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and Discipline Premiums**

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ABSTRACT

Returns to Higher Education - Graduate and Discipline Premiums*

This paper reviews and evaluates progress in recent research on the graduate premium in general as well as the differential graduate premiums by discipline, accounting for higher-education choice by individuals under substantial uncertainty. The contribution of this review, relative to previous reviews, is the collection of a wider variety of evidence that all bears on a relatively narrow issue, namely the graduate and discipline premiums, allowing for selection into undergraduate degree and degree subjects which include the option value of undertaking postgraduate degrees. The issue of subject-job match quality after graduation is only treated as a sensitivity check to the main results, due to concerns with self-selection. We emphasize that the sizes of the graduate and discipline premiums are context-specific, especially regarding how HE is structured and financed in a country, without going into details. Much higher weight is placed on the most up-to-date research that sheds light on the causal effects of higher-education and subject choice, and the conclusions are heavily driven by the best evidence rather than by consensus built around correlations. This paper ends with a short summary of the empirical evidence and a brief discussion of possible areas for future research.

JEL Classification: I26, I23, I24

Keywords: graduate premium, discipline premiums, higher-education choice, subject-job match, causal effects

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1. Introduction

Returns to education have been at the center of labor economics ever since its emergence as a standalone subfield of economics. While earlier studies have typically focused on returns to (years of) schooling in general, effectively treating education as homogeneous, more recent research allow for heterogeneity between and within different stages of education. Over the last few decades, most countries have experienced substantial expansion of the higher-education (HE) sector, often accompanied by a shift of the cost to individuals on the grounds of perceived large private financial benefits from their degrees (Cappelli 2020). This implies that the issue of the graduate and discipline premiums — the increase in average pay (either in wages or earnings) associated with having a university degree and by subjects studied — is becoming increasingly important, not only for individuals and their families who must make the high-stake decisions regarding HE, but also for policymakers due to the implications for skill shortages, public finance, and equity.

While the extent and the exact timing vary from country to country, a common feature of HE is the specialization by students in a particular discipline (often used interchangeably with subject or major in the literature) which prepares them for a related professional occupation (Malamud 2010; Speer 2021). A well-established stylized fact of HE is the substantial differences in observed wages and earnings across HE disciplines among graduates, even conditional on gender, race, ethnicity, family background, country and so on (OECD 2017).

The contribution of this review, in comparison to previous reviews (e.g. Altonji 2012 and 2016a; Walker and Zhu 2013; Webber, 2014a), is the collection of a wider variety of evidence that all bears on a relatively narrow issue, namely the graduate and discipline premiums, allowing for selection into undergraduate degree and degree subjects which include the option value of undertaking postgraduate degrees. The issue of subject-job match quality after graduation is only treated as a sensitivity check to the main results, due to concerns with self-selection. We emphasize that the sizes of the graduate and discipline premiums are context-specific, especially regarding how HE is structured and financed in a country, without going into details. Much higher weight is placed on the most up-to-date research that sheds light on the causal effects of HE and subject choice, and the conclusions are heavily driven by the best evidence rather than by consensus built around correlations.

The remainder of the paper is organized as follows. Section 2 briefly reviews the relevant theoretical frameworks underlying the graduate and discipline premiums, emphasizing the challenges in empirical research. Section 3 surveys the recent literature on the choice of college major. Section 4 focuses on recent developments in empirical studies on the graduate premium by college major, allowing for the endogenous selection of disciplines. Finally, Section 5 concludes.

2. Theoretical Framework and Empirical Challenges

Compared to primary and secondary schools which are largely publicly funded and tend to follow a national curriculum, HE institutions are much more heterogeneous across countries in selectivity and subjects offered. From a student's perspective, whether to go to college and the subsequent choice of a particular institution-subject combination are arguably the most important private investment decisions he or she will ever face. Moreover, the decisions are further complicated by the substantial uncertainties about personal academic ability in the chosen subject, the probability of successfully completing the degree and subsequently securing a job in the related occupation.

There is a general consensus that the level of education has a causal effect on labor-market outcomes, including wages and earnings, at the individual level (Card 2001). Education is progressive in nature. While compulsory education is thought to mainly develop general human capital, which embodies core skills such as numeracy and literacy, further education including HE develop more specific human capital which are more valued in specific jobs, industries and occupations. Returns to education (and skills) are believed to be determined by a race between the supply of skills and the **skill biased technical change** (SBTC), which increases the relative demand for more skilled workers (Acemoglu and Autor, 2011). Indeed, studies suggesting that overall returns to HE had remained steady in many countries, and even risen in the US, despite sizable HE expansions recently, have been interpreted as evidence in support of the SBTC theory. However, there has been hardly any evidence on the change in graduate premiums by discipline over time.

