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Research Article

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On the Intergenerational Transmission of STEM Education among Graduate Students

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Abstract: We provide novel evidence on the existence and extent of the intergenerational transmission of STEM (science, technology, engineering and mathematics) education using a recent large administrative dataset of Italian graduates obtained from the AlmaLaurea survey. We find sizeable intergenerational associations in university graduation from STEM programs and demonstrate that these varies strongly according to both the parent's and the child's gender. The paternal outweighs the maternal intergenerational relationship and is larger for sons than for daughters. While the documented STEM education transmission is not driven by parental liberal profession for most STEM fields, this is the case for some non-STEM fields (economic and legal studies), consistent with the presence of barriers to entry into some professions.

Keywords: gender, intergenerational transmission, parents, STEM

JEL-Codes: J16, J24, I24

1 Introduction

In Europe, the demand for professional and associate professional occupations in the fields of science, technology, engineering and mathematics (STEM) is expected to grow by 13 and 7% respectively between 2015 and 2025, as opposed to a

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predicted 3% increase in employment for all occupations (EU Skills Panorama 2014 2015). The projected growth of STEM occupations is even more rapid in the US, with the mathematical science occupations group expected to grow by 28% over the 2014–2024 period, compared to a predicted growth of 6.5% for all occupations (Fayer, Lacey, and Watson 2015). Yet, there are concerns that the future supply of STEM-related skills will be insufficient worldwide. This shortage is partly due to the underrepresentation of women in these fields, an issue that has been highlighted by policymakers and social scientists (European Commission 2015; Kahan and Ginther 2017; UNESCO 2017). Moreover, this trend is expected to exacerbate the gender gap in wages, since STEM occupations offer higher earnings than non-STEM jobs. In addition, the STEM premium gap has widened over time for both women and men (Noonan 2017).[1] Recent studies have empirically explored the role of STEM education as a driver of innovation and economic performance. Their findings include that STEM graduates were more likely to become involved in the creation of patents in Italy (Bianchi and Giorgelli 2019), that the presence of STEM graduates stimulated economic growth and innovation in the USA (Ray 2015), and that their presence generated positive externalities in society at large (Winters 2018). The ability to attract future generations of STEM students, to increase the supply of STEM professionals, and to reduce the gender imbalance requires an understanding of the forces that drive self-selection into STEM fields. This has very recently motivated a growing literature that explores the determinants of entry into and completion of STEM university degrees, as well as the gender gaps present in such programs. Although family background has been widely recognized as a major determinant of educational attainment in developed countries (see for instance Bjorklund and Salvanes (2010)), the influence of parental education in shaping their children's choice to enter a STEM field and on their likelihood to graduate remains under-explored. Furthermore, while a considerable literature has thoroughly investigated the intergenerational transmission of inequality in education, as measured by years of schooling, we are not aware of any previous study that has explicitly addressed intergenerational patterns in STEM educational attainments.

In this paper, we provide a novel assessment of the relationship between the educational outcomes of parents and children and estimate the intergenerational associations in STEM programs. Our study thus lies at the intersection of two distinct strands of literature, one on intergenerational factors in educational attainment and the other on the determinants of STEM educational outcomes, both

1 Women in STEM earned 35% more than their female counterparts in non-STEM jobs in 2015 in the US, while the corresponding premium was 30% for men. Both premia have grown since 2009, when they were 33% for women and 25% for men (Noonan 2017).

of which we briefly review in Section 2. We contribute to the first strand by identifying a new channel of transmission, which operates through parent's field of graduation. We also build on the second strand, showing that a hereto neglected aspect of family background, parents' field of study, plays a sizeable role. Furthermore, our analysis allows for gendered intergenerational associations according to both parents' and students' gender. To this regard, we take inspiration from the evidence on the existence of role models provided, among others, by Amin, Lundborg, and Rooth (2015), who show that a mother's schooling matters for the education of female children.

Our analysis exploits the 2017 AlmaLaurea survey, a recent high quality dataset that covers a large portion of the population of Italian graduates. This data has the advantage of containing text-type information on parental fields of study, which we code using an own-built procedure. Coherently with this information set, our target population is the sub-population of graduates, and the intergenerational parameters we estimate are informative about the *completion* of STEM degrees. The data do not allow us to make inferences about students' choice of a STEM program in university, nor about whether they remain in their chosen field or drop-out from university. Nonetheless, completion of post-secondary studies remains particularly relevant for long-term labor market outcomes.[2]

As emphasized by Bjorklund and Salvanes (2010), one motivation for the study of the intergenerational persistence of educational achievement is equality of opportunity. Individuals cannot choose their families, meaning that "the more important family background is—for instance as measured by parental education—for final educational achievement, the less equality of opportunity there is." Our interest in exploring whether students tend to remain in the same field of study as their parents is driven by this equality of opportunity argument, given that STEM fields are differently rewarded in the labor market. Our research is further driven by gender equality concerns, given that STEM disciplines are heavily male dominated.

The Italian case study we analyze is characterized by figures on STEM education and gender gaps that are similar to those observed in other developed countries. In our sample, STEM fields account for approximately 23% of university graduates, close to the OECD average of 24% in 2016 (OECD 2018). The gender gap is also present in the data, with just 15% of female graduates in our sample completing STEM degrees, compared to 34% of male graduates.[3] According to

2 Recent figures on the labor market benefits of tertiary education are available in OECD (2019).

3 Across OECD countries in 2017, only 20% of new entrants to short-cycle tertiary programs and 30% of new entrants to bachelor's programs in STEM fields were women (OECD 2019).

recent employment surveys of Italian graduates, STEM graduates' earnings are 16.4% higher than non-STEM graduates five years after degree completion (1571 vs 1350 euros per month) (Amalaurea 2018).[4] Interestingly, these wage differentials are comparable to those calculated in the US based on the 2015 American Community Survey, which show that STEM degree holders enjoy an earnings premium of 12 percent over non-STEM degree holders, regardless of the field in which they work (Noonan 2017).[5]

Our estimates indicate indicate that intergenerational associations in STEM university graduation are sizeable and largely heterogeneous across parent and child genders. Furthermore, this persistence is only partially attributable to the graduate's choice of high school type[6] and to parental influence on this intermediate decision. Fathers exert a larger influence than mothers on university completion. Having a STEM-educated father appears more important for sons than for daughters, while having a STEM-educated mother matters more for female students. When we allow for interdependent parents' STEM education parameters, we find non-trivial interactions that confirm the prominent role of the father's field of education with respect to the mother's on university completion as well as reveal a mother-daughter relationship. Moreover, while we provide evidence that the identified intergenerational associations are not explained by the transmission of parental liberal profession for most of STEM fields, the latter does matter for some non-STEM fields (economic and legal studies), consistent with a mechanism documented by Aina and Nicoletti (2018) in Italy.

Our paper is the first to document a large set of heterogeneous intergenerational STEM education links across parent and child genders. Though our analysis is not causal, it does uncover a new intergenerational relationship – that of STEM degree completion – which has significant implications for equality of opportunity relative to occupation and gender. We believe that our study will trigger further research, potentially benefitting from new data collection and methods, aimed at identifying the mechanisms driving the intergenerational associations in graduation field documented here. Indeed, disentangling their causal component is crucial for the design of policy interventions endeavoring to reduce the impact of family background on educational achievement and to promote gender equality in STEM fields as well as within the household.

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4 This gap reaches about 700 euros when comparing the wages of engineering graduates with those of psychology graduates (1,753 vs 1,042 euros) (Amalaurea 2018).

5 The STEM premium can increase up to 31% for STEM graduates employed in a STEM occupation (Noonan 2017).

6 We classify high schools into STEM and non-STEM based on the field of high school specialization and the science/math curricular content. See Section 3 and the Online Appendix A.3 for details.

The paper is structured as follows. Section 2 provides a short review of the emerging literature on the determinants of STEM educational outcomes and an overview of the main features of the wide-reaching literature on the intergenerational transmission of human capital. Section 3 introduces the data and the process of classifying parents' degrees, as well as describes the sample. Section 4 presents our empirical strategy, while Section 5 focuses on the gendered results of the intergenerational analysis of STEM versus non-STEM educational outcomes. In Section 6, we explore the role of parental liberal professions in intergenerational transmission, assessing parents' and children's specific field of study. Concluding remarks follow in Section 7.

2 Related Literature

In this section, we briefly describe the two streams of literature on which our paper builds. We start by reviewing recent studies on educational outcomes and the gender gap in STEM fields. We then provide a brief summary of key advancements in the long-lasting literature on the intergenerational transmission of human capital.

