the set of available courses affects the type of courses students choose and the utility they derive from these choices and then inferring what institutional preferences best explain why the university chose to offer the courses observed in the data. For this analysis, it is thus necessary to define exactly what constitutes a "course". In Section 3, I specify a model in which an additional course provides meaningful choice variety to students and presents a direct cost to the university. Since my primary focus is on the course offerings of the university, I define a course as the unit the university gives teaching credit for (and thus effectively pays for). At UCA, the university gives teaching credit for course sections; that is, an instructor who teaches two sections of Introductory Economics receives two courses worth of teaching credit. As such, I use course sections (defined by a course number, instructor, and meeting time) as the unit of analysis. For brevity, the remainder of the paper refers to course sections simply as "courses".[7]

Figure 1 charts general statistics on instruction spending and enrollment in introductory courses at UCA. First, chart A displays the share of instruction spending which is paid to instructors with various contract arrangements. The chart shows 94% of spending on introductory courses is paid to instructors that are either tenured, tenure-track, or on long term contracts but ineligible for tenure.[8] The remaining 6% is paid to instructors who are

[7]One may argue that offering a new course should provide more choice variety to students than offering an additional section of an existing course. In theory, one could allow for multiple levels of variety with a hierarchical nesting structure in which the top level of nests is defined by academic field and the bottom level of nests is defined by a course number. However, a model of university course offerings which is consistent with this richer student model would be intractable. One may also claim that offering a new course should cost the university more than offering an additional section of an existing course. Due to data limitations, I am unable to separately estimate the cost of offering a new course and the cost of offering an additional section of an existing course. For tractability and as a result of data limitations, I assume new courses and additional sections of existing courses provide the same choice variety to students and cost the same amount to the university.

[8]See Appendix A for additional information on categories of instructor contract types.

not on long term contracts. The university is free to release these instructors before each semester; therefore, I treat this share as the component of the budget which UCA is free to reallocate across fields in the short-run. Chart B displays the share of student enrollment which is taught by instructors with different contract terms. Because non-contract instructors generally have lower salaries and teach larger classes, the share of enrollment taught by non-contract instructors is substantially larger than the share of the budget paid to these instructors.

Charts C and D decompose spending and enrollment for contracted instructors by academic field and Charts E and F repeat this exercise for non-contract instructors.[9] Charts C and D show that while 36% of expenditures paid to contracted instructors teaching introductory courses are paid to STEM instructors, courses taught by these instructors attract only 26% of student enrollment in introductory courses taught by contracted instructors. Similarly, Charts E and F show that non-contract STEM instructors receive 44% of salaries paid to non-contract instructors but attract only 41% of student enrollments. This illustrates that for both contracted instructors—whom UCA cannot release in the short run—and for non-contract instructors—whom UCA can release before each semester—STEM instructors receive a disproportionately high share of salaries relative to the enrollments they attract.

My method for inferring university preferences requires understanding how changing the set of offered courses would affect student choices and utility. If offering an additional course section has the same effect per dollar on student utility across fields, the university's choices are maximizing student utility. If these effects per dollar differ across fields, observed course offerings do not maximize student utility. Moreover, the magnitudes of these differences can be used to quantify the university's relative preferences for total student utility and the number of students choosing introductory courses in each field.

In subsequent sections, I develop a course choice model and estimate the parameters of this model to construct these marginal effects. Before proceeding to these model-based results, the statistics in Table 2 expand upon the previous charts to provide suggestive evidence on the relative magnitudes of these marginal effects. The statistics show that in Fall and Spring semesters of the 2006-07 to the 2009-10 academic years, UCA spent \$1,508,220 offering introductory STEM courses taught by non-contract instructors yielding 8,973 observations of students choosing introductory STEM courses. This implies that \$1,000 of spending on non-contract instructors attracts 5.95 students to introductory STEM courses on average. Conversely, over the same period, UCA spent \$461,545 offering introductory humanities and arts courses taught by non-contract instructors yielding 3,674 observations

[9] Contracted instructors are either tenured, tenure-track, or on long term contracts but ineligible for tenure. See Appendix A for additional information.

of students choosing introductory humanities or arts courses. This implies an average rate of return of 7.96 students per $1,000 of spending.

This illustrates that $1,000 of discretionary spending offering introductory humanities and arts courses attracts 33.8% more students than $1,000 of discretionary spending offering introductory STEM courses on average. While these are average returns rather than marginal effects per dollar, the differences suggest spending marginal dollars offering introductory humanities and arts courses may increase total student utility more than spending marginal dollars offering introductory STEM courses. If this is the case, UCA is offering more introductory STEM courses and fewer introductory humanities and arts courses than the bundle which maximizes student utility. I interpret this as a willingness to sacrifice student utility to draw students away from humanities and arts courses and into STEM courses.

In Section 4, I present estimates of the marginal effects per dollar of offering additional courses on total student utility across fields and show that the marginal returns are 37.0% larger in humanities and arts relative to STEM. This mirrors the difference in average returns documented in Table 2 and shows a willingness to sacrifice student utility to draw students away from humanities and arts courses and into STEM courses.

3 Methodology

To estimate a university's relative preferences for total student utility and the number of students choosing courses in each field I employ a two step procedure: First, I analyze observed student choices taking the set of offered courses as given; second, I analyze the university's decision of which courses to offer given the anticipated responses of students. The primary goal of the first step is to estimate marginal effects per dollar of offering additional courses in each academic field on total student utility and the number of students choosing courses in each field. To do this, I use a static nested logit model of course choices given the set of available alternatives where nests are determined by the academic field of a course. A crucial feature of this model is that the nesting parameter allows marginal effects of offering additional courses to reflect empirical variation in the relationship between course offerings and course choices.

The second step uses differences in these marginal effects per dollar to infer institutional preferences for total student utility and the type of courses students choose. To do this, I derive first order conditions describing the optimal field composition of offered courses for a university which values total student utility and the number of students choosing courses in each field and faces budget and contract constraints. These first order conditions depend on university preference parameters and the marginal effects per dollar obtained in the first step. Inverting the system of first order conditions yields an expression for university preference parameters as a function of marginal effects and costs obtained previously. Substituting yields estimates of university preference parameters which best explain why the observed field composition was optimal for the university given its constraints.

3.1 Student choices

In this framework, the goal of the student choice model is to yield credible estimates of the marginal effects of offering additional courses on student course choices and choice utility. To that end, I include features which allow marginal effects to better reflect empirical variation but abstract from complex strategic behaviors of students.

To begin, let $i \in [1, N]$ index observations of students choosing courses, let $t \in [1, T]$ index academic semesters, let $j \in [1, J]$ index courses, and let $f \in [1, F]$ index academic fields.[10] Assume observed student characteristics affect relative preferences for academic fields and that students have unobserved preferences for courses so that the utility from choosing course j is given by:

$$U_{ijt} = X_{it}\beta_f + \epsilon_{ijt} \tag{1}$$

For ease of notation, let $u_{itf} = X_{it}\beta_f$ denote the deterministic component of utility. In the empirical application, X_{it} includes ACT scores, high school GPA, gender, and student level.[11]

Assume unobserved preferences ϵ_{ijt} are drawn from a Type 1 Extreme Value distribution with a nesting structure in which nests are defined by academic fields. This implies unobserved preferences can be additively decomposed into a field specific component ψ_{ift} and an idiosyncratic course specific component η_{ijt} scaled by a constant λ:

$$\epsilon_{ijt} = \psi_{ift} + \lambda\eta_{ijt}$$

where η_{ijt} are iid draws from a Type 1 Extreme Value distribution, ψ_{ift} and η_{ijt} are independent, and ψ_{ift} is drawn from a conjugate distribution derived in Cardell (1997). With this structure, the probability that student i chooses one specific course in field f in semester t

[10] For simplicity, I treat choices of multiple courses in the same semester by the same student as independent observations. For a course choice model which allows students to choose multiple courses at once, see Ahn et al. (2017). In the empirical application, fields are STEM, Social Science, Humanities and Arts, and Business and Occupational. As discussed in Section 2, multiple sections of the same course receive different values of j to reflect the fact that each section presents a direct cost to the university.

[11] As I discuss in Section 3.3, X_{it} cannot include fixed effects for academic semesters.

is given by:

$$P_{itf} = \frac{\exp\left(\frac{u_{itf}}{\rho}\right)\left[\sum_{j\in f}\exp\left(\frac{u_{itf}}{\rho}\right)\right]^{\rho-1}}{\sum_{f'=1}^{F}\left[\sum_{j\in f'}\exp\left(\frac{u_{itf'}}{\rho}\right)\right]^{\rho}} \tag{2}$$

$\rho \in (0,1]$ is a nesting parameter which measures the degree of independence in unobserved preferences ϵ_{ijt}. When $\rho = 1$, variance in ψ_{ift} is zero so that unobserved preferences are iid draws from a Type 1 Extreme Value distribution and choice probabilities are equivalent to those in multinomial logit. When $\rho \to 0$, the scalar λ approaches zero so that unobserved preferences are equal for all choices within the same nest (Train, 2009).

With this structure, choice probabilities simplify to:[12]

$$P_{itf} = \frac{d_{tf}^{\rho-1}\exp\left(u_{itf}\right)}{\sum_{f'=1}^{F} d_{tf'}^{\rho}\exp\left(u_{itf'}\right)} \tag{3}$$

where d_{tf} represents the number of courses in field f which are offered in semester t.

3.2 Student outcomes

Later in this section, I will introduce universities as institutions which value total expected student utility and the expected number of students choosing courses in each field. To construct these important outcomes as a function of course offerings, let $\mathbf{d}_t = \begin{bmatrix} d_{t1} & \cdots & d_{tF}\end{bmatrix}$ represent a vector containing the offerings in each field in semester t. The first outcome of interest is total expected student utility in semester t as a function of offered courses $\mathbf{d}_t$ defined by:

$$\begin{aligned} V_t\left(\mathbf{d}_t\right) &= \sum_{i=1}^{N}\mathbb{E}\left[\max\left\{U_{ijt}\right\} \mid \mathbf{d}_t\right] \\ &= \sum_{i=1}^{N}\left\{\log\left(\sum_{f=1}^{F} d_{tf}^{\rho}\exp\left(u_{itf}\right)\right) + c\right\} \end{aligned} \tag{4}$$

where $c \approx 0.5772$ is the Euler-Mascheroni constant.

The second outcome of interest is the expected number of students choosing courses in

[12]Note that Equation 2 can also be simplified to:

$$P_{itf} = \frac{\exp\left(u_{itf} + (\rho-1)\log\left(d_{tf}\right)\right)}{\sum_{f'=1}^{F} d_{tf'}\exp\left(u_{itf'} + (\rho-1)\log\left(d_{tf'}\right)\right)}$$

This illustrates that in this setting, the nested logit specification is equivalent to an Ackerberg and Rysman (2005) crowding estimator which uses a multinomial logit structure for unobserved preferences but includes the crowding term $(\rho-1)\log\left(d_{itf}\right)$ in the deterministic utility of choices belonging to field f.

field f in semester t defined by:

$$\begin{aligned} n_{tf}\left(\mathbf{d}_t\right) &= \sum_{i=1}^{N} d_{tf} P_{itf} \\ &= \sum_{i=1}^{N} \left[\frac{d_{tf}^{\rho} \exp\left(u_{itf}\right)}{\sum_{f'=1}^{F} d_{tf'}^{\rho} \exp\left(u_{itf'}\right)} \right] \end{aligned} \tag{5}$$

These expressions illustrate the close relationship between the outcomes V_t and n_{tf} and the university's choice $\mathbf{d}_t$.

As I show in Subsection 3.6, it is not these outcome formulas *per se* which are useful for identifying university preferences parameters; rather, it is the marginal effects of offering additional courses in each field on these outcomes. These marginal effects are given by:[13]

$$\frac{\partial V_t\left(\mathbf{d}_t\right)}{\partial d_{tf'}} = \sum_{i=1}^{N} \rho P_{itf'} \tag{6}$$

$$\frac{\partial n_{tf}\left(\mathbf{d}_t\right)}{\partial d_{tf'}} = \begin{cases} \sum_{i=1}^{N} \rho P_{itf}\left(1 - d_{tf} P_{itf}\right) & f' = f \\ -\sum_{i=1}^{N} \rho d_{tf} P_{itf} P_{itf'} & f' \neq f \end{cases} \tag{7}$$

These formulas illustrate the important role of the nesting parameter ρ in determining the marginal effects of offering additional courses on outcomes. Equation (6) shows that marginal effects of offering additional courses on total expected utility are increasing in ρ. This makes sense because larger values for ρ imply there is more independence in unobserved preference within fields so that additional courses provide valuable variety.