There are good reasons to expect graduate earnings to vary by subject(s) studied. More technical or quantitative disciplines might foster skills that are more valued in the labor market, especially with the advancement of modern technologies. Alternatively, the observed earnings differences across college majors could be driven by non-random selection, thus reflecting pre-college

educational attainment and abilities as well as individual preferences. It is virtually universal that HE participants have higher educational attainments than non-participants. Moreover, due to the progressive nature of most disciplines, graduates majoring in Science, Technology, Engineering and Mathematics (STEM) tend to have stronger mathematical skills, measured at primary and secondary-school stages, which in turn are strongly associated with higher earnings, regardless of HE participation (see e.g. Crawford and Cribb 2013). A Danish study exploiting a rare curriculum reform that allows more flexible combinations of mathematics with other high-school subjects further indicates a significant positive causal effect of math on earnings, working partly through higher HE participation, for students induced to choose math after being exposed to the scheme (Joensen and Skyt Nilsen 2009). This implies that failure to account for differences in prior academic attainment or basic skills might lead to incorrect conclusions for both prospective students and public policy makers (Webber 2014a).

Altonji et al. (2012) propose a unified model which captures the dynamics of education and occupation choice. A clear distinction is made between *ex ante* and *ex post* returns to educational investment, to reflect the inherent uncertainty about preferences, ability, and educational attainment, as well as labor-market outcomes. Human capital is acquired sequentially in stages, with partial irreversibility of post-compulsory education, in particular HE, due to the cumulative and subject-specific human capital formation. General and subject-specific ability, preferences, family background and uncertainty all play much more important roles in individual choices and attainments in HE compared to earlier stages of education (Altonji et al. 2012; Oreopoulos and Petronijevic 2013).

Intuitively, students make initial HE choices (relative to no HE) based on their academic preparedness for the subject, their preferences and earnings expectations, which in turn depend on the information available to them at the time. Moreover, the choices of HE institution and major might be more influenced by an individual's family background, resulting in greater inequality. Depending on the country specific HE structures, there is variable flexibility and cost of switching subjects when new information is revealed. Upon successful completion of the degree, there is also an issue of a potential mismatch between subjects studied and occupations chosen.

Understanding the causal effect of HE and field of studies on earnings and wages is essential for HE policies favoring some subjects over others, especially when government provides most of the

funding of HE. However, estimating returns to HE while accounting for HE choices is empirically very challenging due to the non-random selection involved in sequential educational choices with learning. To the extent that HE choices are partially based on individual ability and anticipated returns in the future, the OLS estimates in most studies are likely to be severely biased arising from omitted variables which affect both educational choices and labor-market outcomes.

The graduate and discipline premiums are ultimately an empirical question, due to the vast differences in HE structures, tuition fees and funding, as well as economic development and culture across countries. Therefore, it is not surprising that the availability of high-quality micro data with rich information is a pre-condition for credible estimation of the returns to HE in general and different college majors specifically. As a minimum requirement, the data must allow for sufficient controls of individual characteristics, family backgrounds, as well as pre-college educational attainments. Moreover, the identification of the causal effect would typically require the availability of variables that only influence an individual's educational choice, such as the cost of or access to HE, but have no direct effect on wages. Therefore, it is perhaps not surprising that the causal evidence comes mostly from a few developed countries with the best data, notably the US, Canada and selected European countries.

3. Choice of major

Choosing which degree subject to study has a significant influence both on the subsequent occupational choice set for the individuals concerned and on the future supply of skills in the labor market. The growing research on major choices suggests that the levels of education and subjects beyond compulsory education are jointly determined by various factors, including expected future earnings, (innate) general and subject-specific abilities, parental influences, non-pecuniary factors (preferences or heterogeneous tastes), career stereotypes (social norms) and attitudes, and labor-market conditions. Moreover, there is emerging research on the divergence of major choices across different demographic and socio-economic groups. There is a political concern to understand the differences in major choices between different socio-economic groups in order to reduce inequality. During upper-secondary education, some countries formally divide students into science and arts streams while others may require students to specialize in a limited number of subjects. These pre-college subject choices are consequential for major choices in HE. A growing literature suggests

that prospective students, especially those with low income/education parents, are misinformed about their innate abilities and expected earnings, resulting in less efficient decision-making (Baker et al. 2018). The choice of major is considered as a dynamic process, and the decision or beliefs are updated as new information becomes available when studying (Zafar 2011; Stinebrickner and Stinebrickner 2014).