A growing body of research has investigated the determinants of students' choice to pursue and complete studies in STEM at the university level. Factors identified as potentially influential range from peer effects (Anelli and Peri 2019) to the gender of siblings (Brenoe 2018; Oguzoglu and Ozbeklik 2016), prior exposure to science (De Philippis 2017; Gottfried and Bozick 2016), information barriers (Barone et al. 2017), beliefs and expectations (Wiswall and Zafar 2015), and sociocultural background as measured by conservative political and religious attitudes (Grossmann, Osikominu, and Osterfeld 2016).

Researchers have also increasingly devoted attention to the drivers of the gender gap in the entry into and completion of STEM university programs. High school STEM readiness and scientific content and pre-college math ability have been found to be strong predictors of such gap in different countries (see Card and Payne (2017) and Saltiel (2019) for the US, Delaney and Devereux (2019) for Ireland, Granato (2018) for Italy). An opposite conclusion is reached by Justman and Mndez (2018) for Australia. Having a higher proportion of female peers in high school is estimated to widen gender differences in post-secondary STEM programs in Denmark (Brenoe and Zolitz 2018). Meanwhile, peer quality in high school has been shown to have persistent effects on college outcomes for girls in China, where girls doing well in mathematics appears to encourage female classmates to pursue a STEM career (Mouganie and Wang 2019). Relatedly, assigning female advisers during the first year of college is believed to narrow the gender gap in STEM enrollment and graduation in Lebanon (Canaan and Mouganie 2019).

Other papers demonstrate gender differences in student persistence in STEM programs and analyze the reasons for these disparities (Ehrenberg 2010; Fischer 2017; Griffith 2010; Isphording and Qendrai 2019). Griffith and Main (2019) find that gender diversity in the first year of engineering programs improves all students' propensity to continue.[7]

The literature on intergenerational mobility in education has instead extensively documented how the children of more educated parents tend to have increased educational attainments. As shown by Black and Devereux (2011), the initial focus of these studies was on measuring the intergenerational correlation of earnings and education outcomes (see the extensive review by Solon (1999) on labor market mobility). However, in the last two decades, the availability of new high-quality data for some developed countries has prompted researchers to explore the causal mechanisms that underpin these relationships, which Bjorklund and Salvanes (2010) broadly group as follows: (i) the direct effect of parental education on raising the marginal productivity of children's education; (ii) parental transmission of unobserved genetic cognitive abilities and traits; (iii) families' cultural background and the effects of parenting skills on children's choices; (iv) endowments (i.e. wealth or financial resources); and (v) the interaction of public investment with parental education.

The main advances in the identification of the causal effects of parental education on children's education are thoroughly reviewed in Bjorklund and Salvanes (2010), Black and Devereux (2011), and Holmlund and Lindhal (2011), who illustrate and summarize the results obtained with different methodological approaches, including twins as parents, adoptees, and instrumental variables. In particular, Holmlund and Lindhal (2011) provide insight relative to the conflicting conclusions derived by causal studies based on different identification strategies. To this end, they rely on a replication study with Scandinavian data and conclude that parental education level constitutes a large part of the parental nurture effect, an encouraging message from a policy perspective. More recently, Lundborg et al. (2018) use Swedish data to derive causal evidence that parental education increases the cognitive and non-cognitive skills of their children, with consistent results across twins and adoptees. Summarizing the results of the literature they state that "a substantial part of the transmission of education across generations reflects a causal effect of parental education". This view is confirmed by the recent

7 A related body of research focuses on the gender gap in math performance (Contini, Di Tommaso, and Mendolia 2017) and emphasizes the role of culture (Guiso et al. 2008; Nollenberger, Rodriguez-Planas, and Sevilla 2016) and the impact of teachers' gender biases (Carlana 2019).

quasi-experimental results of Suhonen and Karhunen (2019), who find a strong positive causal relationship between the educational attainment of parents and that of their offspring in Finland.

The above-described state of the art of both strands of literature (STEM education determinants and intergenerational transmission of education) highlights the novelty of our investigation of the relationship between parents' and children's STEM higher education attainment among a recent cohort of Italian graduates. Indeed, our paper offers the first broad correlational study on educational field intergenerational transmission, paving the way for further research on the underlying causal mechanisms. To the best of our knowledge, the only related evidence is that provided by Granato (2018) in her analysis of the early determinants of the STEM gender gap in Italy, based on previous waves of the AlmaLaurea dataset. She finds that parental social status and education are positively associated with the probability of achieving a STEM degree. Though Granato does not examine the data specifically from an intergenerational transmission perspective, she does observe positive estimated associations between parental and children's pursuit of STEM education that are consistent with the findings we present in the next sections.

3 Data and Sample Selection

This study relies on a recent wave of the AlmaLaurea[8] survey on the 2017 cohort of graduates from Italian universities (the 20th *Profilo dei Laureati* survey). Seventy-four universities participated in the survey, covering about 90% of all Italian graduates, with a total of 276,195 respondents. We focus on the population of students who completed high school in Italy and who enrolled and graduated under the most recent university system (*nuovo ordinamento*).[9] That is, from either a 3-year degree program (called a *Laurea*, or the equivalent of a bachelor's degree) or from a 5-year degree program (called *Laurea magistrale a ciclo unico*, leading to a title equivalent to a master's degree–long first master's degree). This group comprises a total of 190,971 survey respondents. Of these, we retained records with no

8 AlmaLaurea is an Italian interuniversity consortium established in 1994 with the objective of conducting statistical studies on the Italian university system. AlmaLaurea runs surveys annually on the profile of the country's graduates (entitled "*Profilo dei Laureati*") and their employment status after 1, 3, and 5 years ("*Condizione occupazionale dei Laureati*").

9 This refers to degrees obtained after the so-called Bologna process, a 1999 reform of the educational system.

missing values on all the covariates used in the empirical analysis, for a large final sample of 159,610 respondents, or about 84% of the respondents who met our original criteria.[10]

The dataset includes both administrative and survey information, with the former covering students' university degree, including field of study and the latter the type of high school attended and parental background.[11] The STEM skills supply is defined as the number of degrees awarded in science, technology, engineering and math at the tertiary level. However, there is no common and detailed definition of which fields of study constitute STEM disciplines. We use the definition provided by the EU Commission in 2015, based on Eurostat's Classification of Fields of Education and Training (1999), which we modify to adhere to the classification provided by the latest revision of the International Standard Classification of Education (2013).[12]

The AlmaLaurea dataset provides self-reported data (by students) on parents' degree titles, which is crucial for our analysis. These data do not undergo any cleaning or standardization by the AlmaLaurea team and the resulting heterogeneity in the reported degree titles is large. One contribution of this paper is thus the coding of the parents' degrees from the text entered by respondents and their classification into STEM/non-STEM through our own procedure (see Online Appendix A.2). Our primary data source lacks information on parents' type of high school (HS) attended.

In addition to the university field of study, we also consider the kind of high school from which the student graduated. Specifically, we categorize secondary education qualifications by distinguishing between degrees from scientific high schools and selected technical schools, considered to be STEM based on their high mathematical and technical curricular content, and all the remaining high

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10 Graduation field has a similar distribution among the excluded records and the retained sample: 23% of respondents in the retained sample graduated in STEM fields, as opposed to 22% in the excluded records.

11 The surveys also collect information on previous university studies among the cohort of graduates, though unfortunately with limited detail, making it impossible to identify changes in the field of study or to study its association with parental education. Similarly, AlmaLaurea does not provide useful information for studying the determinants of dropping out of university. Individual universities may use admission data for this purpose, though no university, to our knowledge, collects detailed information on parental education (and more specifically, parental field of study) upon admission to university. Because of these data limitations, we cannot estimate the relationship between parental education and the decision to drop out of post-secondary programs.

12 More details on the classification adopted, along with a list of the disciplines that make up the STEM fields are provided in the Online Appendix (see Section A).

schools, considered to be non-STEM (further details are available in the Online Appendix A.3).

Table 1 reports the descriptive statistics on our working sample. Among graduates, approximately 23% completed a STEM university degree and 52%

Table 1: Descriptive statistics.