Similarly, Equation (7) shows that larger values for ρ yield more positive own-field marginal effects on enrollment and more negative cross-field effects on enrollment.[14] Once again, this makes sense because more independence in unobserved preferences within fields implies that additional courses are less similar to other courses within the same field and thus may induce some students to switch fields.

[13]Note that d_{tf} is actually a discrete variable and thus these derivatives are not defined; however, the number of introductory course offerings in each field is large enough that approximating it as a continuous variable is reasonable.

[14]Because $d_{tf} P_{itf}$ is the probability that student i chooses any course in field f and is thus less than one, the own-field effect on enrollment is always positive.

3.3 Identification and estimation of student parameters

I estimate student parameters β_f and ρ by maximum likelihood. The likelihood function is given by:

$$\mathscr{L}(\mathbf{y} \mid \beta, \rho) = \prod_{i=1}^{N} \prod_{t=1}^{T} \prod_{f=1}^{F} P_{itf}^{y_{itf}} \tag{8}$$

where y_{itf} equals 1 if student-course observation i chooses a course in field f in semester t and zero otherwise.

Because ρ plays a crucial role in my method for inferring university preference parameters, it is important to discuss how empirical variation allows me to identify ρ. To show identification of ρ, take two academic semesters t_1 and t_2, two academic fields f_1 and f_2, and a sub-population of students with observed covariates $X_{it} = X$. Note that this sub-population can only span multiple semesters because X_{it} does not include fixed effects for academic semesters.

Let Φ_{tf} denote the probability that a student chooses any course in field f in semester t. These probabilities are given by:

$$\Phi_{tf} = \frac{d_{tf}^{\rho} \exp\left(X\beta_f\right)}{\sum_{f'=1}^{F} d_{tf'}^{\rho} \exp\left(X\beta_{f'}\right)} \tag{9}$$

and the natural logarithms of these probabilities are:

$$\ln\left(\Phi_{tf}\right) = \rho \ln\left(d_{tf}\right) + X\beta_f - \ln\left[\sum_{f'=1}^{F} d_{tf'}^{\rho} \exp\left(X\beta_{f'}\right)\right] \tag{10}$$

The difference in log probabilities across the two academic fields within semester t is then given by:

$$\ln\left(\frac{\Phi_{tf_1}}{\Phi_{tf_2}}\right) = \rho \ln\left(\frac{d_{tf_1}}{d_{tf_2}}\right) + \left(X\beta_{f_1} - X\beta_{f_2}\right) \tag{11}$$

Furthermore, the difference in this difference across the two academic semesters is given by:

$$\ln\left(\frac{\Phi_{t_1f_1}}{\Phi_{t_1f_2}}\right) - \ln\left(\frac{\Phi_{t_2f_1}}{\Phi_{t_2f_2}}\right) = \rho\left[\ln\left(\frac{d_{t_1f_1}}{d_{t_1f_2}}\right) - \ln\left(\frac{d_{t_2f_1}}{d_{t_2f_2}}\right)\right] \tag{12}$$

Rearranging yields:

$$\rho = \frac{\ln\left(\frac{\Phi_{t_1f_1}}{\Phi_{t_1f_2}}\right) - \ln\left(\frac{\Phi_{t_2f_1}}{\Phi_{t_2f_2}}\right)}{\ln\left(\frac{d_{t_1f_1}}{d_{t_1f_2}}\right) - \ln\left(\frac{d_{t_2f_1}}{d_{t_2f_2}}\right)} \tag{13}$$

This illustrates that ρ is identified by the empirical relationship between the relative number of offered courses in each field and the relative probability of choosing any course in that field. For example, if there are relatively more field f_1 courses offered in semester t_1 so that:

$$\frac{d_{t_1 f_1}}{d_{t_1 f_2}} > \frac{d_{t_2 f_1}}{d_{t_2 f_2}}$$

the denominator in Equation (13) is positive. This implies ρ will be close to one if the corresponding increase in the relative probability of choosing any course in field f_1 is similar and will be close to zero if there is little increase in this relative probability. This makes sense because larger values for ρ imply more independence in unobserved preferences within fields. If there is more independence in unobserved preferences within fields then offering additional courses in field f provides attractive variety which induces more students to choose courses in field f. Conversely, if unobserved preferences are largely determined by field then offering additional courses in field f does not add variety and will not induce more students to choose courses in field f.

3.4 University's course offering problem

Suppose the university has an endowment E_t to spend offering courses in semester t. While a large portion of this endowment is already earmarked to pay instructors who are on long term contracts, there is a smaller portion of the semester specific budget which is used to make marginal hiring decisions. To distinguish between courses taught by instructors on long term contracts and courses taught by instructors hired for semester t only, let d_{tf}^C represent the number of field f courses taught by instructors on long term contracts in semester t and let d_{tf}^N represent the number of field f courses taught by instructors hired for semester t only. Furthermore, let c_f^C denote the average cost of field f courses taught by instructors on long term contracts and let c_f^N denote the average cost of field f courses taught my instructors hired for semester t only.

I assume the university faces a budget constraint which says that total spending on instruction cannot exceed the endowment and contract constraints which assert that the university must offer at least the number of field f courses which are observed being taught by instructors on long-term contracts. In notation, the constraints are:

$$\sum_{f=1}^{F} \left(d_{tf}^C c_f^C + d_{tf}^N c_f^N \right) \leq E_t \tag{14}$$

$$d_{tf} \geq d_{tf}^C \quad \forall f \tag{15}$$

The goal of this paper is to quantify how much student utility a university is willing to sacrifice to change the type of courses students choose. As such, I employ a simple linear objective structure for the university which assumes the university values total expected student utility and the expected number of students choosing courses in each field:

$$\Pi_t\left(\mathbf{d_t}\right) = \theta V_t\left(\mathbf{d}_t\right) + \sum_{f=1}^{F} \gamma_f n_{tf}\left(\mathbf{d}_t\right) \tag{16}$$

Without loss of generality, I normalize $\theta = 1$ and $\gamma_F = 0$.[15] In this specification, γ_f measures how much total expected student utility the university is willing to sacrifice to draw one student out of the normalized field F and into field f.

The university's full course offering problem in semester t is then:

$$\mathbf{d}^{\star}_{\mathbf{t}} = \text{argmax}_{\mathbf{d_t}} \left\{ V_t\left(\mathbf{d}_t\right) + \sum_{f=1}^{F-1} \gamma_f n_{tf}\left(\mathbf{d}_t\right) \right\} \quad \text{s.t.} \sum_{f=1}^{F} \left(d^C_{tf} c^C_f + d^N_{tf} c^N_f\right) \leq E_t,\ d_{tf} \geq d^C_{tf} \tag{17}$$

3.5 Illustration of optimal course offerings and revealed preferences

In the following subsection, I will derive the first order conditions characterizing the solution to Equation (17) and demonstrate how these are used to recover preference parameters γ_f. In this subsection, I will illustrate the university's problem and the strategy for recovering γ_f graphically in a simplified setting with only two fields ($F = 2$) and one academic semester ($T = 1$).

Figure 1 graphs the set of feasible outcomes which can be achieved given the university's constraints, indifference curves for several hypothetical universities, and the optimal choices of these universities given the set of available alternatives. The horizontal axis measures the expected number of students choosing courses in field 1 and the vertical axis measures total expected student utility.[16] The solid semi-circle represents a production possibilities frontier (PPF) of all possible (n_1, V) outcomes which could be achieved given the university's endowment E_t and costs of offering non-contract courses c^N_f.[17] Dashed line segments

[15] Normalizing $\gamma_F = 0$ is without loss of generality because the student model implies total enrollment $\sum_{f=1}^{F} n_{tf}\left(\mathbf{d}_t\right)$ is preserved. Normalizing $\theta = 1$ is without loss of generality because the scale of the university's objective is not determined.

[16] Since there are only two fields in this example, the expected number of students choosing courses in field 2 is the complement $n_2 = N - n_1$ and thus can be ignored without loss of generality.

[17] This illustration assumes all courses are non-contract courses for clarity. The inverted U-shape of the PPF is generated by the nested logit structure and because student characteristics affect relative preferences for fields. If unobserved preferences followed a multinomial logit structure and deterministic utility was the same across all students ($u_{itf} = u_f$) then one field would strictly dominate the other and the utility maximizing bundle would contain either all field 1 courses or all field 2 courses. The nested logit structure allows for crowding in the unobserved characteristic space within fields which makes students value variety across fields. Heterogeneity in deterministic preferences for fields across students implies that some students

represent potential university indifference curves with payoffs increasing in the direction of the arrows.[18]

In this illustration, University A has horizontal indifference curves implying it only values total expected student utility ($\gamma_1^A = 0$). Given the PPF representing all feasible outcomes, University A chooses to operate at point A—unsurprisingly, this is the feasible outcome which yields the most total expected student utility. Comparatively, University B (C) has downward (upward) sloping indifference curves implying it is willing to sacrifice some student utility to increase (decrease) the expected number of students choosing courses in field 1. Given the PPF, University B (C) chooses to operate at point B (C) which yields less student utility but more (fewer) students choosing courses in field 1.

Suppose the observed university is offering courses which produce outcome B: The goal of this paper is to determine what value of γ_1^B best explains why outcome B was preferred to all other feasible outcomes on the PPF. This is equivalent to computing the derivative of the PPF—or marginal rate of transformation (MRT)—at point B. Figure 2 zooms in on the choice of University B to illustrate this derivative. Conceptually, the marginal rate of transformation at point B is given by the instantaneous change in total expected student utility relative to the instantaneous change in the expected number of students choosing courses in field 1 as the university marginally reallocates funds from field 1 to field 2. Denote the instantaneous increase in total expected student utility at point B by dV_B. This is given by the marginal effect per dollar of offering an addition field 2 course on total expected student utility at point B minus the marginal effect per dollar of offering an addition field 1 course at point B:

$$dV_B = \left(\frac{1}{c_2^N}\right)\left(\left.\frac{\partial V}{\partial d_2}\right|_B\right) - \left(\frac{1}{c_1^N}\right)\left(\left.\frac{\partial V}{\partial d_1}\right|_B\right) \tag{18}$$

dV_B is positive since point B has more field 1 courses than the utility maximizing bundle implying the marginal return on spending in field 2 is higher than the marginal return on spending in field 1 at point B.

Denote the instantaneous change in the expected number of students choosing courses in field 1 by dn_{1B}. This is given by the marginal effect per dollar of offering an addition field 2 course on the expected number of students choosing courses in field 1 at point B minus

value variety in courses within field 1 more than variety in courses within field 2 and vice versa. Both features imply that utility maximizing course offerings will generally include courses in both fields.

[18]Indifference curves are linear to match the linear structure of Equation (16). While in theory, multiple semesters of course offerings yield variation for identifying non-linear institutional preferences, the small number of semesters would mean that these non-linear effects would be very poorly identified. If true institutional preferences are non-linear then this method produces local linear approximations of true preferences. These local linear approximations would correctly measure relative preferences over total expected student utility and the expected number of students choosing courses in each field at observed offerings; however, they would incorrectly predict responses to counterfactual costs.

the marginal effect per dollar of offering an addition field 1 course on the expected number of students choosing courses in field 1:

$$dn_{1B} = \left(\frac{1}{c_2^N}\right)\left(\left.\frac{\partial n_1}{\partial d_2}\right|_B\right) - \left(\frac{1}{c_1^N}\right)\left(\left.\frac{\partial n_1}{\partial d_1}\right|_B\right) \tag{19}$$

dn_{1B} is always negative since offering more field 2 courses always decreases the expected number of students choosing courses in field 1 and offering fewer field 1 courses always decreases the expected number of students choosing courses in field 1.