The major and occupation choices may happen both on the intensive margin and on the extensive margin. Overconfident students tend to sort into high-paid jobs on the extensive margin and women are more likely to choose less math-intensive STEM majors (Reuben et al. 2015; Jiang 2021). Moreover, current research has exclusively focused on major choice independent of choice of higher-education institutions (HEIs). The joint decision between institution and major(s) is an important feature of the HE decision-making. Students may have preferences on the prestige of HEIs, which may affect the selection of the major with the highest financial return given the prior academic achievements. Students with less academic preparation may benefit from taking science degrees in less-selective institutions. Some marginal students enter top-ranked schools in the face of higher non-completion rates (Arcidiacono et al. 2016). There is less empirical research on differential major choices or the impact of major choices by different demographic groups. Lastly, while individual factors affecting major choices have been studied in depth, the relative importance of different factors has not been fully explored.

3.1. Pre-HE subject choice

It is natural to think that major choice is partially determined prior to attending universities. Some universities specify ‘facilitating subjects’ taken in secondary schools as prerequisites for different university subjects. Other universities may offer broader curriculums such that students study general courses in the first year and choose specific programs in the second year (Zolitz and Feld 2021). Attempts have been made to revise the breadth of curriculum of a given degree (Seah et al. 2020). However, there is a heavy cost of switching to a very different degree, say from one in the humanities to an engineering degree. Policy should aim to improve the efficiency of major choice before students enter universities.

3.1.1. Expected earnings and labor-market conditions

Expected earnings is one of the major determinants when choosing subjects. Based on survey data, Berger (1988) documented a positive relationship between expected lifetime earnings and major choices. However, using revealed choices might be problematic since the choices are formed by the combination of expected earnings and preferences. Emerging research has used subjective expectations by collecting data from students (Zafar 2011).

To examine the role of expected earnings on major choices, Arcidiacono et al. (2012) compare the subjective expectations of the chosen subject and the earnings of different careers with the counterfactual expectations on major. Their results suggest that both expected earnings and abilities are strong determinants of major choices. Students are more likely to choose a subject and a career which have the highest expected earnings compared to other subjects in the same institute.

Making use of the panel element in experimental data collected from New York University, Wiswall and Zafar (2015a) examine the relationship between the changes in expected future earnings and the subjective probabilities of majoring in each field. They find that students have biased expectations of future earnings and argue that expected earnings and perceived abilities are important determinants of major choices. They show that OLS results are severely upward biased due to the positive relationship between earnings expectations and unobserved preferences. Their results also indicate heterogeneous perceived bias in expected earnings across students and that unobserved factors may play an important role in receiving the information.

Inaccurate information on earnings may result in less efficient initial decisions on majors and students will update their beliefs and switch subjects. Based on the data collected from community colleges, Baker et al. (2018) show that less than 40% of college students have accurate information on the earnings of majors. The information is not always available and is sometimes difficult to understand. Students from lower-income backgrounds are more likely to make mistakes in estimating the probability of employment.

Exposure to higher levels of unemployment during typical schooling years results in the selection of subjects with higher economic returns and better employment outcomes. In the face of labor-market slack, students may pay more attention to the economic return of a subject or the signal of a subject to potential employers (Blom et al. 2021).

3.1.2. Preferences or heterogeneous tastes

Increasing evidence suggests that subject choice is largely driven by preferences or heterogeneous tastes for subjects, more than expected earnings.

By exploiting the exogenous variation in the returns to each major during the business cycle, Beffy et al. (2012) find a weak relationship between expected earnings and subject choice and argue that non-pecuniary factors are key determinants of schooling choices in France. In the context of uncertainty of length of the study, the authors propose a three-stage model to simulate the decisions of students including the decision on major, level of study, and labor-market participation.

Zafar (2012) shows that the non-pecuniary factors including enjoying coursework, enjoying work at potential jobs, and gaining the approval of parents, explain more than half of the variation in choices of majors in the US. The author contributes to the literature by focusing on differences in the expectations and preferences between male and female, providing important insights on which policy is effective in reducing gender gaps. The large gender gap is driven mostly by preferences and tastes rather than confidence or beliefs.

Based on a primary dataset containing measures of overconfidence, competitiveness, risk aversion, Reuben et al. (2015) examine the explanatory power of these features on gender differences in major choice. Their results find that men are more likely to overestimate their ability than women. Risk-averse students are less likely to select a major with greater earnings uncertainty. They only find robust effect of measures of competitiveness and confidence, but not of risk aversion, on expected earnings. Their results are consistent with the literature in which overconfident students sort into high-paid occupations on the extensive margin. Although the study focuses on gender differences, the results may be valid more generally.

The large gender gap in subject choice could largely be explained by attitudes, career stereotypes and preferences. Using an extended Roy model, Jiang (2021) examines the role of ability-sorting in the gender gap of STEM major choice, based on unique data collected from Purdue university. The gender gap in STEM major choice cannot be explained by differential ability-sorting between male and female students. Instead, the results indicate that women's participation declines at each stage of the STEM pipeline, implying that factors other than ability contribute to the gap in STEM occupations. Moreover, women are more likely to attend less math-intensive STEM majors and are consequently likely to be well-matched with non-STEM occupations.