Variable	Mean	Std. dev.	Min	Max
*female**	0.607	0.488	0	1
$STEM_2$ (Degree)*	0.228	0.420	0	1
$STEM_1$ (HS)	0.515	0.500	0	1
Father education				
$FEdu_1$ (STEM degree)	0.063	0.242	0	1
$FEdu_2$ (Non-STEM degree)	0.143	0.350	0	1
$FEdu_3$ (HS)	0.457	0.498	0	1
$FEdu_4$ (JHS or less)	0.338	0.473	0	1
Mother education				
$MEdu_1$ (STEM degree)	0.037	0.188	0	1
$MEdu_2$ (Non-STEM degree)	0.157	0.364	0	1
$MEdu_3$ (HS)	0.508	0.500	0	1
$MEdu_4$ (JHS or less)	0.298	0.457	0	1
Parents' combined education				
$PEdu_{11}$	0.012	0.108	0	1
$PEdu_{12}$	0.023	0.149	0	1
$PEdu_{13}$	0.025	0.156	0	1
$PEdu_{14}$	0.003	0.056	0	1
$PEdu_{21}$	0.011	0.105	0	1
$PEdu_{22}$	0.066	0.248	0	1
$PEdu_{23}$	0.058	0.234	0	1
$PEdu_{24}$	0.008	0.089	0	1
$PEdu_{31}$	0.012	0.107	0	1
$PEdu_{32}$	0.056	0.230	0	1
$PEdu_{33}$	0.293	0.455	0	1
$PEdu_{34}$	0.096	0.295	0	1
$PEdu_{41}$	0.002	0.045	0	1
$PEdu_{42}$	0.013	0.111	0	1
$PEdu_{43}$	0.132	0.339	0	1
$PEdu_{44}$	0.191	0.393	0	1
Observations	159,610			

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Notation: $STEM_2$ takes the value 1 if the individual graduates from a STEM field degree at university; $STEM_1$ takes the value 1 if the individual graduates from a STEM field degree at high school; $FEdu_j, MEdu_j$ $j \in \{1,2,3,4\}$ and $PEdu_{fm}$ $f,m \in \{1,2,3,4\}$, are dummy variables denoting levels of parental education as clarified in the table. Variables marked with * indicate administrative data, unmarked variables indicate survey data.

completed a STEM high school degree. Among these graduates, the plurality of their parents have completed at most a secondary education (fathers: 46%; mothers: 51%). Differences in the share of fathers and mothers holding a tertiary education qualification are minor, though more fathers than mothers completed a STEM degree and the opposite is true for non-STEM degrees. Students raised in families in which both parents hold STEM degrees make up just 1% of the graduates, whereas approximately 7% of graduates were raised in families in which both parents hold a non-STEM degree. The largest share of students in our sample come from families in which both parents have at most a high school diploma (approximately 29%), followed by families in which both parents have a junior high school qualification or less (approximately 19%). About 30% of students have at least one parent who has a post-secondary qualification, which we rely on for the assessment of intergenerational associations in STEM education. Note also that, in our working sample of Italian graduates, we observe a sizeable transition from a STEM degree at high school to a non-STEM degree at university—about 35% of students, and a less likely reverse type of transition—about 5% of students. About 90% of those who obtain a non-STEM degree at high-school, do so also at university (and the share reaches about 92% for female students). However, the persistence of field of study is substantially reduced when one considers students who qualify with a STEM degree at high school: only 35% of them graduates in a STEM degree also at university and this fraction decreases to 26% for female students. This source of variation will be exploited in our empirical analysis.

4 Empirical Strategy

We begin examining the intergenerational persistence in post-secondary field of study by estimating the parameters of Equation (1) below using OLS.[13]

$$STEM_{i2} = \alpha_0 + \sum_{j=1}^{4} \alpha_j^F \, FEdu_{ij} + \sum_{j=1}^{4} \alpha_j^M \, MEdu_{ij} + \alpha_X' X_i + \varepsilon_{i2} \tag{1}$$

where $STEM_{i2}$ denotes a dummy taking the value 1 if university student i graduates in a STEM field and 0 otherwise; $FEdu_{ij}$, $MEdu_{ij}$ $j \in \{1, 2, 3, 4\}$ are dummy variables denoting the education level of fathers and mothers of student i respectively, where $j = 1$ if the father (mother) has a post-secondary STEM degree, $j = 2$ if the father (mother) has a post-secondary degree in a non-STEM field, $j = 3$ if the father (mother) has a high school (HS) degree and $j = 4$ if the father (mother) has a junior

13 We use linear probability models to facilitate interpretation given the large number of interactions that we allow in some of the specifications.

high school (JHS) qualification or less (reference category in our regression specification). We experimented with different sets of control variables in X_i. In the baseline regressions, these controls include region of residence, social class, and parents' jobs.[14] Later, we also explicitly consider the mediating role of $STEM_{i1}$, namely an indicator taking value 1 if student i holds a degree from a STEM high school and 0 otherwise.

The key parameters of interest in Equation (1) are α_j^F, α_j^M, $j \in \{1, 2, 3\}$, where α_j^F, α_j^M denotes the intergenerational parameter linking the father's or mother's educational level to the probability that the student completes a STEM university degree with respect to the reference category (JHS). Positive estimates of α_1^F, α_1^M denote the intergenerational persistence of university studies in STEM fields. The difference $\alpha_1^F - \alpha_2^F$, $(\alpha_1^M - \alpha_2^M)$ represents the differential influence of having a father (mother) who holds a STEM degree with respect to a father (mother) who holds a non-STEM degree.

Interactions among parents within the household might not be trivial, thus we also consider alternative specifications in which our key regressors identify all possible combinations of parental education levels. We define $PEdu_{ifm}$ $f, m \in \{1, 2, 3, 4\}$ as a set of mutually exclusive dummy variables taking the value 1 based on the father's education level f and mother's education level m. For instance, $PEdu_{i11}$ takes the value 1 if both parents of student i hold a STEM university degree and 0 otherwise, while $PEdu_{i12}$ takes the value 1 if the father holds a STEM university degree and the mother holds a non-STEM university degree, and 0 otherwise. We then estimate Equation (2) below, where β_{fm} denotes the differential influence of having a father with qualification f and a mother with qualification m on the probability of completing a STEM university degree with respect to the case in which both parents hold a junior high school degree or lower:

$$STEM_{i2} = \beta_0 + \sum_{f=1}^{4} \sum_{m=1}^{4} \beta_{fm} PEdu_{ifm} + \beta_X' X_i + \zeta_{i2} \tag{2}$$

To disentangle the influence that parental field of education exerted on type of high school attended and then extended to choice of university degree and its completion from the influence exerted directly on university graduation, we also estimate Equation (3).

14 All regressions include the following set of controls: region of residence, social class (upper class, middle class, and lower class, the reference category) and parents' jobs, i.e. a set of dummy variables that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, blue-collar workers, and homemakers, with blue-collar workers being the reference category.

$$STEM_{i2} = \delta_0 + \sum_{j=1}^{4} \delta_j^F \, FEdu_{ij} + \sum_{j=1}^{4} \delta_j^M \, MEdu_{ij} + \delta_{HS\_STEM} \, STEM_{i1} + \delta_X^{'} X_i + \omega_{i2} \quad (3)$$

where $\delta_j^F, \delta_j^M \ \forall j \in \{1, 2, 3, 4\}$ identify—with some abuse of notation—the "direct effect" of the father's and mother's education level, respectively, on the completion of a STEM university degree.

Conditioning on our working sample of graduates, we can relate the parameters of Equation (1), the so-called "total effect" of parental education α on the probability that the child completes a STEM university degree to the "direct effect" exerted on university completion δ and the "indirect effect" exerted through parental influence on a STEM high school completion, as follows: $\alpha_j^P = \delta_{HS\_stem}\lambda_j^P + \delta_j^P, \forall j \in \{1, 2, 3, 4\}, \forall P \in \{M, F\}$, where λ_j^P are the parameters of Equation (4) below, mirroring the specification of Equation (1) related to university education for high school completion.

$$STEM_{i1} = \lambda_0 + \sum_{j=1}^{4} \lambda_j^F \, FEdu_{ij} + \sum_{j=1}^{4} \lambda_j^M \, MEdu_{ij} + \lambda_X^{'} X_i + \varepsilon_{i1} \quad (4)$$

If the true value δ_{HS_stem} was zero, there would be no linear dependence between attending a STEM high school and completing a STEM university degree, so the possibility of "indirect effects" – *ceteris paribus* – of parents through this specific channel would be ruled out. When $\delta_{HS\_stem} \neq 0$, the relative magnitude of the "indirect effect" through this specific channel depends on the size of λ^F, namely the intergenerational transmission of STEM studies at high school.

5 Evidence of the Intergenerational Transmission of STEM Education

The OLS estimates of the coefficients of Equation (1) are displayed in Table 2, while Table 3 presents estimates of Equation (2), which allows for interdependent intergenerational parameters between parents.