Combining both shows that the marginal rate of transformation at point B is given by:

$$\begin{aligned} MRT_B &= \frac{dV_B}{dn_{1B}} \\ &= \frac{\left(\frac{1}{c_2^N}\right)\left(\left.\frac{\partial V}{\partial d_2}\right|_B\right) - \left(\frac{1}{c_1^N}\right)\left(\left.\frac{\partial V}{\partial d_1}\right|_B\right)}{\left(\frac{1}{c_2^N}\right)\left(\left.\frac{\partial n_1}{\partial d_2}\right|_B\right) - \left(\frac{1}{c_1^N}\right)\left(\left.\frac{\partial n_1}{\partial d_1}\right|_B\right)} \end{aligned} \tag{20}$$

Therefore, the value of γ_1^B which best explains why outcome B was preferred to all other feasible outcomes is given by: $\gamma_1^B = MRT_B$. This illustrates how marginal effects of offering additional courses and costs of offering courses can be used to solve for institutional preference parameters which best explain why observed course offerings were optimal for the university given its constraints in a simplified setting with only two fields ($F = 2$) and one academic semester ($T = 1$).

3.6 Optimal course offerings and revealed preferences

To extend the analysis to F academic fields and T semesters, I first derive the first order conditions which characterize an interior solution to the university's problem stated in Equation (17). These first order conditions are:

$$\left(\frac{1}{c_{f_1}^N}\right)\left[\frac{\partial V_t\left(\mathbf{d}_t^\star\right)}{\partial d_{tf_1}} + \sum_{f'=1}^{F-1}\gamma_{f'}\left(\frac{\partial n_{tf'}\left(\mathbf{d}_t^\star\right)}{\partial d_{tf_1}}\right)\right] = \left(\frac{1}{c_{f_2}^N}\right)\left[\frac{\partial V_t\left(\mathbf{d}_t^\star\right)}{\partial d_{tf_2}} + \sum_{f'=1}^{F-1}\gamma_{f'}\left(\frac{\partial n_{tf'}\left(\mathbf{d}_t^\star\right)}{\partial d_{tf_2}}\right)\right] \quad \forall f_1, f_2 \tag{21}$$

Intuitively, these conditions state that the net marginal benefit of offering an additional course relative to the cost of offering this course must be the same across all academic fields. If this were not the case, the university could improve its payoff by reallocating funds away from fields with low returns to fields with high returns. Net marginal benefit includes both benefit from increasing total expected student utility and net benefit (cost) from drawing students into more (less) favored fields.

Rearranging and stacking fields and semesters yields:

$$\mathbf{dn}^{\star} \times \Gamma = \mathbf{dV}^{\star} \tag{22}$$

where

$$\begin{aligned}
\underset{(F,F-1)}{\mathbf{dn_t}^{\star}}(f_1, f_2) &= \left(\frac{1}{c^N_{f_1}}\right)\left(\frac{\partial n_{tf_2}\left(\mathbf{d}^{\star}_{\mathbf{t}}\right)}{\partial d_{tf_1}}\right) - \left(\frac{1}{c^N_F}\right)\left(\frac{\partial n_{tf_2}\left(\mathbf{d}^{\star}_{\mathbf{t}}\right)}{\partial d_{tF}}\right) \\
\underset{(F\times T,F-1)}{\mathbf{dn}^{\star}} &= \begin{bmatrix} \mathbf{dn}^{\star}_{\mathbf{1}} \\ \vdots \\ \mathbf{dn}^{\star}_{\mathbf{T}} \end{bmatrix} \\
\underset{(F,1)}{\mathbf{dV}^{\star}_{\mathbf{t}}}(f) &= \left(\frac{1}{c^N_F}\right)\left(\frac{\partial V_t\left(\mathbf{d}^{\star}_{\mathbf{t}}\right)}{\partial d_{tF}}\right) - \left(\frac{1}{c^N_f}\right)\left(\frac{\partial V_t\left(\mathbf{d}^{\star}_{\mathbf{t}}\right)}{\partial d_{tf}}\right) \\
\underset{(F\times T,1)}{\mathbf{dV}^{\star}} &= \begin{bmatrix} \mathbf{dV}^{\star}_{\mathbf{1}} \\ \vdots \\ \mathbf{dV}^{\star}_{\mathbf{T}} \end{bmatrix} \\
\underset{(F-1,1)}{\Gamma(f)} &= \gamma_f
\end{aligned}$$

This system of equations can then be inverted to derive the following expression for preference parameters $\mathbf{\Gamma}$ as a function of marginal effects and costs:

$$\Gamma = (\mathbf{dn}^{\star})^{+}(\mathbf{dV}^{\star}) \tag{23}$$

where M^{+} denotes the pseudo-inverse of M.

Estimates of marginal effects $\frac{\partial n_{tf}}{\partial d_{tf'}}$ and $\frac{\partial V_t}{\partial d_{tf'}}$ at observed offering vectors $\tilde{\mathbf{d}}_{\mathbf{t}}$ can be obtained using Equations (6) and (7) and estimates of student preference parameters. Furthermore, measures of average costs c^N_f can be directly obtained from instructor salary data. For observed offerings $\tilde{\mathbf{d}}_{\mathbf{t}}$ to have been optimal for the university, first order conditions must have been satisfied at marginal effects at $\tilde{\mathbf{d}}_{\mathbf{t}}$, costs, and university preference parameters γ_f. Therefore, equation (23) shows how marginal effects at $\tilde{\mathbf{d}}_{\mathbf{t}}$ and costs can be used to obtain estimates of preference parameters Γ which best explain why the observed course offering vectors $\tilde{\mathbf{d}}_{\mathbf{t}}$ were chosen by the university.

3.7 Discussion

The methods presented in this section illustrate how observed course choices, instructor salary data, and observed course offerings can be used to measure how much student utility a university is willing to sacrifice to change the type of courses students choose. At this point, several important caveats are in order: First, the student choice model assumes course sizes are unconstrained so that a student can choose any offered course which she has not passed previously. In reality, many courses cap enrollments for pedagogical reasons. As such, true demand for courses in which enrollment caps are binding may be substantially higher than censored observed demand. If field f has more binding enrollment caps than other fields, estimates of relative student preferences for field f and relative marginal effects of offering additional field f courses on total student utility will be downward biased leading me to overstate institutional preferences for enrollment in field f. Were data on enrollment caps available, one could modify the course choice problem to accommodate supply constraints. I leave this extension for future work.

Second, the methods presented in this section assume class size does not affect course utility. If larger classes detract more from field f courses than courses in other fields, omitting class size effects leads to downward bias in estimates of relative student preferences for field f courses and in estimates of relative marginal effects of offering additional field f courses on total student utility. As before, this would lead me to overstate institutional preference for enrollment in field f. If one could extend the course choice model to accommodate class size effects this would have theoretical value in addition to the empirical benefits mentioned previously. In a model with class size effects, additional course offerings in field f affect choices and utility by decreasing class sizes rather than just by adding variety through idiosyncratic preference terms. This would provide a richer mechanism by which university choices influence student outcomes. While it would be straightforward to extend the model to a general equilibrium setting where class size affects course utility, estimating such a model presents serious methodological and computational challenges. I also leave this extension for future work.

Third, the methods presented in this section assume instructors are defined entirely by the field in which they teach. In other words, the university in this setting cannot make a field more attractive by hiring higher quality instructors. While it is possible to incorporate instructor heterogeneity in the model and estimation, empirical evidence suggests instructor compensation—which is the most relevant instructor characteristic from the perspective of the university—has small effects on course utility at UCA. As such, I exclude these effects for clarity. See Appendix B for a model and inference method which uses variation in instructor compensation to recover university preferences and for empirical evidence that instructor compensation has minor effects on student course choices at UCA.

4 Results

I use the methods described in Section 3 to analyze the introductory course offerings of the University of Central Arkansas (UCA) in Fall and Spring academic semesters of academic years 2006-07 through 2009-10. This section reports results of this analysis in several stages: First, I present estimates of the student course choice model described in Section 3.1. Second, I use estimates of the student course choice model to construct marginal effects of offering additional introductory courses on total student utility. Following this, I incorporate cost data to report estimates of the marginal effects of offering additional introductory courses on total student utility relative to the cost of offering these courses. Next, I use these marginal effects per dollar and other variables to recover the university's relative preferences for total student utility and the number of students choosing introductory courses in each field which best explain observed course offering. Parameter estimates are reported along with block-bootstrapped standard errors. The block-bootstrap procedure samples entire student panels rather than individual course choice observations to allow for persistent unobserved preferences for academic fields.

4.1 Student Course Choice Parameters

Table 3 reports estimates of student course choice parameters. The estimates imply a first year male student with average ACT scores and HS GPA is most attracted to introductory social sciences courses followed by STEM, humanities or arts, and business or occupational. First year female students with average scores and grades have the same relative preferences over fields for introductory courses; however, the magnitudes suggest first year female students are relatively more attracted to introductory social science courses and less interested in introductory business or occupational courses than their male counterparts. While introductory business courses are quite unpopular with freshmen, they are relatively more popular with advanced students. In fact, male sophomores and juniors with average scores and grades prefer introductory business courses to introductory courses in all other fields.

The estimates also imply students with higher ACT scores are relatively more likely to enroll in introductory STEM courses. For example, while a first year male student with average ACT scores prefers taking introductory social science courses, a first year male student whose ACT scores are 1.09 standard deviations above the mean is approximately indifferent between introductory STEM and social science courses. The finding that students with higher ACT scores are relatively more likely to enroll in introductory STEM courses is consistent with existing literature which shows initial preparation is an important determinant of whether a student pursues a STEM education (Arcidiacono, 2004; Stinebrickner and Stinebrickner, 2014).

Finally, estimates of the nesting parameter suggest there is substantial correlation in unobserved preferences for courses within the same field. As discussed in Subsection 3.2, it is crucial to account for this correlation when estimating marginal effects of offering additional courses since this correlation determines how similar new courses are to existing ones.

4.2 Marginal Effects of Course Offerings on Total Student Utility

Table 4 uses estimates of the student course choice model discussed previously to construct marginal effects of offering additional introductory courses on total student utility. In the notation, Table 4 reports: $\frac{\partial V_t(\mathbf{d}_t)}{\partial d_{tf}}$ across fields f and semesters t. Marginal effects are reported relative to the effects of offering an additional introductory STEM course which are normalized to one and stars report whether effects in other fields are significantly greater than one.

Results show that the marginal effects of offering additional introductory courses on total student utility are highest in business and occupational courses followed by social science, humanities and arts, and STEM in all academic semesters. In all cases, effects in non-STEM fields are significantly greater than effects in STEM which are normalized to one. This illustrates that in all semesters, students would benefit most from additional introductory business or occupational courses and least from additional introductory STEM courses.

While the figures in Table 4 show significant differences in the marginal benefits of additional introductory courses, they do not account for differences in the costs of these courses. To account for these differences, Table 5 reports marginal effects of offering additional introductory courses in field f on total student utility per cost of offering a non-contract introductory course in field f. In notation, Table 5 reports: $\left(\frac{1}{c_f^N}\right)\left(\frac{\partial V_t(\mathbf{d}_t)}{\partial d_{tf}}\right)$.[19] These marginal effects per dollar play a crucial role in the system of university first order conditions in Equation (22) which is used to infer how much student utility the university is willing to sacrifice to change the type of courses students choose.

Results show that with one exception, marginal effects per dollar are largest in humanities and arts courses followed by social science, business and occupational, and STEM in

[19] As before, marginal effects per dollar are reported relative to the effects per dollar of offering an additional introductory STEM course which are normalized to one and stars report whether effects per dollar in other fields are significantly greater than one.

all academic semesters. Once again, in all cases, effects per dollar in non-STEM fields are significantly greater than effects per dollar in STEM which are normalized to one. These differences imply that UCA is willing to sacrifice some student utility to draw students out of introductory humanities and arts courses and into introductory STEM courses.

4.3 University Preference Parameters

Column 1 of Table 6 reports estimates of γ_f which measure how much student utility the university is willing to sacrifice to change the type of courses students choose. The estimates suggest UCA is willing to sacrifice 0.171 units of total student utility to induce one student to choose an introductory STEM course instead of an introductory business or occupational course, is willing to accept 0.059 units of total student utility to have one student choose an introductory social science course instead of an introductory business or occupational course, and is willing to accept 0.152 units of total student utility to have one student choose an introductory humanities or arts course instead of an introductory business or occupational course.