3.1.3. Abilities and preparedness

The current literature has focused on major choice under the uncertainty of innate abilities and preference on majors. With imperfect information on subjects and their own innate abilities, grades or any feedback at school will reveal information for students to make better choices of major.

Making use of all college applicants in Ireland, Delaney and Devereux (2021) show that math ranking is positively correlated with the selection of STEM subject and negatively correlated with the selection of Arts and Social Science, with the effect of subjects ranking larger for boys than girls. The ranking could explain 4%-10% of the gender gap in choosing STEM subjects in colleges.

Based on a unique dataset containing both general and specific abilities of students, Bartolj and Polanec (2012) study the impacts of these abilities on major choice. Their results suggest that students with higher general ability tend to choose economics and students with higher specific ability are more likely to choose the corresponding major. They argue that not accounting for the differential effect of distinctive abilities on subject selection may result in ambiguous results and major choices could be altered by training students with subject-specific abilities prior to attending universities.

By exploiting a natural experiment, Fricke et al. (2018) examine the effect of exposure to related schoolwork on the major choice. They find that doing coursework in economics and law raises majoring in economics and law by 2.7 and 1.6 percentage points respectively, suggesting that students update their own preferences and abilities by doing relevant schoolwork. This also implies that allowing students to try out different subjects before they make a final decision on their college major might help them to avoid high subject-switching costs at later stages.

Using applicants' data from the University of California, Arcidiacono et al. (2016) examine the relationship between academic preparation and learning outcomes. Their results suggest that less-prepared ethnic minorities at higher ranked campuses at the University of California have higher probabilities of non-completion. They find that the match between academic preparation and the rank of campus is important for study in the sciences. They also note an important trade-off between school prestige and major choices and argue that majoring in a sciences degree at a less-selective campus carries higher returns than majoring in a non-sciences degree in a more selective campus.

3.1.4. Family and peers influence

Parents and peers in schools may have influence on students' choices of universities and majors.

Using a novel experimental method and modelling college choice as a collective decision by a family, Huntington-Klein (2017) finds that students themselves have more influence than parents on the choice of hypothetical colleges with different attributes, including earnings at age 25, course enjoyment, quality of social life, tuition fees and opinions of parents. Students also value the expected earnings and the enjoyment of courses more than parents do. Xia (2018) documents a positive relationship between a student's major choice and close family members' wages and argues that students use their family member's wage information to form their own expectations of future earnings.

The peer effect on major choice is mixed and ambiguous, partly because of the daunting challenge of identifying the causal effect of peer interactions. By exploiting random assignment of gender composition across high-school classes, Anelli and Peri (2017) find no significant relationship between gender composition in high school and major choice and college performance. There is a positive relationship for men when being exposed to extreme gender composition in a class, resulting in a higher probability of choosing prevalently male majors. However, the effect fades away by the time of graduation due to attrition and change of major.

By studying major choices after the compulsory courses in the first year of college, Zolitz and Feld (2021) find that female students are more likely to choose female-dominated majors and less likely to choose male-dominated majors when being exposed to a higher share of female students, and vice-versa for men. Female students' major choice is more likely to follow that of their female peers and role models.

3.1.5. Impacts from the supply side

Andrews and Stange (2019) examine deregulation in Texas since 2003 through which colleges are given more autonomy and consequently have raised tuition fees for high-demand and more costly programs. The results suggest that the deregulation in Texas after 2003 has not worsened the probability of poor students enrolling into high earning programs, or their outcomes relative to non-poor students. The authors argue that the increased representation of poorer students in high-

earning programs after the deregulation result from the increasing grant aid and large needs-based state aid programme.

3.2. While studying in universities

Students form and alter their major choices in light of new information on the returns to majors and their innate abilities that is revealed during university studies.

Based on two surveys collected, Zafar (2011) documents that students update their beliefs in a rational way. Students are generally overconfident in their academic performance. Students are more likely to update their beliefs when the realized outcome is significantly different from their initial expectations. Students who are uncertain about their performance initially are more likely to make greater changes to their beliefs.

Stinebrickner and Stinebrickner (2014) collect data at the time of college entrance and follow the students to examine the relationship between initial beliefs and outcomes. They find future academic performance plays a larger role in determining the learning outcomes compared to future expected earnings. Due to misperceptions about the ability in a particular major, a significant number of science students leave colleges without a science degree after realizing their academic ability in science. Moreover, they also argue that learning a science module is the primary way to reveal the ability in science and suggest that having a science module at early ages could reveal students' abilities in science and encourage more capable students into a science degree.