Table 2 reveals several interesting patterns. Parents' education level appears to be strongly associated—net of controls—with the probability of their children completing a STEM university degree. The role of fathers and mothers differs according to their field of study. Students whose father has a STEM degree are 15 percentage points (p.p.) more likely to complete a STEM degree than those whose father has a JHS or lower education level. This magnitude is almost great enough to counterbalance the observed gender gap in STEM degree completion in our sample. The estimated differential effect of a father with a STEM degree with respect to

Table 2: Estimates of the intergenerational parameters of parental education, pooled and by gender of the student. Dependent variable: completion of a STEM degree at university.

	Pooled (1) (mean: 0.228)	**Males (2) (mean: 0.341)**	**Females (3) (mean: 0.155)**	**Males-Females (4)**
Father education				
α_1^F	0.1534***	0.1617***	0.1245***	0.0373***
	(0.0059)	(0.0096)	(0.0071)	(0.0120)
α_2^F	−0.0134***	−0.0551***	0.0001	−0.0552***
	(0.0042)	(0.0074)	(0.0049)	(0.0089)
α_3^F	0.0353***	0.0270***	0.0291***	−0.0022
	(0.0027)	(0.0051)	(0.0029)	(0.0059)
Mother education				
α_1^M	0.1100***	0.0825***	0.1202***	−0.0377***
	(0.0071)	(0.0115)	(0.0088)	(0.0145)
α_2^M	0.0241***	−0.0026	0.0322***	−0.0348***
	(0.0043)	(0.0075)	(0.0049)	(0.0089)
α_3^M	0.0192***	0.0057	0.0218***	−0.0161***
	(0.0027)	(0.0052)	(0.0029)	(0.0060)
$\alpha_1^F - \alpha_2^F$	0.1669***	0.2169***	0.1244***	0.0925***
	(0.0056)	(0.0087)	(0.0069)	(0.0111)
$\alpha_1^M - \alpha_2^M$	0.0859***	0.0851***	0.0880***	−0.0030
	(0.0068)	(0.0106)	(0.0086)	(0.0136)
$(\alpha_1^F - \alpha_2^F) - (\alpha_1^M - \alpha_2^M)$	0.0809***	0.1318***	0.0363***	0.0954***
	(0.0093)	(0.0146)	(0.0117)	(0.0187)

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Columns (1)–(3) present different sets of OLS estimates of Equation (1) in the paper, reported here for convenience $STEM_{i2} = \alpha_0 + \alpha_1^F FEdu_{i1} + \alpha_2^F FEdu_{i2} + \alpha_3^F FEdu_{i3} + \alpha_1^M MEdu_{i1} + \alpha_2^M MEdu_{i2} + \alpha_3^M MEdu_{i3} + \alpha_X' X_i + \varepsilon_{i2}$, where $STEM_{i2}$ denotes a dummy taking the value 1 if student i graduates from a STEM field at university and 0 otherwise; $FEdu_{ij}$, $MEdu_{ij}$ $j \in \{1, 2, 3, 4\}$ are dummy variables denoting the qualification level of father and mother of student i respectively, where $j = 1$ if the father (mother) has STEM-degree qualification, $j = 2$ if the father (mother) has a non-STEM degree qualification, $j = 3$ if the father (mother) has a high school qualification and $j = 4$ if the father (mother) has a junior high school (JHS) qualification or less. X includes the following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category). Column (1) uses data for all students. Column (2) and (3) use data on male and female students only, respectively. Estimates of column (4) correspond to interaction terms of a fully interacted model specification by student gender. Robust standard errors in parentheses.
* significant at 10%, ** significant at 5%, ***significant at 1% or better.

a father with a non-STEM degree ($\alpha_1^F - \alpha_2^F$) is even larger, about 17 p.p. STEM-educated mothers are less influential than STEM-educated fathers with respect to their children's university outcomes. Having a STEM-educated mother

Table 3: Estimates of the intergenerational parameters of parental education, pooled and by gender of the student. Dependent variable: completion of a STEM degree at university.

	Pooled (1) (mean: 0.228)	Males (2) (mean: 0.341)	Females (3) (mean: 0.155)	Males-Females (4)
Both parents with with degree in STEM				
β_{11}	0.2589***	0.2371***	0.2445***	−0.0074
	(0.0121)	(0.0184)	(0.0157)	(0.0242)
Father with degree in STEM different mother education levels				
β_{12}	0.1720***	0.1600***	0.1474***	0.0126
	(0.0089)	(0.0142)	(0.0108)	(0.0179)
β_{13}	0.1802***	0.1737***	0.1543***	0.0194
	(0.0084)	(0.0136)	(0.0101)	(0.0169)
β_{14}	0.1719***	0.1584***	0.1526***	0.0058
	(0.0216)	(0.0343)	(0.0265)	(0.0433)
Mother with degree in STEM different father education levels				
β_{21}	0.0766***	0.0158	0.0961***	−0.0803***
	(0.0111)	(0.0178)	(0.0139)	(0.0226)
β_{31}	0.1682***	0.1308***	0.1718***	−0.0410*
	(0.0116)	(0.0188)	(0.0143)	(0.0236)
β_{41}	0.1329***	0.0975**	0.1397***	−0.0422
	(0.0260)	(0.0436)	(0.0313)	(0.0537)

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Columns (1)–(3) present different sets of OLS estimates of Equation (2) in the paper on the pooled sample, on the sample of male students and on the sample of females students, respectively. The outcome is $STEM_{i2}$ a dummy taking the value 1 if student i graduates from a STEM field at university and 0 otherwise. All equations include X, the following set of covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category). Estimates of column (4) correspond to interaction terms of a fully interacted model specification by student gender. β_{fm} $f, m \in \{1, 2, 3, 4\}$ denote the differential effect of having a father with qualification f and a mother with qualification m on the probability of completing a STEM university degree, respectively, with respect to the case in which both parents hold a qualification equal or lower to a junior high school degree. Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, ***significant at 1% or better.

increases a student's likelihood to complete a STEM degree by about 11 p.p. over mothers with a JHS or lower education, and 9 p.p. over non-STEM mothers. Moreover, the influence of each parent differs according to the gender of their child. STEM-educated fathers appear more important for sons, whereas STEM-educated mothers are more important for daughters. This is demonstrated by the statistically significant gender gaps estimated for α_1^F and α_1^M (positive for fathers and negative for mothers). Interestingly, fathers with a non-STEM degree have a negative influence on the probability that their sons complete a STEM degree, but not their daughters. Meanwhile, mothers with a non-STEM degree have a positive influence on their daughters' decision to pursue a STEM degree, but not that of their sons. As a result, looking at the differential effect across STEM and non-STEM parental degree, STEM educated fathers appear much more relevant for sons, whereas STEM educated mothers are similarly important for daughters and sons (see the statistically significant 9 p.p. gender gap for $(\alpha_1^F - \alpha_2^F)$ and the unsignificant one for $(\alpha_1^M - \alpha_2^M)$ in the bottom part of the table). [15]

To determine whether these intergenerational parameters are driven by specific parental fields of study, we replicate the estimation of Equation (1) on subsamples that omit each of the 16 parental fields of study (the parental fields of study correspond to those listed in the Online Appendix A.1 for students). The estimated coefficients were hardly affected, as shown in Table B-6 in the Online Appendix, where we report only those few coefficients that showed a change of greater than two p.p. when a specific parental field was excluded. As an additional robustness check, we re-run the estimation classifying health studies as a STEM field for both parents and students, as is sometimes done in the literature (see the discussion in the Online Appendix - Section A), and obtained very similar results.

In Table 3 the intergenerational coefficient of each parent is allowed to vary based on the educational level of the other parent. The first column indicates that STEM-educated fathers have a greater overall influence on their children's completion of STEM degrees than STEM-educated mothers. With respect to a student whose parents both hold STEM degrees, a student whose mother holds a non-STEM degree has a probability of graduating with a STEM degree that is about 9 (≈26–17) p.p. lower, while this decrease is about 18 (≈26–8) p.p. if it is the father that holds a non-STEM degree. Moreover, the influence of a father with a STEM degree is observed in both sons and daughters, while mothers with a STEM degree are more relevant for their daughters than for their sons.