As expected, UCA's revealed relative preferences for field of enrollment have the opposite order as the relative effects on utility per dollar reported in Table 5. That is, the preference parameters rationalize a small relative effect per dollar of adding an additional introductory STEM course as a preference to draw students out of other fields and into introductory STEM courses. Similarly, the parameters rationalize a large relative effect per dollar of adding an additional introductory humanities or arts course as a preference to draw students out of introductory humanities and arts courses and into other fields.

To help quantify the magnitudes of the estimates reported in column 1 of Table 6, I answer the following question for the Fall semester of 2009: What share of total student utility which is at the discretion of UCA would UCA be willing to sacrifice to induce 1% of introductory course enrollments to change fields? The first step is to isolate the component of total student utility which is at the discretion of UCA. To do this, I subtract off the total expected student utility which would be produced if UCA only offered the courses which must be offered to honor existing contracts. In notation, this re-centered expected utility is given by:

$$V_t^N(\mathbf{d}_t) = V_t(\mathbf{d}_t) - V_t\left(\mathbf{d}_t^C\right) \tag{24}$$

where $\mathbf{d}_t^C = \begin{bmatrix} d_{t1}^C & \cdots & d_{tF}^C \end{bmatrix}$ is a vector containing the number of courses taught by instructors on long term contracts in each field in semester t. Removing the component of utility which is produced by contracted courses allows me to highlight the trade-off between field enrollments and the student utility which is at the discretion of UCA in a specific semester.

The next step is to scale estimates of γ_f by 1% of introductory course enrollment in the Fall semester of 2009 (224.9 students) and divide these scaled effects by re-centered utility. Column 2 of Table 6 reports these scaled effects and Column 3 of Table 6 reports these scaled effects as a percentage of re-centered utility. The estimates suggest that UCA is willing to sacrifice 2.66% of discretionary student utility to induce 1% of introductory enrollment to switch from introductory business or occupational courses to introductory STEM courses, UCA is willing to accept a 0.90% increase in discretionary student utility in return for having 1% of introductory enrollment switch from introductory business or occupational courses to introductory social science courses, and UCA is willing to accept a 2.36%% increase in discretionary student utility in return for having 1% of introductory enrollment switch from introductory business or occupational courses to introductory humanities or arts courses.

5 Interpreting Results

Another way to quantify the magnitudes of the estimates reported in column 1 of Table 6 is to solve for counterfactual costs which would induce University of Central Arkansas to offer introductory courses which maximize total student utility. Intuitively, these costs illustrate how much costs would need to change to price out institutional preferences for the type of courses student choose.[20]

To solve for these counterfactual costs, one must first solve for alternative course offerings which maximize total student utility while satisfying the university's budget and contract constraints. Mathematically, this step is to solve:[21]

$$\mathbf{d_t^{SUM}} = \text{argmax}_{\mathbf{d_t}} \left\{ V_t \left(\mathbf{d}_t \right) \right\} \quad \text{s.t.} \sum_{f=1}^{F} \left(d_{tf}^C c_f^C + d_{tf}^N c_f^N \right) \leq E_t,\, d_{tf} \geq d_{tf}^C \tag{25}$$

where $\mathbf{d_t^{SUM}}$ is the allocation which maximizes total expected student utility.

The second step is to solve for counterfactual costs $\tilde{c}_f^N$ which would induce a university with preferences γ_f to choose $\mathbf{d_t^{SUM}}$ given its budget and contract constraints. Figure 3 illustrates this step for the simplified setting with only two fields ($F = 2$) and one academic

[20] Because the composition of students and institutional constraints vary across semesters, these counterfactual costs differ across semesters. For clarity of exposition, I perform this analysis for the Fall, 2009 semester only.

[21] The system of first order conditions which implicitly defines $\mathbf{d_t^{SUM}}$ is so complicated that explicitly solving for $\mathbf{d_t^{SUM}}$ is impractical; however, the number of vectors $\mathbf{d_t}$ which satisfy the institution's constraints is small enough that it is possible to search for $\mathbf{d_t^{SUM}}$ exhaustively. Results in this draft were not obtained by searching over all feasible vectors but rather over a large subset of feasible vectors. As such, the student-preferred allocation described in this draft should be viewed as a local maximum which may differ from the global maximum.

semester ($T = 1$). As before, the horizontal axis measures the expected number of students choosing courses in field 1, the vertical axis measures total expected student utility, and the solid semi-circle labeled PPF represents a production possibilities frontier of all possible (n_1, V) outcomes which could be achieved given the university's endowment E_t and costs of offering non-contract courses c_f^N.[22] The goal of this exercise is to solve for counterfactual costs $\tilde{c}_f^N$ which would induce University B to offer courses which produce the student-preferred outcome A. Visually, this means solving for counterfactual costs which generate the counterfactual production possibilities frontier PPF' which is tangent to University B's indifference curves at point A.

To produce a production possibilities frontier PPF' which is tangent to University B's indifference curves at point A two conditions must be satisfied: First, the marginal rate of transformation of PPF' at point A must equal the slope of university B's indifference curves γ_1^B. Second, the course offerings which generate outcome A must satisfy the university's budget constraint at counterfactual costs $\tilde{c}_f^N$. Mathematically,

$$\gamma_1^B = \frac{\left(\frac{1}{\tilde{c}_2^N}\right)\left(\frac{\partial V}{\partial d_2}\Big|_A\right) - \left(\frac{1}{\tilde{c}_1^N}\right)\left(\frac{\partial V}{\partial d_1}\Big|_A\right)}{\left(\frac{1}{\tilde{c}_2^N}\right)\left(\frac{\partial n_1}{\partial d_2}\Big|_A\right) - \left(\frac{1}{\tilde{c}_1^N}\right)\left(\frac{\partial n_1}{\partial d_1}\Big|_A\right)}$$

$$d_{1A}^N \tilde{c}_1^N + d_{2A}^N \tilde{c}_2^N = E_t$$

where d_{1A}^N and d_{2A}^N are the number of non-contract field 1 and field 2 courses which generate outcome A. Solving for $\tilde{c}_f^N$ yields:

$$\tilde{c}_f^N = E_t \left[\frac{\gamma_1^B \left(\frac{\partial n_1}{\partial d_f}\Big|_A\right) - \left(\frac{\partial V}{\partial d_f}\Big|_A\right)}{d_{2A}^N\left(\gamma_1^B\left(\frac{\partial n_1}{\partial d_2}\Big|_A\right) - \left(\frac{\partial V}{\partial d_2}\Big|_A\right)\right) + d_{1A}^N\left(\gamma_1^B\left(\frac{\partial n_1}{\partial d_1}\Big|_A\right) - \left(\frac{\partial V}{\partial d_1}\Big|_A\right)\right)} \right] \qquad f = 1, 2$$

This illustrates how to solve for counterfactual costs which would induce the university to offer courses which maximize total expected student utility in a simplified setting with only two fields ($F = 2$) and one academic semester ($T = 1$). Because the university's endowment E_t is the same in both PPF and PPF' and since outcome A is on both PPF and PPF' outcome A could be induced with a revenue neutral tax-subsidy policy which changes the effective costs of offering non-contract courses across fields.[23] While such a policy would deliver more choice utility to students, it is unclear whether it would benefit society more broadly. As such, these counterfactual costs should be viewed as a means for quantifying university preference parameters rather than as a specific policy recommendation.

[22] As before, this illustration assumes all courses are non-contract courses for clarity.

[23] The fact that outcome A is on both PPF and PPF' and that both frontiers have the same endowment

With more than two academic fields, one must solve for costs $\tilde{c}_f^N$ which satisfy:

$$\left(\frac{1}{\tilde{c}_{f_1}^N}\right) M_{tf_1}\left(\mathbf{d_t^{SUM}}\right) = \left(\frac{1}{\tilde{c}_{f_2}^N}\right) M_{tf_2}\left(\mathbf{d_t^{SUM}}\right) \quad \forall f_1, f_2 \tag{26}$$

and

$$\sum_{f=1}^{F} d_{tf}^{SUM} \tilde{c}_f^N = E_t^N \tag{27}$$

where d_{tf}^{SUM} is the number of non-contract field f courses offered in the student best allocation in semester t, E_t^N is the residual budget for non-contract courses in semester t given by $E_t^N = E_t - \left(\sum_{f=1}^{F} d_{tf}^C c_f^C\right)$, and

$$M_{tf}\left(\mathbf{d_t^{SUM}}\right) = \frac{\partial V_t\left(\mathbf{d_t^{SUM}}\right)}{\partial d_{tf}} + \sum_{f'=1}^{F-1} \gamma_{f'}\left(\frac{\partial n_{tf'}\left(\mathbf{d_t^{SUM}}\right)}{\partial d_{tf}}\right) \tag{28}$$

is the effect of offering an additional field f course on the observed university's objective at the student-preferred bundle $\mathbf{d_t^{SUM}}$.

Rearranging, substituting the budget constraint, and stacking across fields yields:

$$\left(\mathbf{M_t^1} + \mathbf{M_t^2}\right)\mathbf{\tilde{c}} = \mathbf{ME_t} \tag{29}$$

where

$$\underset{(F-1,F-1)}{\mathbf{M_t^1}}(f_1, f_2) = \left[M_{tf_1}\left(\mathbf{d_t^{SUM}}\right)\right] d_{tf_2}^{SUM}$$

$$\underset{(F-1,F-1)}{\mathbf{M_t^2}}(f_1, f_2) = \begin{cases} \left[M_{tF}\left(\mathbf{d_t^{SUM}}\right)\right] d_{tF}^{SUM} & f_1 = f_2 \\ 0 & f_1 \neq f_2 \end{cases}$$

E_t implies that:

$$\begin{aligned} d_{1A}^N c_1^N + d_{2A}^N c_2^N &= E_t \\ d_{1A}^N \tilde{c}_1^N + d_{2A}^N \tilde{c}_2^N &= E_t \end{aligned}$$

Adding a tax/subsidy defined by: $\tau_f = \tilde{c}_f^N - c_f^N$ to the market cost c_f^N achieves the counterfactual cost $\tilde{c}_f^N$ and thus induces the university to offer courses which yield outcome A. At these course offerings, the cost of this tax/subsidy policy is:

$$\begin{aligned} d_{1A}^N\left(\tilde{c}_1^N - c_1^N\right) + d_{2A}^N\left(\tilde{c}_2^N - c_2^N\right) &= \left(d_{1A}^N \tilde{c}_1^N + d_{2A}^N \tilde{c}_2^N\right) - \left(d_{1A}^N c_1^N + d_{2A}^N c_2^N\right) \\ &= E_t - E_t \\ &= 0 \end{aligned}$$

As such, the tax/subsidy policy is revenue neutral.

$$\underset{(F-1,1)}{\tilde{\mathbf{c}}(f)} = \tilde{c}_f^N$$

$$\underset{(F-1,1)}{\mathbf{ME_t}(f)} = \left[M_{tf}\left(\mathbf{d_t^{SUM}}\right)\right] E_t^N$$

This system of equations can then be inverted to derive the following expression for counterfactual costs which satisfy the university's first order conditions at the student-preferred allocation:

$$\tilde{\mathbf{c}} = \left(\mathbf{M_t^1} + \mathbf{M_t^2}\right)^{-1} \mathbf{ME_t}$$

Because these counterfactual costs satisfy the university's first order conditions at the student-preferred allocation, these costs would induce University of Central Arkansas to offer courses which maximize total student utility given budget and contract constraints.

5.1 Counterfactual costs which induce the student-preferred allocation

Table 7 reports the counterfactual costs which would induce UCA to offer courses which maximize total expected student utility in the Fall semester of 2009 along with course offerings, enrollment shares, and student utilities in both the observed state and in the state with counterfactual costs. Results show it would take a 16.6% increase in the cost of offering an introductory STEM course, a 0.7% increase in the cost of offering an introductory business or occupational course, a 5.5% decrease in the cost of offering an introductory social science course, and a 13.2% decrease in the cost of offering an introductory humanities course to price out institutional preferences and induce the university to offer the student-preferred bundle.