3.3. Post-graduate studies

Human-capital accumulation is a dynamic process. Graduates may take postgraduate education to further enhance their existing skills or to pursue another occupation. Altonji and Zhong (2020) document the link between undergraduate field and graduate field and show that both the fields of undergraduate study and occupation have a strong influence on the choice of the graduate field.

This is indeed an understudied area of research. Both the returns to postgraduate degrees and the motivation behind choosing a different subject of study is unclear in the current literature. Work experience will continue to reveal information on preference and innate abilities and the graduate may pursue another occupation by receiving a more relevant education.

4. The College-Major Premium

4.1. The Graduate Premium

It is well established that a college degree is associated with higher earnings and wages **on average**. Across all OECD countries, the HE earnings premium over a high-school education is about 64% (OECD 2013). But this does not imply a causal effect of HE on earnings due to self-selection, with those with more to gain from HE more likely to go to college. Card (2001) surveys the literature on estimating the causal returns to schooling in general, including HE. In contrast, Oreopoulos and Petronijevic (2013) is dedicated to the review of empirical studies of the causal returns to HE, mostly from the US, using various quasi-experimental approaches.

Card (1995) exploits variation in college proximity to show that youths who grew up near a college were more likely to attend than similar youths who lived further away in the US. He finds that the returns for each year of college education for those marginal students who were induced to attend colleges due to the lower commuting cost ranged from 10-14 percent. Other studies make use of the natural experiment arising from the GI Bill in Canada and the US which provided Vietnam War veterans with financial aid to attend colleges and find that each year spent in college by veterans, randomly drafted in the case of the US, increased earnings by 9-15 percent (Lemieux and Card 2001; Angrist and Chen 2011).

Researchers have also used fixed-effects models to estimate the returns to HE. For instance, Jepson et al. (2014) use administrative data from Kentucky to show that the returns to associate degrees or diplomas from two-year community colleges in the US are about 20% and 40% for men and women, respectively. However, this strategy relies on the availability of earnings data both before and after college, which is generally not the case for the majority of college graduates in most countries.

A more general and arguably more convincing empirical strategy to identify the causal effect of HE on earnings is based on the Regression Discontinuity Design (RDD) approach. Zimmerman (2014) compares the earnings of 7 cohorts of high-school graduates on either side of the admission cutoff at Florida State University, which has the lowest admissions standard in the state university system. The estimated return to the marginal student is about 8.7 percent, with the effect more pronounced for males or free-lunch recipients. The estimate could be interpreted as a lower bound estimate as the comparison group might still attend two-year community colleges for which the

returns are also expected to be positive (see Kane and Rouse 1995). Hoekstra (2009) exploits a large discontinuity in the admission cutoff on enrolment at a flagship state university to estimate a 20% return for white men, although this is interpreted as the economic return to college quality.

According to the review by Patrinos and Psacharopoulos (2020), there are very few causal studies in developing countries on the returns to education in general, let alone HE specifically. This at least partly reflects the more acute data-availability problem in developing countries. However, there are notable exceptions. Dai et al. (2021) exploit a dramatic expansion in HE in China which increased enrolment by 47% between 1998 and 1999 and 5-fold in the decade to 2008. Using a fuzzy discontinuity in months of birth, they show that the expansion increased the education level by one year and each year of college education induced by the expansion increased monthly earnings by 24%. While the size of the estimated effect is significantly higher than the corresponding returns from developed countries, this is comparable with Somani (2021) who finds a 27% return for Ethiopia using a difference-in-differences approach based on the spatial and temporal variation in a rapid expansion of public universities.

4.2. Graduate premiums by college major

As challenging as it may be, understanding the size of the causal effect of higher education in general is still inadequate from the view of the prospective students, who have to make the conscious HE choice in terms of a particular degree course, which usually involves choosing a specific subject at a specific institution. Official statistics typically show very large variations in graduate earnings and wages across degree subjects. However, the extent to which this reflects confounding factors such as ability, preferences, HEI selectivity, composition, life-cycle effects, occupational sorting, as well as biases arising from mismeasurement or aggregation, rather than the causal effect of major choice, is far from clear. Since the mid 1990s, researchers have attempted to estimate the heterogeneous returns to HE by subject, or the graduate discipline premium.