We then proceed to estimate Equations (3) and (4), which decompose the "total effect" of parental education disentangling the "indirect effect" occurring through parental influence at high school. The results are reported in Table 4 and Table 5. The coefficient δ_{HS_STEM} is statistically significant: students who attended a STEM high school are much more likely (about 25 p.p.) to complete a university degree in

15 The sign and magnitude of the coefficients reported in Table 2 reflect two distinct features: the conflicting effects of the parental field of study on the binary outcome (completing or not completing a STEM degree) and the different role of parental liberal profession (depending on both the field of graduation and gender of the parent). We explore the role of parental liberal profession more in depth in Section 6.

Table 4: Estimates of the intergenerational parameters of parental education, pooled and by gender of the student, controlling for field choice at high school (HS). Dependent variable: completion of a STEM degree at university.

	Pooled (1) (mean: 0.228)	Males (2) (mean: 0.341)	Females (3) (mean: 0.155)	Males-Females (4)
STEM choice in HS				
δ_{HS_stem}	0.2455***	0.2763***	0.1710***	0.1054***
	(0.0020)	(0.0035)	(0.0025)	(0.0043)
Father education				
δ_1^F	0.1225***	0.1388***	0.1031***	0.0357***
	(0.0057)	(0.0094)	(0.0070)	(0.0117)
δ_2^F	−0.0194***	−0.0514***	−0.0032	−0.0483***
	(0.0041)	(0.0072)	(0.0048)	(0.0086)
δ_3^F	0.0230***	0.0179***	0.0218***	−0.0039
	(0.0026)	(0.0049)	(0.0028)	(0.0057)
Mother education				
δ_1^M	0.0798***	0.0653***	0.0936***	−0.0283**
	(0.0069)	(0.0111)	(0.0086)	(0.0141)
δ_2^M	0.0186***	0.0005	0.0270***	−0.0266***
	(0.0041)	(0.0072)	(0.0048)	(0.0086)
δ_3^M	0.0118***	−0.0004	0.0172***	−0.0176***
	(0.0026)	(0.0050)	(0.0028)	(0.0057)
$\delta_1^F - \delta_2^F$	0.1419***	0.1902***	0.1062***	0.0840***
	(0.0054)	(0.0085)	(0.0068)	(0.0109)
$\delta_1^M - \delta_2^M$	0.0612***	0.0649***	0.0666***	−0.0018
	(0.0066)	(0.0103)	(0.0084)	(0.0133)
$(\delta_1^F - \delta_2^F) - (\delta_1^M - \delta_2^M)$	0.0807***	0.1254***	0.0396***	0.0858***
	(0.0090)	(0.0142)	(0.0114)	(0.0182)

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Columns (1)–(3) present different sets of OLS estimates of Equation (3) in the paper. The outcome variable $STEM_{i2}$ denotes a dummy taking the value 1 if student i graduates from a STEM field at university and 0 otherwise; $FEdu_{ij}$, $MEdu_{ij}$ $j \in \{1, 2, 3, 4\}$ are dummy variables denoting the qualification level of father and mother of student i respectively, where $j = 1$ if the father (mother) has STEM-degree qualification, $j = 2$ if the father (mother) has a non-STEM degree qualification, $j = 3$ if the father (mother) has a high school qualification and $j = 4$ if the father (mother) has a junior high school (JHS) qualification or less. X includes the following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category). Column (1) uses data for all students. Column (2) and (3) use data on male and female students only, respectively. Estimates of column (4) correspond to interaction terms of a fully interacted model specification by student gender. Robust standard errors in parentheses.
* significant at 10%, ** significant at 5%, ***significant at 1% or better.

Table 5: Estimates of the intergenerational parameters of parental education, pooled and by gender of the student. Dependent variable: completion of a STEM degree at high school.

	Pooled (1) (mean: 0.515)	Males (2) (mean: 0.698)	Females (3) (mean: 0.397)	Males-Females (4)
Father education				
λ_1^F	0.1260***	0.0830***	0.1251***	−0.0421***
	(0.0063)	(0.0086)	(0.0085)	(0.0121)
λ_2^F	0.0241***	−0.0133*	0.0189***	−0.0323***
	(0.0052)	(0.0074)	(0.0067)	(0.0100)
λ_3^F	0.0502***	0.0329***	0.0429***	−0.0099
	(0.0033)	(0.0050)	(0.0040)	(0.0064)
Mother education				
λ_1^M	0.1229***	0.0622***	0.1557***	−0.0935***
	(0.0076)	(0.0103)	(0.0103)	(0.0146)
λ_2^M	0.0222***	−0.0109	0.0304***	−0.0413***
	(0.0051)	(0.0073)	(0.0065)	(0.0098)
λ_3^M	0.0301***	0.0221***	0.0269***	−0.0048
	(0.0033)	(0.0051)	(0.0041)	(0.0065)
$\lambda_1^F - \lambda_2^F$	0.1018***	0.0963***	0.1062***	−0.0098
	(0.0059)	(0.0079)	(0.0082)	(0.0114)
$\lambda_1^M - \lambda_2^M$	0.1008***	0.0731***	0.1253***	−0.0521***
	(0.0071)	(0.0095)	(0.0098)	(0.0137)
$(\lambda_1^F - \lambda_2^F) - (\lambda_1^M - \lambda_2^M)$	0.0010	0.0232*	−0.0191	0.0423**
	(0.0098)	(0.0130)	(0.0136)	(0.0189)

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Columns (1)–(3) present different sets of OLS estimates of Equation (4) in the paper, reported here for convenience $STEM_{i1} = \lambda_0 + \lambda_1^F FEdu_{i1} + \lambda_2^F FEdu_{i2} + \lambda_3^F FEdu_{i3} + \lambda_1^M MEdu_{i1} + \lambda_2^M MEdu_{i2} + \lambda_3^M MEdu_{i3} + \lambda'_X X_i + \varepsilon_{i1}$, where $STEM_{i1}$ denotes a dummy taking the value 1 if student i completes a STEM field high school degree and 0 otherwise; $FEdu_{ij}$, $MEdu_{ij}$ $j \in \{1, 2, 3, 4\}$ are dummy variables denoting the qualification level of father and mother of student i respectively, where $j = 1$ if the father (mother) has STEM-degree qualification, $j = 2$ if the father (mother) has a non-STEM degree qualification, $j = 3$ if the father (mother) has a high school qualification and $j = 4$ if the father (mother) has a junior high school (JHS) qualification or less. X includes the following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category). Column (1) uses data for all students. Column (2) and (3) use data on male and female students only, respectively. Estimates of column (4) correspond to interaction terms of a fully interacted model specification by student gender. Robust standard errors in parentheses. * significant at 10%, ** significant at 5%, ***significant at 1% or better.

a STEM field than the overall mean.[16] The "indirect effect" is small and only proportional to the overall intergenerational transmission of STEM education. In

16 Interestingly, the STEM high school parameter is about 28 p.p. for males and 17 p.p. for females, confirming the lower persistence of females in STEM fields.

the pooled sample, having attended a STEM high school implies a 3 p.p. increase ($100 \cdot 0.25 \cdot 0.13$) in the probability of completing a post-secondary STEM degree for students whose father has a STEM degree. The influence of parental education level is, however, only partially mediated by the kind of high school attended: the "direct effect" of parental education on the choice of a STEM degree at university (with respect to JHS) is reflected in the sign and magnitude of the estimates of coefficients $\delta_j^F, \delta_j^M \ \forall j \in \{1, 2, 3\}$, respectively. Consistent with our observations in Table 2, we find that the parental field of study matters: STEM-graduate fathers lead to a 12 p.p. increase in the probability of their children graduating in a STEM field, compared to a lower increase of 8 p.p. in the case of STEM-graduate mothers. Notably, all of these estimated "direct effects" remain statistically significant and are only slightly lower (20% for fathers, 25% for mothers) than the "total effects" estimated in Table 2, in which we do not control for having attended a STEM high school.[17]

Finally, we employ the estimation of Equation (3) to check the robustness of our intergenerational parameters to the inclusion of additional student characteristics observable at university, but not at high school. These include the location of the university with respect to the region of residence, the type of high school completed, and information on academic and work values reported by students as being important in choosing their university degree. The OLS estimates of the coefficients of Equation (3) with enhanced controls are available in the Online Appendix in Table B-2. They reveal that our intergenerational parameters of interest remain mostly stable with respect to the results in Table 2, even with the insertion of additional controls.[18]

6 The Role of Parental (liberal) Professions

Aina and Nicoletti (2018) study the intergenerational transmission of liberal professions and find that, in Italy, having a father who is a liberal professional has a positive and significant effect on a graduate becoming a liberal professional. The same authors also document the importance of the intergenerational transmission

17 The bottom part of Table 4 shows that the "direct effect" of having a parent with a STEM versus non-STEM degree is also marginally lower with respect to the "total effects" reported in Table 2.