The observed bundle of non-contract courses includes more introductory STEM and business and occupational courses and fewer introductory social science and humanities and arts courses than the student-preferred bundle. Offering more STEM courses and fewer humanities and arts courses than the student-preferred bundle increases STEM enrollment by 2.6 percentage points and business and occupational enrollment by 0.44 percentage points and decreases social science enrollment by 1.39 percentage points and humanities and arts enrollment by 1.65 percentage points.

Finally, deviating from the student-preferred allocation decreases total expected utility by 73.7 utils which corresponds to a 4.8% reduction in re-centered utility as defined in Equation (24). This illustrates that UCA prefers allocating its discretionary budget in a way which yields 2.6 percentage points more STEM enrollment and 1.65 percentage points less humanities and arts enrollment but produces 5.1% less discretionary utility.

5.2 Suggestive Evidence on Mechanisms underlying University Preferences

Although a full analysis of the mechanisms underlying UCA's preferences for STEM enrollment are beyond the scope of this paper, this section briefly considers literature and suggestive evidence which gives clues as to why UCA might prefer STEM enrollment. First, there is ample evidence that STEM degrees have larger labor market returns than degrees in other fields. In a recent review article, Altonji et al. (2012) summarizes the relative returns to different majors: "Engineering consistently commands a high premium, usually followed by business and science. Humanities, social sciences, and education are further behind." Interestingly, this ordering of relative returns closely matches the ordering of UCA's preferences reported in Table 6.

To supplement the findings of Altonji et al. (2012) with suggestive evidence on relative returns at UCA, column 1 of Table 8 reports results from a naïve regression of annual earnings on field of major for workers who earn Bachelor's degrees from UCA. Data on earnings are from Arkansas state unemployment insurance tax filings and include earnings from all employers who pay Arkansas state unemployment insurance taxes (excludes self-employed individuals, federal employees, and all employers outside Arkansas). The sample for this regression is all students who earn Bachelor's degrees between the 1993-94 and 2003-04 academic years and report positive earnings eight years after graduating.[24] The regression controls for ACT scores, high school GPA, gender, and graduation year but should still be considered naïve because there are certainly other omitted factors which are related to both final major and earnings.

Results of this naïve earnings regression suggest earnings are 46.4% higher for STEM graduates relative to observationally equivalent Humanities and Arts graduates, 38.2% higher for Business and Occupational graduates relative to Humanities and Arts graduates, and 10.2% higher for Social Science graduates than Humanities and Arts graduates. These differences in earnings across majors are generally consistent with the summary of relative returns given by Altonji et al. (2012).

A concern with the results in column 1 is that non-random selection into the sub-sample which reports earnings could bias results. In this setting, graduates could be absent from the earnings data either because they are unemployed for the entire year, out of the labor force, working in an excluded sector within Arkansas, or working outside of Arkansas. In this sample, 36.7% of graduates do not report earnings eight years after graduating implying this selection is substantial.

[24] I exclude degree-earners who complete multiple degrees or majors (4.2% of degree earners).

Because there are many possible reasons for absence, it is difficult to even hypothesize how the unobserved characteristics of earners might differ from those of non-earners making it challenging to argue about the signs and magnitudes of biases in column 1, Still, to better understand non-random selection into the earners sub-sample, column 2 of Table 8 reports results from a linear probability model which predicts whether an individual reports earnings eight years after graduating as a function of field of major and controls. Results suggest graduates with Business or Occupational majors and graduates with Social Science majors are more likely to report earnings than graduates with Humanities majors. Point estimates also suggest graduates with STEM majors are more likely to report earnings than graduates with Humanities majors but the estimated difference is small and statistically insignificant.

There is also existing literature which suggests STEM coursework may involve higher psychic costs to students. Numerous studies find that grading policies in STEM courses are harsher than in other fields (Sabot and Wakeman-Linn, 1991; Thomas, 2017; Johnson, 2003; Stinebrickner and Stinebrickner, 2014). One reason why harsher grading policies imply higher psychic costs is that fewer students will expect to reach the upper bounding A grade at which point the marginal benefit of effort must diminish. Furthermore, there may be direct psychic costs associated with receiving lower grades. Relatedly, existing literature also finds that STEM courses are associated with higher study times than courses in other fields (Brint et al., 2012; Stinebrickner and Stinebrickner, 2014). If one assumes an hour of studying is equally costly across fields, this implies STEM courses involve higher psychic costs than other coursework.

Once again, to supplement these findings, columns 1 and 2 of Table 9 contain naïve regressions relating grade outcomes to course field at UCA. The sample for these regressions—which closely mirrors the sample in my main analysis—is all grades earned in introductory courses in Fall and Spring academic semesters between the 2005-06 and 2011-12 academic years.[25] The regressions control for ACT scores, high school GPA, gender, and student level but should once again be considered naïve because there may be omitted factors which are related to both course field and grade outcomes.

Column 1 of Table 9 reports estimates of a linear probability model which predicts whether a student earns the maximum grade of A. In this sample, 25.3% of earned grades are an A implying a substantial number of students reach the upper bounding grade where return on effort must diminish. Results suggest observationally equivalent students are least likely to earn an A in STEM courses and most likely to earn an A in Humanities or Arts courses. Column 2 of Table 9 reports estimates of a censored regression which predicts grade points

[25] I exclude 2.1% of observations which have bad grade data.

as a function of course field and controls.[26] The censored feature accounts for the fact that many students receive the maximum grade of A.[27] Results suggest observationally equivalent students should expect to earn 0.547 fewer grade points in introductory STEM courses relative to introductory Humanities or Arts courses, 0.314 fewer points in introductory Social Science courses relative to introductory Humanities or Arts courses, and 0.214 fewer points in introductory Business or Occupational courses relative to introductory Humanities or Arts courses. In this sample, the standard deviation in grade points is 1.224 grade points implying these differences are substantial relative to the overall variation in grades. These results are consistent with existing literature which finds that grading policies are harshest in STEM courses.

A similar selection concern with the results in columns 1 and 2 of Table 9 is that some students withdraw from courses before earning grades. Withdrawals appear on a student's transcript but do not count towards her grade point average; as such, withdrawals probably mean poor expected performance but it is unclear exactly how poor (ADHE, 2011). In this sample, 9.7% of observations are withdrawals implying the confounding effects of this selection could be non-trivial. To evaluate this selection, column 3 of Table 9 reports results from a linear probability model which predicts whether an observation is a withdrawal as a function of field of major and other controls. Results suggest observationally equivalent students are most likely to withdraw from STEM courses and least likely to withdraw from Humanities and Arts courses. If students generally withdraw when they expect to earn grades that are lower than their observed covariates imply, this suggests the results in column 2 understate the differences between STEM and Humanities and Arts grades.

To summarize, existing literature shows—and naïve regressions in my data suggest—that STEM courses have higher future labor market returns but larger present psychic costs. These findings provide some clues as to why UCA might prefer STEM enrollment. First, if students are myopic or lack information about future labor market returns, a paternalistic university may offer additional STEM courses to induce more students to complete courses with high labor market returns. In this setting, the university's offerings may maximize some notion of long term student welfare but not short term choice utility. Existing literature supports the idea that students may be myopic or lack information about future labor market returns. For myopic behavior, Spear (2000) discusses neurological reasons why adolescents focus more on immediate costs than future gains relative to adults and Oreopoulos (2007) provides evidence that high school students ignore or heavily discount future consequences

[26] Letter grades are assigned to numeric grade point values using the Arkansas Department of Higher Education's metric (A=4, B=3, C=2, D=1, F=0) (ADHE, 2011).

[27] Specifications which ignore censoring (available upon request) produce the same ordering of fields but with smaller differences across fields.

when deciding to drop out of school. For incomplete information, Wiswall and Zafar (2014) find that providing students with information about average labor market outcomes by major leads students to update their beliefs about their own labor market outcomes and the probabilities that they will complete each major. This supports the idea that paternalism may underlie UCA's preference for STEM enrollment.

Alternatively, if STEM education has larger social externalities than coursework in other fields, UCA may be offering additional STEM courses to maximize social welfare more broadly. One mechanical reason why STEM education may have larger social externalities is that higher earning STEM graduates probably pay more in taxes. Estimates in column 1 of Table 8 imply that a male STEM graduate with average ACT scores and high school GPA who graduates in 2001 earns $46,028 in 2009 while an observationally equivalent humanities or arts graduate earns $28,941 in 2009.[28] If these individuals have no dependents, itemized deductions, or tax credits, the STEM graduate pays $7,106 in federal income tax and $2,349 in Arkansas state income tax while the humanities or arts graduate pays $3,749 in federal income tax and $1,189 in Arkansas state income tax.[29] This likely understates the difference in contributions to state coffers as higher income STEM graduates probably also pay more in state sales taxes and other state and local taxes.[30]

Furthermore, although empirical evidence on heterogeneous social returns to higher education by field is thin, theoretical models of education externalities typically assume externalities arise because individuals learn from one another (Moretti, 2004; Lucas, 1988; Jovanovic and Rob, 1989; Glaeser, 1999). Since STEM degrees have more labor market value for individuals, it seems natural to assume that interactions with STEM graduates yield more valuable learning spillovers than interactions with other graduates. This suggests UCA's preference for STEM enrollment may be an attempt to increase the social externalities produced by their graduates.

Moreover, a preference for STEM enrollment is in line with recent federal and state initiatives to induce more students to complete STEM degrees (PCAST, 2012; Chapman, 2014). The justifications for these initiatives were to "retain [the United States'] historical preeminence in science and technology" (PCAST, 2012) and to "[lay] the foundation for a truly world-class workforce" (Chapman, 2014). Implicit in both justifications is the notion that the high productivity of STEM graduates generates social externalities which justify intervention.

[28] Units are nominal dollars in 2009.

[29] See IRS (2009) and ADFA (2009a) for federal and state marginal tax rates in 2009.

[30] In 2009, Arkansas had a 6% general sales tax and a 3% sales tax on food and food ingredients (ADFA, 2009b).

6 Conclusion

In 1973, Daniel Bell described the university as "the axial institution of post-industrial society" (Bell, 1973). This is more true today than it was over four decades ago. Despite this, very little is known about how universities make decisions. A better understanding of how universities make decisions could lead to policies which benefit students and reduce financial burdens on taxpayers, families, and donors.

In this paper, I describe a two-step procedure which uses observed course offerings to infer how much student utility a university is willing to sacrifice to change the type of courses students choose. The first step is to estimate marginal effects per dollar of offering additional introductory courses in each academic field on total student utility and the number of students choosing introductory courses in each field. The second step is to derive first order conditions describing the optimal field composition of offered courses for a university which values total student utility and the number of students choosing courses in each field. These first order conditions depend on university preference parameters and the marginal effects estimated previously. Solving for the parameters which come closest to satisfying this system of first order conditions at observed course offerings yields estimates of university preference parameters which best explain why observed course offerings were optimal for the university given its constraints.

An application to the introductory course offerings at the University of Central Arkansas (UCA) shows that UCA is willing to sacrifice total student utility to increase the number of students choosing introductory STEM courses and decrease the number of students choosing introductory humanities or arts courses. To quantify this trade-off, I show that a 16.6% increase in the cost of offering an introductory STEM course, a 0.7% increase in the cost of offering an introductory business or occupational course, a 5.5% decrease in the cost of offering an introductory social science course, and a 13.2% decrease in the cost of offering an introductory humanities course would induce the university to offer courses which maximize student utility.

Existing literature shows—and naïve regressions in my data suggest—that STEM courses have higher future labor market returns but larger present psychic costs than courses in other fields. While a full analysis of mechanisms is beyond the scope of this paper, I argue that this evidence is consistent with the interpretation that UCA favors STEM enrollment to adjust for myopic behavior or incomplete information of students or to internalize larger social externalities to STEM education.

This paper is the first to suggest observed course offerings can be used to understand university preferences. As such, it leaves substantial room for future extensions. Methodologically, future work may incorporate class capacity constraints or class size externalities to obtain better estimates of the effects of offering additional courses on student choices. Additionally, future work may employ richer dynamic models of student course choices which connect current course offerings to future outcomes such as graduation, final major, or labor market outcomes. Such an analysis could infer university preferences over richer outcomes such as graduation rates and earnings and would have more scope to assess whether policy interventions are socially optimal.