Using the National Longitudinal Study of High School Class of 1972 which has detailed information on GPA, college major and SAT scores, Loury and Garmin (1997) present compelling evidence that the payoff to college in the US depends on the major chosen, even conditional on HEI selectivity and the college performance. Using pooled UK Labour Force Surveys from 1994 to 2009, Walker and Zhu (2011) simulate lifetime earnings to derive net present values (NPVs)

and internal rates of returns (IRR), allowing for undergraduate degree class, postgraduate qualifications, tuition fees, income-contingent student loans and taxes, as well as lifecycle effects of employment and wage growth. For men, there is substantial variation in HE returns across the 4 broad subject groups, with Law, Economics and Management (LEM) on top, and other Social Sciences, Arts and Humanities at the bottom. In between are Combined Degrees and Science, Technology, Engineering and Mathematics/Medicine (STEM). Further simulation results suggest that a tripling of tuition fees would lower the IRR by 1-3 percentage points but not change the relative returns across subjects. Webber (2014b) applies a similar simulation approach to estimate NPVs to various college majors for US graduates in the 1979 National Longitudinal Survey of Youth and the American Community Survey, allowing selection into both HE and specific majors using measures of cognitive and noncognitive ability. The results indicate large variations in NPVs across majors, ranging from \$700k for Arts and Humanities to \$1.5million for STEM. Webber (2016) extends Webber (2014b) by additionally accounting for student loan debt, ability and risk of non-completion. Although the magnitude of the NPVs is lower, the large difference across majors remains. For the median student, NPV estimates range from £85k for Arts and Humanities to £300k for Business majors.

Walker and Zhu (2018) improve on their earlier study for the UK by exploiting the HEI information only available in more recent (restricted versions of the) Labour Force Surveys, matched with course-level selectivity measures based on administrative college-admission records for all UK HEIs. Accounting for selectivity using the Inverse Probability Weighted Regression Adjustment (IPWRA) model which matches different HE options significantly reduces the estimated returns to attending more selective universities. Moreover, the extent to which more selective HEIs boost earnings varies by subject.

The surge in research using the UK Longitudinal Educational Outcomes (LEO) data showcases how the availability of high-quality linked administrative data could be a game changer for one country in educational research. LEO is a person-level administrative dataset connecting individuals' full educational records through stages, with employment, benefit incomes and earnings up to late 20s for virtually the whole population of several cohorts of secondary school leavers in England. Specifically, it allows precise estimation of HE returns for individual degrees across an entire higher-education market, at a much more disaggregated level of HE options than what is feasible with survey data, with controls for the extremely detailed set of prior attainment

measures and unusually rich information on student background and secondary-school fixed-effects.

Belfield et al. (2018) focus on relative earnings and employment outcomes across 30 degree subjects 5 years after graduation (or expected graduation for dropouts) using the LEO data. The raw differences in relative gross earnings range from -25% for Creative Arts to over 30% for Medicine, Math or Economics for both genders, relative to the average graduate earnings. After accounting for pre-university characteristics including scores in national tests at key stages and family background, the range narrows to -15% to about 20% for both men and women, with the ordering of subjects virtually unchanged. Moreover, when they disaggregate the data to the “degree” (subject-institution combinations) level, with about 1,400 distinct degrees that have sufficiently large sizes, the range of the selection-adjusted relative earnings increased to -40% to 100%. Compared to the effects of institution selectivity and socio-economic background, the effects of college major are much larger in magnitude implying that the choice of discipline dominates the choice of college, as far as graduate earnings are concerned.

Using the LEO data, Britton et al. (2021) focus on annual gross earnings at age 30, across the nearly 2,000 “degrees” (subject-institution combinations), with individuals with similar background characteristics including high-school grades but with “did not go to college” as a control group. After accounting for the extremely detailed pre-HE characteristics including national exam grades at ages 11, 16 and 18, as well as the key subject choices in post-compulsory education, the overall HE returns reduce from 26.1 to 6.5 log points for men, and from 47.3 to 21.6 log points for women. While the overall patterns of the relative returns across subjects are consistent with those in Belfield et al. (2018), this study highlights the substantial within-subject variation in returns even across HEIs with similar selectivity. Moreover, selectivity is found to be only weakly related to returns through most of the selectivity distribution, except for the top end where there is a very strong premium.

Even with rich linked administrative data like LEO, one might still be concerned with selection on unobservables such as subject preferences (Dale and Krueger 2002), or noncognitive skills. While the HEI choice set is not available in LEO, the ability to control for upper-secondary school subject choices, neighborhood deprivation and school fixed-effects in Britton et al. (2021) should capture much of the variation in subject preferences. Moreover, evidence based on the Longitudinal Survey

of Young People in England (LSYPE) linked to LEO suggests that the inclusion of rich non-cognitive variables has no effect on the returns estimates once rich measures of prior attainment are controlled for (Buchmueller and Walker 2020).