18 Table B-4 in the Online Appendix contains the estimates obtained when we also add the final high school grade to the list of controls. As before, the estimates of the intergenerational association of parents' and child's education do not vary considerably. Similarly, the pattern of the interdependent effects is not sensitive to the inclusion of the additional controls. See Table B-3 and B-5 in the Online Appendix.

of formal education in achieving the different compulsory steps required to become a liberal professional.[19]

Prompted by these intriguing results and the consistency with our own findings on the intergenerational transmission of STEM education (see Section 5), we explore whether the intergenerational transmission of liberal professions affects our results. To this end, we augment Equation (1) with the interaction of parental qualifications, with a dummy variable capturing whether the parent is a liberal professional.[20] Results are reported in Table 6. With some abuse of notation, we use $\alpha_j^F, \alpha_j^M \; j \in \{1, 2, 3, 4\}$ to denote the influence of parental qualifications when the parent is not a liberal professional. The coefficients $\alpha_{L1}^F, \alpha_{L2}^F, \alpha_{L3}^F, \alpha_{L4}^F$ denote the differential influence of the father's educational level on his child's probability of graduating in a STEM field when the father is a liberal professional. Similarly, $\alpha_{L1}^M, \alpha_{L2}^M, \alpha_{L3}^M, \alpha_{L4}^M$ denote the differential influence of the mother's educational level when she is a liberal professional.

While the intergenerational persistence of completing a STEM university program proves not to be closely related to having parents who are liberal professionals, we do find that the influence of parents who have a non-STEM degree is mainly driven by those who are also liberal professionals, and this influence is concentrated on sons. We document a differential role of fathers' and mothers' occupations with field of study depending on student gender. Liberal professional fathers and mothers with STEM degrees increase the likelihood of their daughters graduating from a STEM field, while their differential influence on sons is negligible. In contrast, liberal professional fathers with non-STEM degrees significantly reduce the probability of their sons completing a STEM degree, with a smaller reduction in their daughters' probability. Liberal professional mothers with non-STEM degrees have a negligible influence on their daughters' likelihood of graduating from a STEM program, though they do have a negative influence on their sons.

Table 6 reports the empirical evidence that corroborates the above observations. Specifically, the differential influence of parents who are liberal

19 As in Aina and Nicoletti (2018), we consider as liberal professionals self-employed workers providing public services which require them: to hold a specific university degree, to obtain a professional license by passing an exam and in some cases – to complete a compulsory period of practice before the licensing exam. Among others, the liberal professions include accountants, lawyers, notaries, psychologists, pharmacists and architects, engineers, geo-biologists and agronomists. Our dataset provides information on whether the father and the mother are liberal professionals while no details are available on their job specialization.

20 In addition to the controls listed in footnote 14, we now include the interaction of the binary indicator for parental liberal profession and the parental educational dummies. The observed frequency of liberal professionals in our sample is 15% of fathers and 5% of mothers.

Table 6: Estimates of the intergenerational parameters of parental education, pooled and by gender of the student. Dependent variable: completion of a STEM degree at university.

	Pooled (1)	Males (2)	Females (3)	Males-Females (4)
Father education				
α_1^F	0.1406***	0.1486***	0.1123***	0.0363***
	(0.0068)	(0.0110)	(0.0082)	(0.0137)
α_2^F	0.0059	−0.0283***	0.0139**	−0.0422***
	(0.0049)	(0.0084)	(0.0057)	(0.0102)
α_3^F	0.0345***	0.0261***	0.0287***	−0.0026
	(0.0028)	(0.0053)	(0.0030)	(0.0061)
Mother education				
α_1^M	0.1060***	0.0797***	0.1152***	−0.0355**
	(0.0075)	(0.0121)	(0.0092)	(0.0152)
α_2^M	0.0271***	0.0009	0.0342***	−0.0333***
	(0.0044)	(0.0077)	(0.0051)	(0.0093)
α_3^M	0.0199***	0.0064	0.0222***	−0.0158***
	(0.0028)	(0.0053)	(0.0029)	(0.0060)
Interaction terms:				
Father education × liberal professional				
α_{L1}^F	0.0346***	0.0079	0.0397***	−0.0318
	(0.0120)	(0.0190)	(0.0148)	(0.0241)
α_{L2}^F	−0.0571***	−0.1068***	−0.0342***	−0.0726***
	(0.0075)	(0.0128)	(0.0087)	(0.0155)
α_{L3}^F	0.0020	−0.0228*	0.0062	−0.0290*
	(0.0075)	(0.0133)	(0.0086)	(0.0159)
α_{L4}^F	−0.0100	−0.0366**	−0.0004	−0.0362*
	(0.0085)	(0.0168)	(0.0090)	(0.0191)
Interaction terms:				
Mother education × liberal professional				
α_{L1}^M	0.0342*	−0.0088	0.0522*	−0.0610
	(0.0204)	(0.0311)	(0.0267)	(0.0410)
α_{L2}^M	−0.0267***	−0.0633***	−0.0111	−0.0522***
	(0.0082)	(0.0141)	(0.0097)	(0.0171)
α_{L3}^M	−0.0172*	−0.0486***	−0.0061	−0.0425**
	(0.0098)	(0.0176)	(0.0110)	(0.0208)
α_{L4}^M	0.0121	−0.0256	0.0132	−0.0388
	(0.0173)	(0.0312)	(0.0191)	(0.0366)

Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. The table reports OLS estimates of linear regressions models that also include following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category). Column (1) uses data for all students. Column (2) and (3) use data on male and female students only, respectively. Estimates of column (4) correspond to interaction terms of a fully interacted model specification by student gender. Robust standard errors in parentheses.
* significant at 10%, ** significant at 5%, ***significant at 1% or better.

professionals and STEM graduates is statistically significant and amounts to about a 3 p.p. increase with respect to the positive intergenerational transmission of STEM education between fathers and children (14 p.p.) and mothers and children (10 p.p.). This result is driven by a differential influence on daughters (α^F_{L1} = 0.04 for fathers, α^M_{L1} = 0.05 for mothers), while no statistically significant differential influence of parental liberal profession can be detected for sons. Conversely, liberal professional fathers who have non-STEM degrees tend to reduce the probability that children graduate in STEM, favoring the completion of non-STEM degrees. This intergenerational parameter is 6 p.p. larger in absolute terms with respect to the intergenerational parameter for fathers with non-STEM degrees who are not liberal professionals. While non-STEM graduate mothers who are not liberal professionals tend to induce an increase in the probability that children graduate in STEM, this positive association vanishes for non-STEM graduate mothers who are liberal professionals (= 0.0271 – 0.0267 = 0.004). Notably, the result in the pooled sample is driven entirely by the parameter of daughters for non-liberal professional mothers and by the parameter of sons for liberal professional mothers, with statistically significant differences depending on the the gender of the child. Our results are consistent with the view that the intergenerational transmission of the non-STEM liberal profession is more pronounced for sons than for daughters. In Table 6, $\widehat{\alpha}^F_{L2}$ (liberal professional fathers with a non-STEM degree) is –0.11 for males and –0.03 for females, while $\widehat{\alpha}^M_{L2}$ (liberal professional mothers with a non-STEM degree) is –0.06 for males and 0 for females.

If entry barriers into liberal professions were higher in non-STEM liberal professions (e.g. notary or lawyer) than in STEM liberal professions (e.g. engineer), this finding would be in line with the discussion by (Aina and Nicoletti 2018, Tab 1, p. 111), who suggest that “high entry barriers into the profession increase the occupational transmission from fathers to children.” The authors find that “non-graduate liberal professionals transmit to their child a level of formal human capital similar to that of blue-collar workers and lower than that of entrepreneurs” (see p. 115).

In short, while our findings reveal remarkable intergenerational transmission paths, they also show that the intergenerational associations are not driven by the transmission of parental liberal profession.