Appendix A: Data Appendix

Definitions

STEM: Biology; Chemistry; Computer Science; Mathematics; Physics and Astronomy.

Social Science: Family and Consumer Sciences; Geography; History; Political Science; Psychology and Counseling; Sociology; World Languages, Literatures, and Cultures.

Humanities and Arts: Art; Communication; English; Mass Communication and Theater; Music; Philosophy and Religion; Writing.

Business and Occupational: Accounting; Economics, Finance, Insurance, and Risk; Education; Elementary, Literacy, and Special Education; Health Sciences; Kinesiology and Physical Education; Management Information Systems; Marketing and Management; Nursing; Occupational Therapy

Long term contracts: Tenured instructors, tenure-track instructors, and instructors who teach on a recurring contractual basis but are ineligible for tenure. See ADHE (2011) for further information.

Short term contracts: Instructors with a non-recurring appointment where funding is temporary and there is no guarantee of a continuing appointment and graduate student instructors. See ADHE (2011) for further information.

Average costs of offering a non-contract course

To compute the average cost of offering a non-contract course in field f I first use information on instructor salaries, contract details, and teaching histories to estimate the cost of offering each course c_j. Instructor salaries are typically paid for multiple services across multiple semesters so one must make assumptions regarding what share of an instructor's total salary is paid for a specific course. Generally speaking, this method uses credit hours to allocate an instructor's total salary to specific courses. I make use of the following information: how much the instructor is paid for an entire contract, a contract identifier which indicates which semesters are covered by the same contract, the number of credit hours an instructor must teach to be considered full time, a numeric measure of what share of full time each instructor is, and the credit hour value of each course.

The first step is to calculate the number of credit hours each instructor would be teaching in each semester if they were only paid to teach. This involves multiplying the share of full time measure by the number of credit hours an instructor must teach to be considered full time. The second step is to sum these teaching only credit hours across all semesters covered by the same contract. This represents the total number of credit hours the instructor would teach in each contract if they were only paid to teach. The third step is to divide instructor salary for each contract by this measure of total contract teaching only credit hours. This yields a measure of salary per credit hour for each contract which can be interpreted as an instructor wage. Finally, multiplying this salary per credit hour measure by the credit hour value of each course yields the instructor salary paid for each course.

To compute the average cost of offering a non-contract course in field f I average these course specific costs over all non-contract courses offered in field f. Importantly, this method captures only the cost of hiring instructors to teach a course and does not include the cost of teaching assistants, the cost of classroom supplies, or the shadow price of the classroom used. If these unobserved costs are proportional to observed costs then incorporating these costs involves applying a constant scalar to both sides of the university's budget constraint in Equation (14). In this case, omitting unobserved costs does not affect estimates of university preference parameters γ_f but does result in understating counterfactual costs by the scaling constant. If unobserved costs are not proportional to observed costs then I am under (over) stating the relative cost of offering non-contract courses in certain fields. This leads to downward (upward) bias in estimates of relative institutional preferences for enrollment in these fields.

Appendix B: Intensive margin of instruction spending

The body of this article assumes instruction spending only affects students through the number of courses offered. However, if higher paid instructors are more attractive to students, universities could also influence student choices and utility by spending more on instructors. There can be both budget allocation decisions on the extensive margin—how many courses to offer in each field—and budget allocation decisions on the intensive margin—how much to pay instructors in each course—which are made by the university and directly affect student outcomes.

In this appendix, I modify the model presented in Section 3 to include both intensive and extensive margin spending decisions and discuss alternative methods for recovering university preference parameters in this setting.[31] Following this, I present evidence which suggests intensive margin spending has minor effects on student choices at UCA and justify my decision to abstract from intensive margin spending decisions in the analysis.

Theoretical model with intensive margin spending decisions

To incorporate intensive margin spending, in this Appendix only, let c_{jt} represent spending on instruction in course j in semester t, let m_f represent the minimum cost of offering a course in field f, and let e_{jt} represent spending in excess of this minimum which may affect the desirability of course j. For courses taught by instructors on long term contracts, c_{jt} must be paid to honor these contracts. For the share of the budget that remains after all existing contracts are honored, a course in field f is offered if and only if $c_{jt} \geq m_f$.

To allow for the possibility that excess spending affects the desirability of a course, modify student utility in Equation (1) to be:[32]

$$U_{ijt} = X_{it}\beta_f + \theta \log (e_{jt} + 1) + \epsilon_{ijt}$$

The parameter θ measures the extent to which higher paid instructors make courses more attractive to students.

For simplicity, assume ϵ_{ijt} are iid draws from a type 1 extreme value distribution. Similar to Section 3.2, total expected student utility in semester t, the expected number of students choosing courses in field f in semester t, and the effects of both extensive margin spending and intensive margin spending on both of these outcomes can be defined as a function of model parameters and observed data. The effects of intensive margin spending on total expected student utility in semester t and on the expected number of students choosing courses in field f in semester t are given by:[33]

$$\frac{\partial V_t (\mathbf{d_t}, \mathbf{e_t})}{\partial e_{jt}} = \sum_{i=1}^{N} P_{itj} \left(\frac{\theta}{e_{jt} + 1} \right)$$

[31] An earlier draft of this paper (available upon request) contains a more detailed discussion of this model and these estimation methods.

[32] The log function is used to ensure diminishing marginal returns to avoid a corner solution in which the university spends its entire discretionary instruction budget on a single course. I add 1 to ensure marginal effects of excess spending are finite over the entire support of excess spending.

[33] Other equations are straightforward to derive and are omitted for brevity.

$$\frac{\partial n_{tf}\left(\mathbf{d_t},\mathbf{e_t}\right)}{\partial e_{jt}}=\begin{cases}\sum_{i=1}^{N}\left\{\left(\frac{\theta}{e_{jt}+1}\right)P_{itj}\left(1-P_{itj}\right)-\sum_{j'\in f\setminus j}\left(\frac{\theta}{e_{jt}+1}\right)P_{itj}P_{itj'}\right\} & j\in f\\ -\sum_{i=1}^{N}\sum_{j'\in f}\left(\frac{\theta}{e_{jt}+1}\right)P_{itj}P_{itj'} & j\notin f\end{cases}$$

where $\mathbf{e_t}$ is a vector containing all excess spending decisions and $\mathbf{d_t}$ is a vector containing all offered courses. As one might expect, these equations illustrate the crucial role of the parameter θ in determining the effects of intensive margin spending on student outcomes.

With these marginal effects, one can construct the set of intensive margin university first order conditions analogous to the extensive margin conditions given by Equation (22):

$$\frac{\partial V_t\left(\mathbf{d_t},\mathbf{e_t}\right)}{\partial e_{j_1t}}+\sum_{f'=1}^{F-1}\gamma_{f'}\left(\frac{\partial n_{tf'}\left(\mathbf{d_t},\mathbf{e_t}\right)}{\partial e_{j_1t}}\right)=\frac{\partial V_t\left(\mathbf{d_t},\mathbf{e_t}\right)}{\partial e_{j_2t}}+\sum_{f'=1}^{F-1}\gamma_{f'}\left(\frac{\partial n_{tf'}\left(\mathbf{d_t},\mathbf{e_t}\right)}{\partial e_{j_2t}}\right)\quad\forall f_1,f_2$$

As in Section 3.6, this system can be rearranged to solve for the university preference parameters which best explain why observed intensive margin spending decisions were preferred to all feasible alternative decisions.

The intuition underlying this method is analogous to the intuition behind the extensive margin methods discussed in the body: If the university were purely trying to maximize total expected student utility, it would choose excess spending levels so that the marginal effect of increasing excess spending on total expected student utility is the same across all courses. If the university is consistently overpaying instructors in a certain field relative to the allocation which maximizes student utility, it must be that the university is trying to draw more students into this field thus revealing an institutional preference to increase the number of students in this field.

Effects of intensive and extensive margin spending

I chose to abstract from intensive margin spending decisions in my analysis because empirical evidence suggests intensive margin spending has much smaller effects on student choices than extensive margin spending. Table A1 reports estimates of the elasticity of enrollment with respect to spending on instructors estimated with several specifications of the regression:

$$\log\left(S_{jt}\right)=\tilde{\theta}\log\left(c_{jt}\right)+\xi_k+\eta_{jt}$$

where S_{jt} is the number of students enrolled in course j in semester t and ξ_k is a course number fixed effect (e.g. ECON 101). Specification 2 suggests the elasticity of enrollment with respect to instructor salary could be as large as 0.171 for non-contract courses. This would imply that doubling spending on instruction for all non-contract field f courses but keeping other course characteristics fixed would increase non-contract field f enrollment by 17.1%. However, specification 4 suggests this moderately large estimate is driven by a small number of very small courses. When I exclude 45 course observations with five or fewer students, the elasticity drops to 0.07. This suggests doubling spending on non-contract field f instruction but keeping other course characteristics fixed only increases non-contract field f enrollment by 7%. Elasticities for all instructor contract types (columns 1 and 3) suggest similarly small effects.

While it is not the focus of this paper, I should note that this finding is in line with existing literature which finds that higher paid instructors have small or zero effects on student outcomes at universities (Bettinger and Long, 2010; Figlio et al., 2015).

Comparatively, Table A2 reports estimates of elasticities of enrollment with respect to spending on course offerings computed using estimates of the nested logit course choice model, observed non-contract course offerings, and estimates of costs of offering non-contract courses.[34] Estimates of these elasticities range from 0.276 to 0.350 across fields and semesters. This suggests that doubling the number of non-contract field f courses offered to students increases non-contract field f enrollment by 27.6 - 35.0%.

The large differences between intensive margin elasticities and extensive margin elasticities suggest UCA can increase student utility more and attract more students into desirable fields by spending marginal dollars offering additional courses rather than increasing spending on instruction. This implies that no values for γ_f can rationalize both observed intensive and observed extensive margin spending decisions at UCA. Furthermore, the small effects of intensive margin spending suggest variation in spending on instruction at UCA exists for some reason other than influencing student choices and utility. For this reason, I focus on extensive margin decisions which have significant effects on student choices and utility at UCA. Future research may seek to better explain variation in spending on instruction.

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[34] Specifically, the formula is:

$$\epsilon = \frac{\partial n_{tf}(\mathbf{d}_t)}{\partial d_{tf}} \times \frac{c_f^N d_{tf}^N}{n_{tf}^N(\mathbf{d}_t)}$$

where $n_{tf}^N(\mathbf{d}_t)$ is observed enrollment in non-contract field f courses in semester t.