It is worth noting at this point that all the studies discussed above do not control for post-HE choices, the most important of which is sorting into different occupations. The rationale for omitting post-HE variables is a concern for endogeneity which would bias the causal interpretation of college major estimates. However, a different strand of research has allowed for controls for post-HE choices including occupation, industry, public vs. private sector, full-time vs. part-time employment and geographical location (Robst 2007; Carroll and Tani 2013; Robst and vanGilder 2016; Ransom 2021). Using a fixed-effect model on a sample of US graduates who have worked between college and graduate school, Altonji and Zhong (2020) show that there exists large variation in returns to graduate fields, which in turn depend on undergraduate majors. While not facilitating a causal interpretation of the college major in general, these studies nevertheless provide evidence on the heterogeneous effects of HE with respect to post-HE choices and offer useful insights into potential channels through which post-HE choices mediate the effect of HE decisions.

As highlighted by Altonji et al. (2012), most of the literature on HE returns by subject studied assumes selection on observables. One notable exception is Kirkeboen et al. (2016) using rich Norwegian administrative data with information on preferred and next-best alternatives of HE applicants regarding institutions and subjects. Instrumental Variables (IVs) are constructed from discontinuities that effectively randomize applicants near unpredictable admission cutoffs into HEIs and majors. The results show that different fields of study have substantially different labor-market payoffs, even after accounting for institution and peer quality. Earnings effects from attending more selective institutions are relatively small compared to the payoffs to field of study, the latter pattern being consistent with individuals choosing fields in which they have a comparative advantage.

4.3. Wider labor-market outcomes and subject-occupation mismatch

There is growing evidence of a causal impact of HE and college-subject choice on wider labor-market outcomes, beyond earnings and wages.

While the main focus of Webber (2014b) is on the variation in NPVs across majors for college graduates in the US, it also attempts to account for differences in unemployment probabilities. As majors with high returns tend to have lower unemployment risk, the gap in the adjusted NPVs in favour of Business and STEM graduates become even larger, relative to Arts graduates. These findings echo the UK evidence in Walker and Zhu (2011), although the latter were unable to account for endogenous major choice due to the limited information in the Labour Force Survey.

A few studies have shed light on the effect of college majors on graduating in a recession. Using Canadian longitudinal university-employer-employee matched data of over 20 years and accounting for cohort, region and year fixed-effects, Oreopoulos et al. (2012) show that male graduates who graduated in a recession suffer persistent earnings losses lasting 10 years on average. However, the cost of recessions for new graduates is unevenly distributed across institution-major combinations, with graduates in the bottom predicted-earnings quintile suffering 4 times as much as those in the top predicted-earnings quintile. This process is shown to be driven by more skilled graduates switching to better firms, more quickly. Altonji et al. (2016b) find very similar effects of labor-market entry conditions on graduate careers for the US, with a large recession reducing initial earnings by 10%. However, graduates in high-skilled (STEM) majors are less impacted by recessions for most labor-market outcomes initially, leading to widening earnings inequality across majors. Moreover, the results also suggest that graduates in high-skilled majors enjoy better occupation quality and job-match quality, even in the presence of adverse entry conditions.

The wider literature on major-job mismatch typically finds that overeducation rates vary markedly across majors. Robst (2007) documents that 45% of US graduates in the 1993 National Survey of College Graduates (NCSG) report jobs unrelated or only partially related to their college majors. Majors that emphasize general skills, e.g. Liberal Arts, are more likely to be mismatched but suffer lower wage penalties. In contrast, majors emphasizing occupation-specific skills, e.g. Health Professionals, are less likely to be mismatched but suffer higher wage penalties for mismatch. However, this study is unable to rule out ability-sorting as the driver of the findings, due to a lack of ability measures in the NCSG. Carroll and Tani (2013) attempt to overcome the ability bias by allowing for individual fixed-effects, using a short panel of graduates from Australia. While the overeducation rates vary across majors, the overeducation wage penalty becomes insignificant for young graduates once the time-invariant individual characteristics are accounted for, implying lower ability or other unobservable characteristics might account for overeducation in the first

place. Zheng et al. (2021) provide rare evidence on the differential overeducation rates and earnings penalties in a developing country context. Using major-industry mismatch measures of Chinese online job applicants constructed from word segmentation and dictionary building techniques, they show that about half of Chinese online jobseekers, 90% of which are college graduates, are overeducated by at least two years, with an average 5.1% pay penalty. The effect of overeducation on pay varies significantly by college quality, city type, and the match of college major with industry. Graduates in STEM or LEM majors from national key universities, the most selective group of HEIs, are much less likely to be overeducated in the first place, and even enjoy a significant pay premium when they are overeducated. The findings are robust to alternative measures of overeducation, subsample analyses with fixed levels of education, and methods that addresses endogeneity in overeducation using measures of self-esteem, self-efficacy, and number of certifications.