One might ask whether these results are driven by a specific field, as opposed to by STEM or non-STEM fields more generally. We address this issue by relying on the estimates of multinomial logit models in which we let the probability that the child graduates in a specific field depend on the field and education level of the mother and the father (see the Online Appendix A.1 and A.2 for a list of the 10 broad fields of study we consider for students and parents). We focus on the pooled

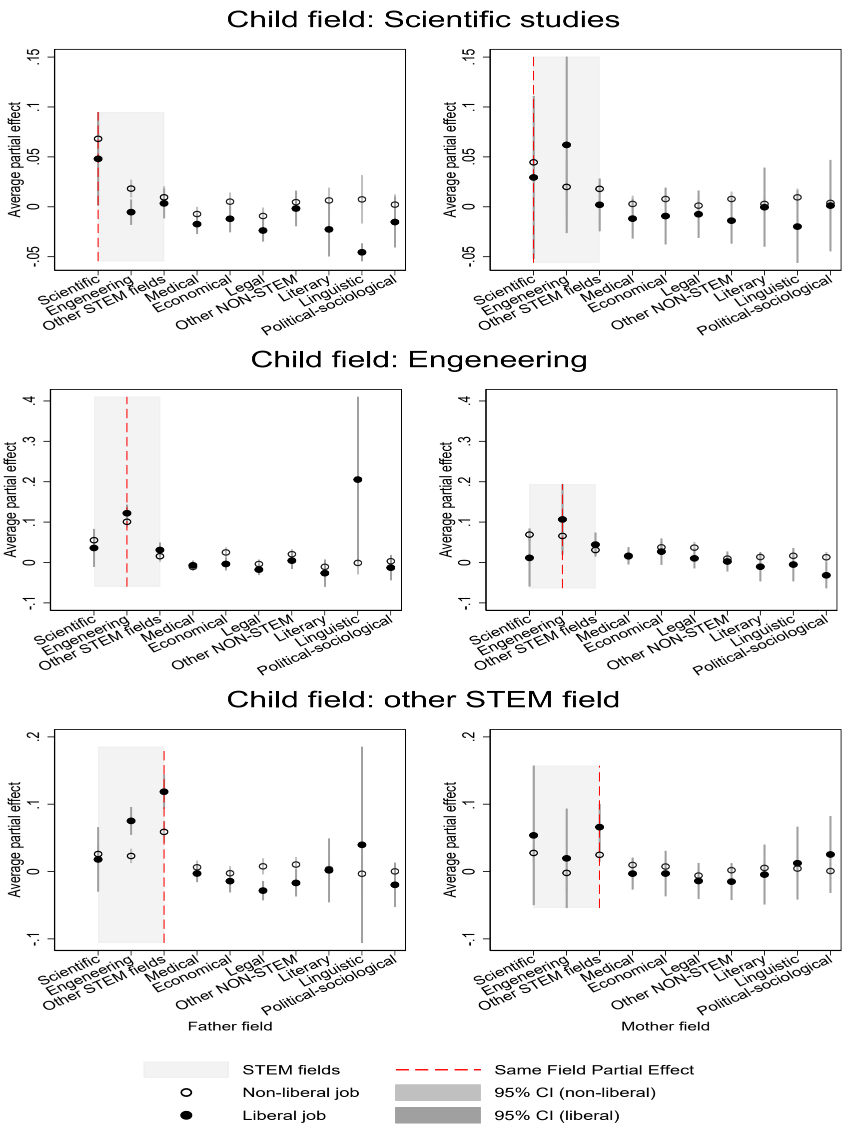

Figure 1: Average partial effects of parents field of study by liberal profession, by field of the child.
Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Each panel report estimate average partial effects obtained from parameter estimates of a multinomial logit models considering the actual field of graduation of the student among 10 mutually exclusive fields (scientific studies, engineering, other STEM fields, medical studies, economical studies,

sample of male and female students in order to avoid overparametrization and ease the interpretation of the results. The multinomial logit probabilities are specified as:

$$\begin{aligned}\text{Prob}\,(Field_{ik} = k|X_i) \\ &= \Lambda\Big(\sum_l \mu_{f,l} F\_Field_{il} + \mu^L_{f,l} F\_Field_{il} \star F\_Lib_i + \mu_{m,l} M\_Field_{il} \\ &\quad + \mu^L_{m,l} M\_Field_{il} \star M\_Lib_i + \mu' Z_i\Big)\end{aligned} \tag{5}$$

where i denotes the child, k denotes the child's field of study, l denotes the parent's field of study, M_Field_{il} and F_Field_{il} are mother's and father's fields of study, respectively, F_Lib_i and M_Lib_i are dummies for the father and mother practicing a liberal profession and Z_i includes the same set of variables listed in footnote 14 and dummies for parental qualifications lower than a university degree.

Striking patterns emerge when we explore the heterogeneity with respect to parental fields of study and liberal professions. Figures 1–3 report the results of the multinomial logit model estimates expressed as average partial effects (APEs) of the parental field of study on the probability that a child graduates in a specific field. These figures show the likelihood that children graduate in a particular field, with the results divided into APEs for the father's field of study (left-hand panels) and the mother's field of study (right-hand panels). The light gray shaded areas highlight parental STEM fields, while the vertical dashed red bar indicates the APE for the case in which the parent and the child graduate in the same field. We report the 95% confidence intervals for each APE using bars with different shades of gray. We first examine the consistency between the parents' and children's field of graduation. Somewhat unexpectedly for this relatively high level of disaggregation, we find a strong relationship between the two. In 10 out of 10 cases, the highest APE between fathers with a non-liberal profession is observed when father and child study the same field. This pattern changes only slightly for fathers with liberal professions (8 out of 10 cases; 9 out of 10 if one aggregates STEM and non-

legal studies, literary, linguistic studies, political-sociological studies, other non-STEM fields) as function of mother and father educational qualifications and field of graduation (for graduate parents). The model specification also include following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category), dummies for parents' qualification lower than university. The parental field dummies are interacted with a parental liberal profession dummy.

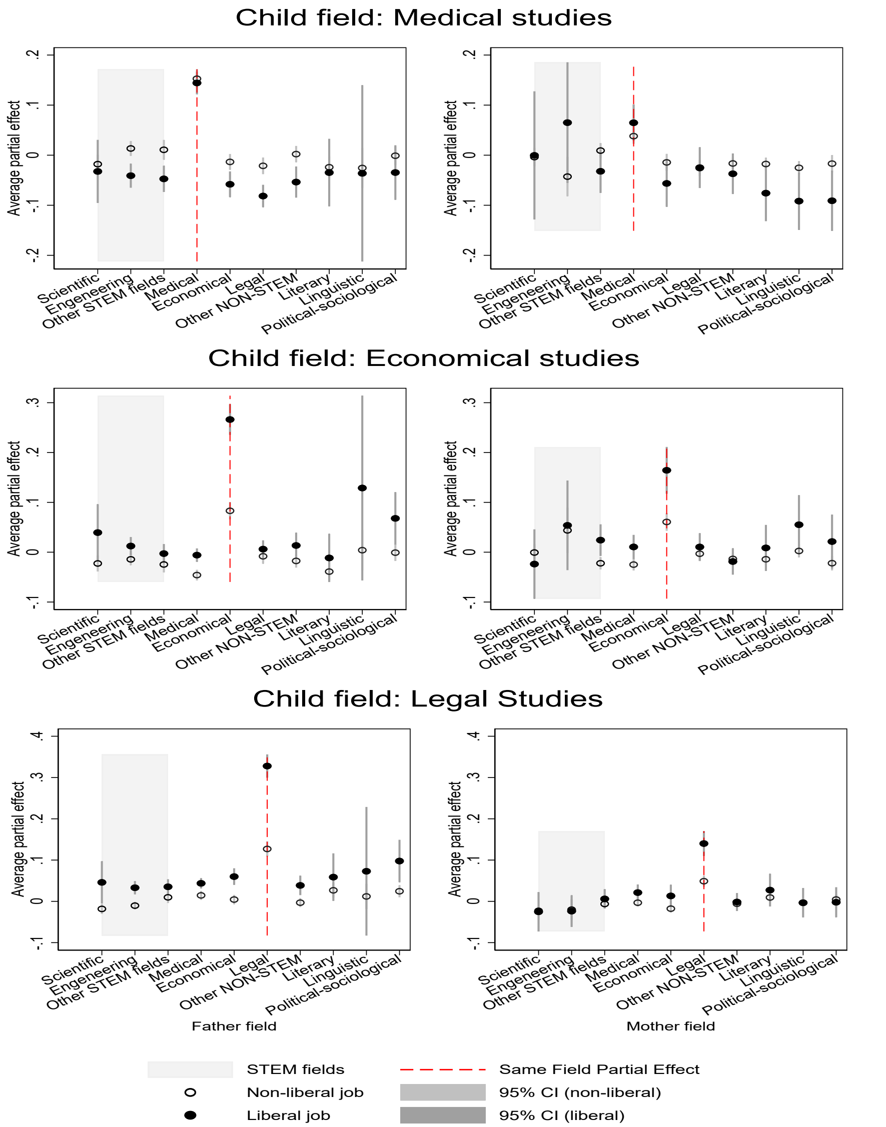

Figure 2: Average partial effects of parents field of study, by field of the child.
Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Each panel report estimate average partial effects obtained from parameter estimates of a multinomial logit models considering the actual field of graduation of the student among 10 mutually exclusive fields (scientific studies, engineering, other STEM fields, medical studies, economical studies, legal studies, literary, linguistic studies, political-sociological studies, other non-STEM fields)

STEM fields). A similar level of consistency is observed for mothers. For mothers, the highest APE is observed when mother and child share the same field: 8 out of 10 cases for mothers with non-liberal professions (or 10 out of 10 if the fields are aggregated into STEM and non-STEM) and a somewhat smaller share for mothers with a liberal profession (5 out of 10, increasing to 8 out of 10 when fields are aggregated into STEM and non-STEM). These findings suggest that the intergenerational transmission we observe is indeed influenced by the individual field of study, resulting in a high persistence of participation in STEM fields across generations and, consequently, the intergenerational transfer of the labor market advantages of working in STEM fields.