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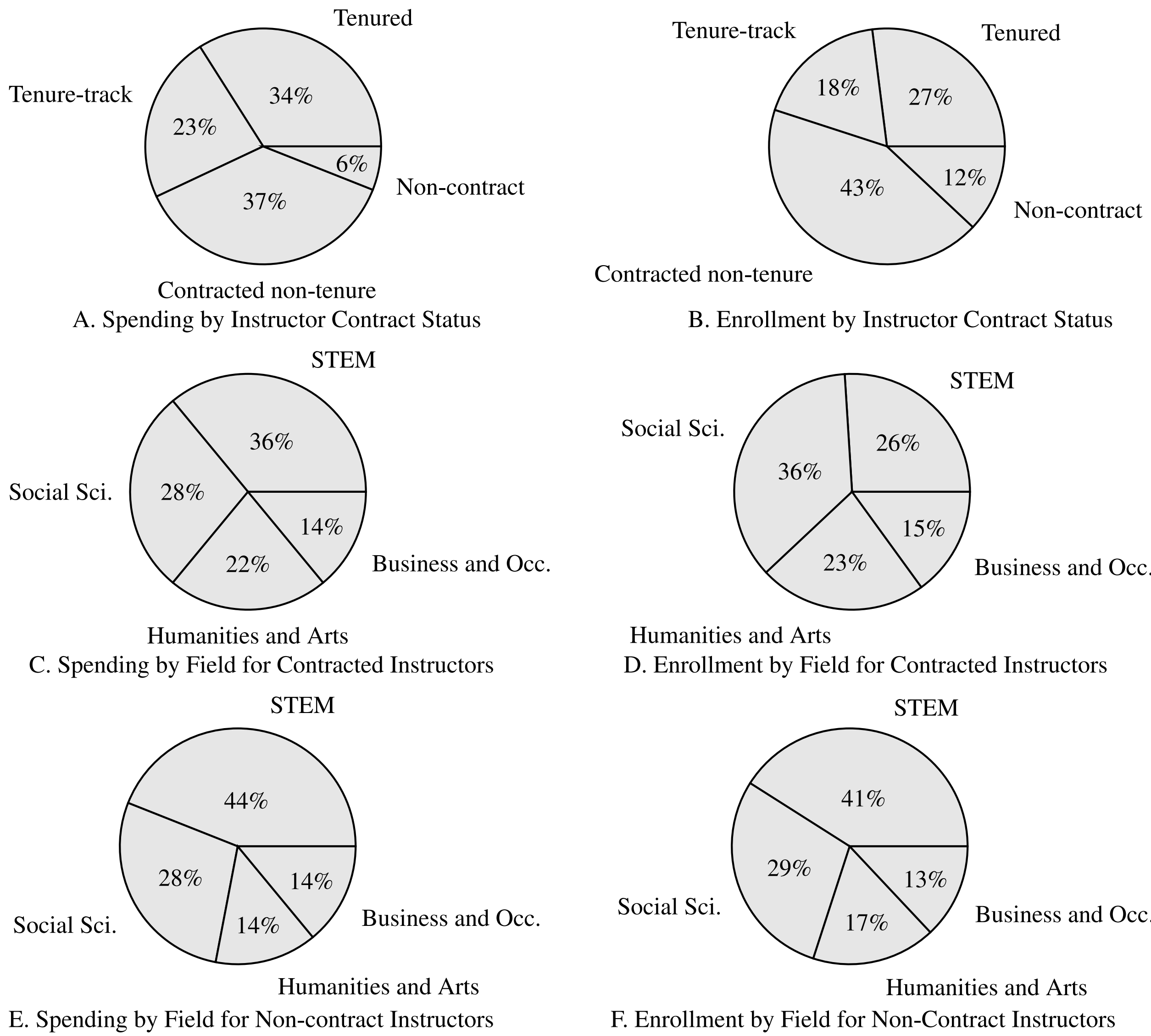
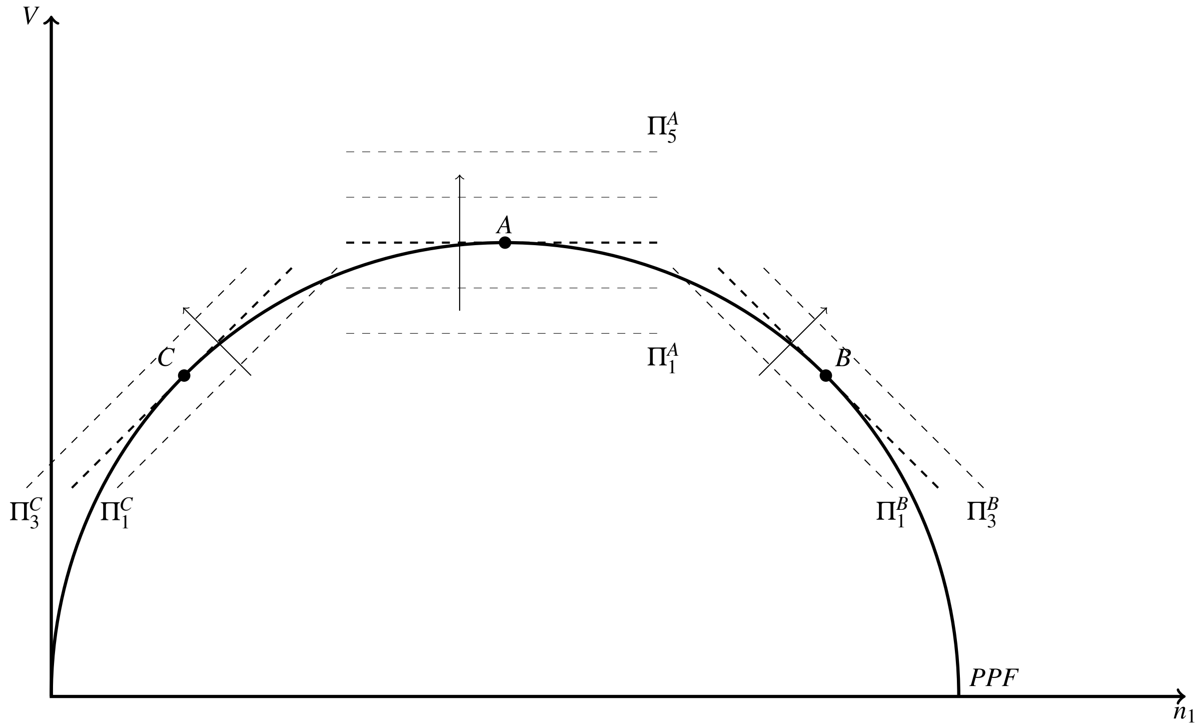
Figure 1: Spending and Enrollment in Introductory Courses by Instructor Rank and Field



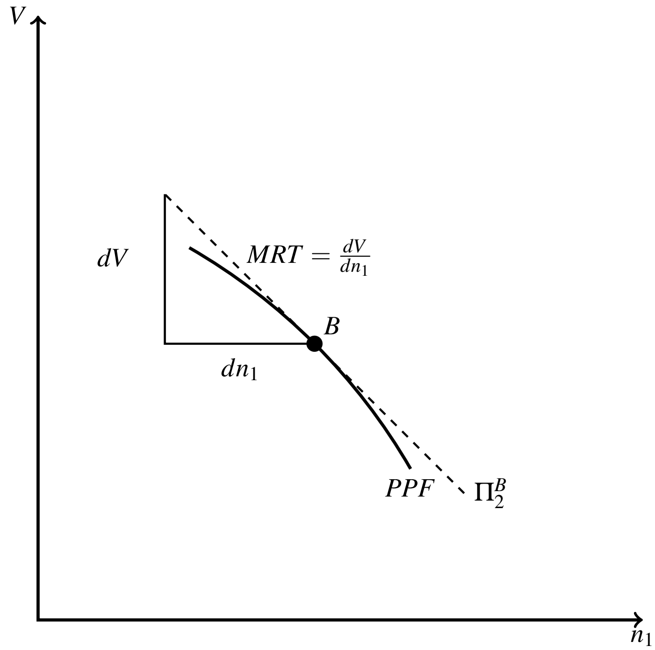
Statistics are for introductory courses taught in Fall and Spring semesters of 2006-07 to 2009-10 academic years at the University of Central Arkansas. Spending is spending on instructor salaries. Contracted instructors are Tenured, Tenure-track, and contracted non-tenure. See Appendix A for more information.

Figure 2: Optimal Course Offerings



The vertical axis is total expected student utility. The horizontal axis is expected number of students choosing courses in field 1 (the expected number of students choosing courses in field 2 is the complement). The solid semi-circle is a production possibilities frontier representing the frontier of outcomes which can be achieved given the university's constraints. Dashed line segments represent potential university indifference curves with payoffs increasing in the direction of the arrows. University A only values total expected student utility $\left(\gamma_1^A = 0\right)$ and offers courses to achieve outcome A. University B has institutional preferences to increase the expected number of students choosing courses in field 1 $\left(\gamma_1^B > 0\right)$ and offers courses to achieve outcome B. University C has institutional preferences to decrease the expected number of students choosing courses in field 1 $\left(\gamma_1^C < 0\right)$ and offers courses to achieve outcome C.

Figure 3: Revealed Institutional Preferences



This is Figure 1 zoomed in to focus on the tangency condition of university B. The derivative of the PPF at point B, or marginal rate of transformation (MRT), is given by the instantaneous change in total expected student utility relative to the instantaneous change in the expected number of students choosing courses in field 1 as the university marginally reallocates funds from field 1 to field 2. The instantaneous change in total expected student utility is given by the marginal effect per dollar of offering an addition field 2 course on total expected student utility minus the marginal effect per dollar of offering an addition field 1 course:

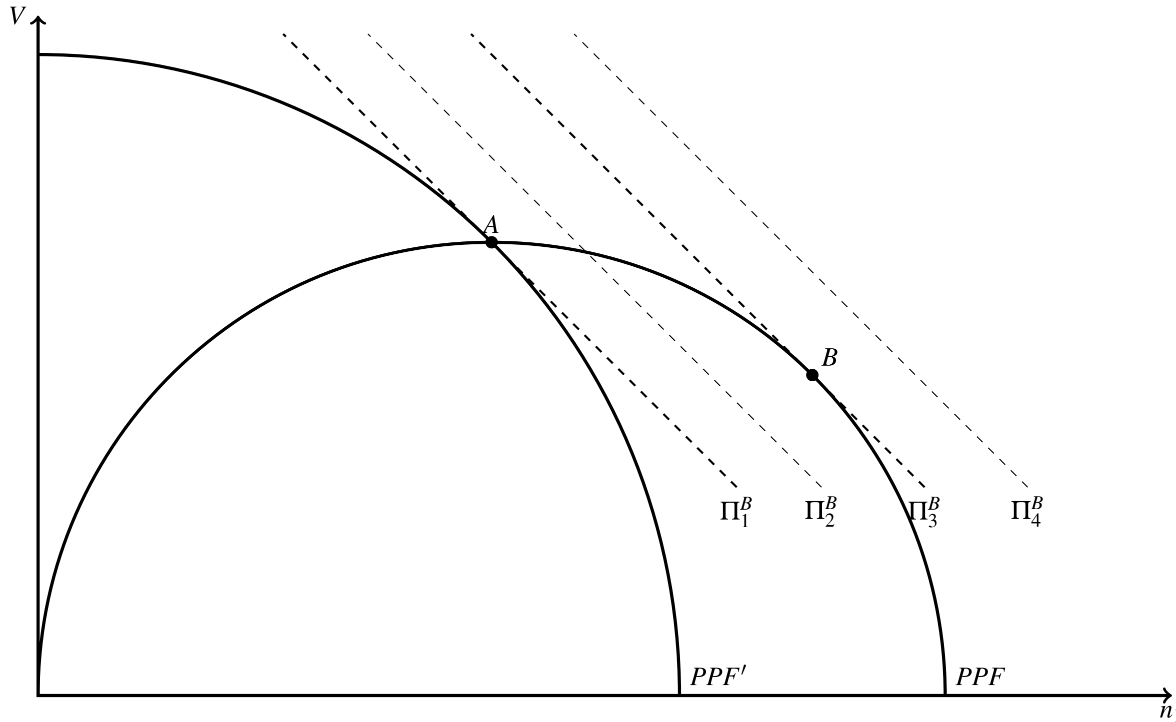
$$dV = \left(\frac{1}{c_2^N}\right)\left(\frac{\partial V}{\partial d_2}\right) - \left(\frac{1}{c_1^N}\right)\left(\frac{\partial V}{\partial d_1}\right)$$

The instantaneous change in the expected number of students choosing courses in field 1 is given by the marginal effect per dollar of offering an addition field 2 course on the expected number of students choosing courses in field 1 minus the marginal effect per dollar of offering an addition field 1 course on the expected number of students choosing courses in field 1.

$$dn_1 = \left(\frac{1}{c_2^N}\right)\left(\frac{\partial n_1}{\partial d_2}\right) - \left(\frac{1}{c_1^N}\right)\left(\frac{\partial n_1}{\partial d_1}\right)$$

This graphically demonstrates how marginal effects of spending can be used to solve for the slope of the indifference curves which rationalize why point B was optimal for this university.

Figure 4: Counterfactual Costs to Induce Student-Best Offerings



PPF' is the production possibilities frontier in a counterfactual setting where budget and contract constraints are held fixed but costs of offering courses are changed so that it is more expensive to offer field 1 courses and less expensive to offer field 2 courses. In this counterfactual setting, University B offers courses to achieve outcome A which would have maximized total expected student utility under the true production possibilities frontier PPF. Because the university's budget E is the same in both PPF and PPF' and since outcome A is on both PPF and PPF' outcome A can be induced with a revenue neutral tax-subsidy policy.