Kinsler and Pavan (2015) attempt to disentangle the selection effect and the true differential returns both within and between majors in the heterogeneous returns across college majors in the US. Using a structural model to account for major and occupation sorting, they show significant returns to jobs well-matched to major, with science majors not working in jobs related to their field of study suffering a 30% pay penalty relative to their well-matched counterparts. They conclude that while selection plays a role, for business in particular, the large differences in major premiums are dominated by true differences across majors, with the returns to business and science majors still economically significant.

4.4. The effect of major choice on income inequality and the gender wage gap

Closely related to the graduate and discipline premiums, recent progress in research has also shed light on the distributional effect of major choice on incomes. With the substantial expansion of the HE sector in most countries, one would also expect to see compositional changes in college graduates along such dimensions as gender, race, socio-economic background, subject choice and ability.

Grogger and Eide (1995) show that the shift to high-skilled subjects and the rising returns to math ability account for a significant proportion of the rise in college premium in the 1980s for US men and women, respectively. Combining the Labour Force Survey with two cohort studies containing

measures of cognitive skills, Lindley and McIntosh (2015) suggest that the rising graduate wage inequality in the UK is largely driven by increased variation in student ability within subjects following HE expansion, and to a lesser extent by decreasing concentrations of occupations for each subject. Using the Russia Longitudinal Monitoring Survey for Graduates over 2002-2016, Kyui and Radchenko (2021) highlight the role of both skill-price changes and the uneven HE expansion across subject in the rising graduate wage variance in Russia.

Closely related to the literature on the gendered pattern in the choice of college majors and the subsequent subject-occupation match, researchers have studied the impact of HE choice on the gender wage gap. Using the 1996 Labour Force Survey from both the UK and Germany, Machin and Puhani (2003) show that university subjects account for 24-30 percent of the explained variations in the graduate gender wage gap in both countries, depending on the set of controls used in the Blinder-Oaxaca wage decomposition. Francesconi and Parey (2018) study the gender wage gap 12-18 months after graduation using a large survey of 6 cohorts of German graduates. They find that college subject is the single most important factor, accounting for up to 83% of the 11.3 log points wage gap that can be explained by observable variables, which include personal characteristics, high-school grades, family background, graduation mark as well as fixed-effects for cohort, region and universities.

5. Summary

Using various sources of exogenous variations in higher education, research has firmly established that there exist significant positive returns to HE and quite substantial graduate premiums, even after allowing for differences in ability, family background, direct and indirect costs of HE and the impact of the tax system. However, much of the research assumes homogeneity of HE.

More recent studies, often taking advantage of novel administrative or survey data, have further shown compelling evidence of true differences in college wage or earnings premiums across undergraduate majors, accounting for selection into specific fields according to ability, expected future-earnings differentials, and preferences. These findings also seem to be robust to additional controls for life-cycle effects, tuition fees, student loans and the tax system. Moreover, there is also growing evidence of significant effects of choices of college major on other labor-market outcomes, such as employment and job-match quality, among others.

While the magnitudes of the estimated graduate and subject premiums might reflect key institutional differences among the countries studied, such as HE funding and fees, the existence of substantial discipline premiums in favor of a very similar set of subjects is likely to hold universally. Given the ever-changing labor market and varying demand for skilled labor, regularly updated estimates of graduate and discipline premiums, though necessarily backward-looking, are still highly valuable to prospective students and parents to overcome information failures in HE choices. To the extent that they reflect credit constraints in the private finance of HE or poor development of general or subject-specific skills in schools, well-designed public policies have the potential to address the underlying issues. For instance, curriculum reforms to strengthen and maintain mathematical skills throughout secondary education might help streamline career pathways and narrow the heavy gender bias in STEM subjects from the outset. Moreover, more flexibility in education that reduces the cost of subject-switching both pre- and during college would also help reduce the impact of imperfect information and the inherent uncertainty in HE choices.

Finally, our understanding of the graduate and discipline premiums would benefit from studies from more countries with different education systems and different economic, social and cultural contexts. Given the advancements in economists' toolkits to uncover causal mechanisms, the binding constraint for empirical research seems to be the availability of high-quality, linked administrative data for most countries. Alternatively, school-curriculum reforms or discontinuity in HE entrance-exam-score cut-offs should be fully explored (Walker and Zhu 2013).

Further research is also urgently needed for other aspects of HE where the evidence base is still relatively weak. This includes the returns to postgraduate degrees which have become increasingly popular in the last decade or so, the effect of HE choice on the levels and variation of earnings and employment throughout the lifecycle, and the wider impact of HE choice beyond the labor market such as its impact on health, partnership and intergenerational mobility. The evidence base of any external effects of specific subjects such as STEM also needs to be strengthened to justify public subsidies. Moreover, there is currently a lack of systematic evidence on the impact of the breadth of the HE curriculum, which underpins skills supply and skills mismatch across occupations and industries. Empirical evidence is more critical than ever to shed light on the skills that are provided through HE.

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