Table 1: University of Central Arkansas

Institutional Characteristics	
Undergraduates	9,887
Full-time faculty	547
Admission Rate	92%
Yield	44%
ACT 25th pctile	20
ACT 75th pctile	26
6 year graduation rate	45%
Student characteristics	
Full-time	84%
24 and under	90%
In-state	89%
Female	59%
White	66%
Black	18%
Hispanic	5%
Other race	11%

Source: National Center for Education Statistics. Fall, 2015. Yield is the percent of students who choose to enroll conditional on being offered admission. ACT scores are composite scores. Graduation rate is for students pursuing a Bachelor's degree.

Table 2: Average Effects of Spending on Enrollment for Non-contract Courses

	Course Sections	Avg cost per course	Total Cost	Enrollment	Students per $1,000
STEM	315	$4,788	$1,508,220	8973	5.95
Social Science	205	$4,736	$970,901	6401	6.59
Humanities and Arts	118	$3,911	$461,545	3674	7.96
Business and Occupational	85	$5,420	$460,717	2778	6.03

Statistics are for introductory courses taught by instructors on short-term contracts in Fall and Spring semesters of 2006-07 to 2009-10 academic years at the University of Central Arkansas. The Students per $1,000 column represents the average effects of spending on enrollment in introductory non-contract courses.

Table 3: Student Course Choice Parameters

	STEM	Social Science	Humanities and Arts	Business and Occupational
Intercept	1.330***	1.390***	1.157***	*omitted*
	0.027	*0.027*	*0.022*	
ACT Z Score	0.125***	0.070***	0.111***	*omitted*
	0.009	*0.009*	*0.010*	
Missing ACT	-0.168***	-0.187***	-0.259***	*omitted*
	0.023	*0.019*	*0.022*	
GPA Z-score	0.015*	-0.108***	-0.116***	*omitted*
	0.009	*0.009*	*0.010*	
Missing GPA	0.028	0.126***	0.186***	*omitted*
	0.028	*0.024*	*0.027*	
Female	0.309***	0.525***	0.387***	*omitted*
	0.018	*0.016*	*0.017*	
Sophomore	-1.604***	-1.473***	-1.332***	*omitted*
	0.027	*0.026*	*0.026*	
Junior	-1.863***	-1.834***	-1.887***	*omitted*
	0.027	*0.026*	*0.028*	
Senior	-1.177***	-1.308***	-1.366***	*omitted*
	0.034	*0.033*	*0.036*	
Nesting Parameter	0.435			
	0.029			

Block bootstrap standard errors (300 repetitions) in italics. ***/** denotes p-value for test that coefficient is not equal to zero is p<.01 / p<.05. Results are for a nested logit model of students choosing introductory courses given available alternatives. Nests are defined by academic fields. Data are from Fall and Spring semesters of 2006-07 to 2009-10 academic years at the University of Central Arkansas

Table 4: Effects of Offering Additional Courses on Total Student Utility

	STEM	Social Science	Humanities and Arts	Business and Occupational
Fall, 2006	1	1.236***	1.173***	1.253***
		0.008	*0.009*	*0.012*
Spring, 2007	1	1.205***	1.147***	1.295***
		0.008	*0.009*	*0.012*
Fall, 2007	1	1.247***	1.165***	1.312***
		0.008	*0.009*	*0.013*
Spring, 2008	1	1.212***	1.108***	1.353***
		0.007	*0.008*	*0.013*
Fall, 2008	1	1.250***	1.106***	1.339***
		0.008	*0.008*	*0.011*
Spring, 2009	1	1.199***	1.134***	1.432***
		0.007	*0.008*	*0.013*
Fall, 2009	1	1.204***	1.056***	1.251***
		0.007	*0.008*	*0.011*
Spring, 2010	1	1.245***	1.062***	1.347***
		0.008	*0.008*	*0.012*
All semesters	1	1.225***	1.119***	1.321***
		0.007	*0.008*	*0.011*

Block bootstrap standard errors (300 repetitions) in italics. *** denotes p-value for test that coefficient is greater than 1 is p<.01. Effects are relative to the effects of offering an additional STEM course which are normalized to one. The ‘All semesters’ row averages across all academic semesters. Effects are estimated using estimates of student course choice parameters.

Table 5: Effects of Offering Additional Courses on Total Student Utility per Dollar

	STEM	Social Science	Humanities and Arts	Business and Occupational
Fall, 2006	1	1.250***	1.436***	1.107***
		0.008	*0.011*	*0.011*
Spring, 2007	1	1.219***	1.404***	1.144***
		0.008	*0.01*	*0.011*
Fall, 2007	1	1.261***	1.426***	1.159***
		0.008	*0.011*	*0.011*
Spring, 2008	1	1.225***	1.356***	1.195***
		0.007	*0.01*	*0.011*
Fall, 2008	1	1.264***	1.354***	1.183***
		0.008	*0.01*	*0.01*
Spring, 2009	1	1.213***	1.388***	1.265***
		0.008	*0.01*	*0.012*
Fall, 2009	1	1.217***	1.293***	1.105***
		0.008	*0.01*	*0.01*
Spring, 2010	1	1.258***	1.300***	1.190***
		0.008	*0.01*	*0.011*
All semesters	1	1.239***	1.370***	1.167***
		0.007	*0.01*	*0.009*

Block bootstrap standard errors (300 repetitions) in italics. *** denotes p-value for test that coefficient is greater than 1 is p<.01. Effects per dollar are relative to the effects per dollar of offering an additional STEM course which are normalized to one. The 'All semesters' row averages across all academic semesters. Effects per dollar are estimated using estimates of student course choice parameters and average costs of offering non-contract courses by field.

Table 6: University Preferences for Enrollment by Field

	University's Relative Preference for Enrollment	Relative Preferences Scaled by 1% of total enrollment in Fall, 2009	Scaled Relative Preferences as a Percentage of Recentered Utility in Fall, 2009
	(1)	(2)	(3)
STEM	0.171***	38.47	2.66%
	0.009		
Social Science	-0.058***	-13.05	-0.90%
	0.008		
Humanities and Arts	-0.152***	-34.19	-2.36%
	0.008		
Business and Occupational	*Omitted*		
Total Enrollment in Fall, 2009	22494		
Recentered total student utility in Fall, 2009	1446.4		

Block bootstrap standard errors (300 repetitions) in italics. *** denotes p-value for test that coefficient is different from zero is p<.01. Column 1 contains estimates of γ_f. Column 2 scales estimates of γ_f by 1% of total student enrollment in the Fall 2009 semester (224.9 students). Column 3 divides the scaled estimates in column 2 by re-centered total student utility in Fall 2009 where re-centered utility is expected total student utility net of expected total student utility if only contracted courses are offered. The interpretation of column 3 is that UCA is willing to sacrifice 2.66% of re-centered student utility to draw 1% of total enrollment from Business and Occupational courses to STEM courses.

Table 7: Counterfactual Costs which Induce Student Best Offerings

Costs of Course Offerings	STEM	Social Science	Humanities and Arts	Business and Occupational
Observed non-contract costs	$4,788.0	$4,736.1	$3,911.4	$5,420.2
Counterfactual non-contract costs	$5,584.3	$4,474.2	$3,396.1	$5,456.4
Number of Course Offerings	STEM	Social Science	Humanities and Arts	Business and Occupational
Contract	180	221	170	90
Observed non-contract	56	31	17	11
Counterfactual non-contract	6	59	54	4
Enrollment Shares	STEM	Social Science	Humanities and Arts	Business and Occupational
Observed	27.46%	35.09%	22.90%	14.56%
Counterfactual	24.85%	36.48%	24.55%	14.12%

	Total Student Utility	**Recentered Utility**
Contract only	102194	
Observed	103641	1446
Counterfactual	103715	1520

Semester of counterfactual analysis is Fall, 2009. Counterfactual non-contract costs induce UCA to offer non-contract courses which maximize total expected student utility. Contract courses are taught by instructors on long term contracts. Non-contract courses are taught by instructors on single semester contracts. Re-centered utility is total utility net of contract only utility.

Table 8: Naive Earnings Regressions

Field of major	(1) Log annual earnings conditional on reporting 8 years after graduating	(2) Reporting earnings 8 years after graduating
STEM	0.464***	0.0210
	(0.0586)	(0.0221)
Social Science	0.102**	0.0523***
	(0.0515)	(0.0196)
Humanities	*Omitted*	*Omitted*
Business and Occupational	0.382***	0.0893***
	(0.0444)	(0.0168)
General / Missing Field	0.281***	0.125***
	(0.0466)	(0.0179)
Observations	7,375	11,645
R-squared	0.060	0.013

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Additional controls include ACT scores, high school GPA, gender, and graduation year. Columns 2 is a linear probability models. Data are for students who earn Bachelor's degrees between the 1993-1994 and 2003-2004 academic years. 27.5% of degrees cannot be matched to a field and thus are included in the General / Missing Field category. Graduates who complete multiple degrees or majors are excluded (4.2% of degree earners).

Table 9: Naive Grade Regressions

Field of course	(1) Earning an A grade conditional on completing	(2) Grade points conditional on completing (Censored Regression)	(3) Withdraw / Incomplete Grade
STEM	-0.118***	-0.547***	0.0372***
	(0.00233)	(0.00826)	(0.00155)
Social Science	-0.0732***	-0.314***	0.0145***
	(0.00220)	(0.00781)	(0.00147)
Humanities	*Omitted*	*Omitted*	*Omitted*
Business and Occupational	-0.0514***	-0.214***	0.00910***
	(0.00276)	(0.00983)	(0.00186)
Observations	259,004	259,004	286,682
R-squared	0.156	N/A	0.024

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Controls include ACT scores, high school GPA, gender, and student level. Columns 1 and 3 are linear probability models. A withdrawal or incomplete is recorded on a student's transcript but does not impact the student's GPA (9.7% of observations). Letter grades are assigned to numeric grade point values using the Arkansas Department of Higher Education's metric (A=4, B=3, C=2, D=1, F=0). 25.3% of grades are an A. Data are for introductory courses in Fall and Spring academic semesters between the 2005-06 and 2011-2012 academic years.

Table A1: Elasticity of enrollment with respect to instructor salary

	log(Enrollment)	log(Enrollment)	log(Enrollment)	log(Enrollment)
log(Instructor Salary)	0.0855***	0.171***	0.0248***	0.0706***
	0.0107	*0.0359*	*0.00644*	*0.0204*
Course fixed effects	Yes	Yes	Yes	Yes
Non-contract courses only	No	Yes	No	Yes
Only courses with enrollment>5	No	No	Yes	Yes
Observations	8,556	873	8,300	828
R-squared	0.517	0.600	0.602	0.574

Standard errors in italics. *** denotes p-value for test that coefficient is not equal to zero is p<.01. Data are from Fall and Spring semesters of 2004-05 to 2009-10 academic years at the University of Central Arkansas (additional years included to better accommodate course fixed effects). Non-contract courses are taught by instructors on single semester contracts.

Table A2: Elasticity of enrollment with respect to spending on course offerings

	STEM	Social Science	Humanities and Arts	Business and Occupational
Fall, 2006	0.3092	0.2764	0.3371	0.3493
	0.0205	*0.0184*	*0.0226*	*0.0233*
Spring, 2007	0.3117	0.2769	0.3370	0.3478
	0.0208	*0.0183*	*0.0226*	*0.0232*
Fall, 2007	0.3085	0.2778	0.3363	0.3502
	0.0204	*0.0185*	*0.0225*	*0.0235*
Spring, 2008	0.3123	0.2791	0.3347	0.3484
	0.0208	*0.0186*	*0.0223*	*0.0233*
Fall, 2008	0.3124	0.2810	0.3341	0.3465
	0.0208	*0.0189*	*0.0222*	*0.0231*
Spring, 2009	0.3138	0.2790	0.3379	0.3454
	0.0209	*0.0185*	*0.0226*	*0.0231*
Fall, 2009	0.3126	0.2789	0.3332	0.3473
	0.0209	*0.0186*	*0.0221*	*0.0232*
Spring, 2010	0.3119	0.2826	0.3333	0.3456
	0.0208	*0.0190*	*0.0220*	*0.0230*
All semesters	0.3115	0.2790	0.3355	0.3476
	0.0208	*0.0186*	*0.0224*	*0.0232*

Bootstrap standard errors (300 iterations) in italics. Elasticities are computed using the estimated nested logit model of course choices. The 'All semesters' row averages across all academic semesters.