Figure 1 shows that for most of students graduating from science and engineering programs, their parents' participation in a liberal profession results in limited differences when parents graduated in the same field. However, differences do emerge when we consider the category "Other-STEM fields". These fields might offer the possibility to work as biologist or as architect. While we cannot further disaggregate this class due to sample size restrictions, we do observe that the role of liberal professional parents is not negligible for the "Other-STEM fields" category, as the APEs are higher when mothers (or fathers) graduate in the same field and hold a liberal profession (about 6% points higher for both mothers and fathers).

Figures 2 and 3 allow us to repeat this analysis for students graduating in non-STEM fields and confirm the pattern we previously documented through the estimates of linear probability models. Indeed, there is substantial evidence of intergenerational transmission of field of study, which is partly driven by parents holding a liberal profession. In economic fields of study, the gap in APEs for liberal vs non-liberal parents is as high as 10 percentage points for mothers (APEs are 0.06 for non-liberal and 0.16 for liberal workers who graduated in this field) and 18 percentage points for fathers (APEs are 0.08 for non-liberal and 0.26 for liberal workers who graduated in this field). In legal fields, the gap becomes 20% points for fathers and 9% points for mothers (APEs are 0.12 for non-liberal 0.32 for liberal workers in the case of fathers and 0.048 for non-liberal and 0.14 for liberal workers

as function of mother and father educational qualifications and field of graduation (for graduate parents). The model specification also include following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category), dummies for parents' qualification lower than university. The parental field dummies are interacted with a parental liberal profession dummy.

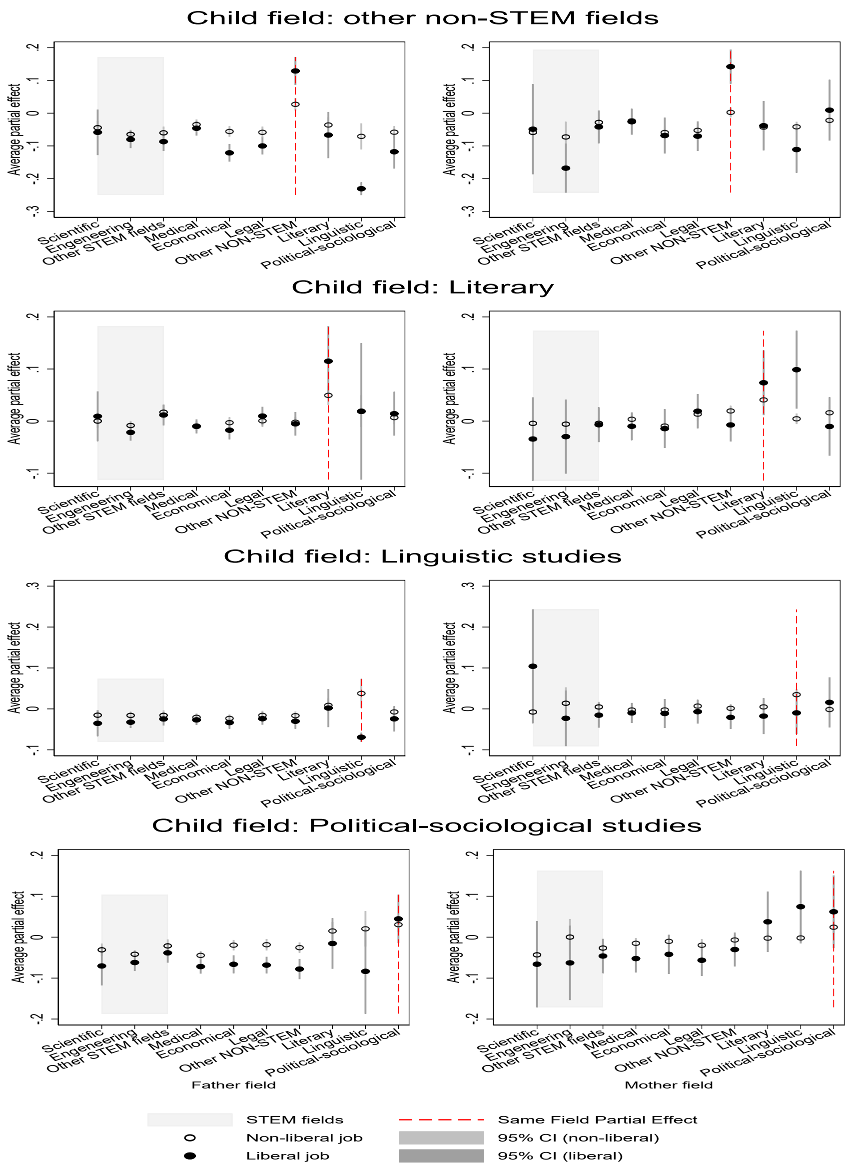

Figure 3: Average partial effects of parents field of study, by field of the child.
Source: Almalaurea XIX Profilo dei Laureati survey (2017 cohort of graduates). Sample: 159,610 students who graduated from high school and from university in Italy, from 3-years and 5-years degree cycles with non-missing value of all covariates included in the analysis. Each panel report estimate average partial effects obtained from parameter estimates of a multinomial logit models considering the actual field of graduation of the student among 10 mutually exclusive

in the case of mothers). In other non-STEM fields, the gap is 10% points for fathers and 14% points for mothers (APES for fathers are: non-liberal 0.026, liberal 0.13; for mothers: non-liberal 0.002, liberal 0.14). Economic fields make it possible to work as a professional accountant or business accountant, while graduates in legal fields tend to become lawyers or notaries. Due to the small sample size, we cannot disaggregate the fields that comprise the "Other non-STEM" category, which may allow access to professions such as chemist, veterinary surgeon, agronomist, or psychologist. The "Other non-STEM" aggregate also includes fields like teaching, physical education and defense and security. Finally, for the literary field we do also observe slightly higher APEs for parents holding a liberal job; a pattern attributable to professions such as journalist, publisher, or radio/TV reporter.

In short, the intergenerational transmission at the level of field of study that the multinomial logit model estimates is high. While the intergenerational transmission is not driven by parents having a liberal profession for most STEM fields, notably scientific and engineering for fathers, it seems largely driven by parental liberal profession in some non-STEM fields, specifically economical and legal studies. This finding is consistent with previous evidence in the literature (Aina and Nicoletti 2018) and with the existence of barriers to entry in some professions.

7 Concluding Remarks

The paper documents the presence of sizeable intergenerational associations in university graduation from STEM fields in Italy. We find evidence of a more prominent role of fathers' field of qualification with respect to mothers'. The stronger role of fathers is particularly pronounced in their sons, while the influence of mothers with a STEM degree is primarily noticeable in their daughters.

We find that having a father who has a STEM university degree increases the likelihood of a student graduating from a post-secondary STEM program by 15 p.p.

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fields (scientific studies, engineering, other STEM fields, medical studies, economical studies, legal studies, literary, linguistic studies, political-sociological studies, other non-STEM fields) as function of mother and father educational qualifications and field of graduation (for graduate parents). The model specification also include following covariates: a dummy for the region of residence in the south, a set of dummies denoting the social class that distinguish between upper class, middle class and lowerclass (the reference category), a set of dummies denoting fathers' and mothers' professions that distinguish between self-employed workers, entrepreneurs, liberal professionals, managers, teachers, white-collar professionals, homemakers and blue-collars (the reference category), dummies for parents' qualification lower than university. The parental field dummies are interacted with a parental liberal profession dummy.

(16 p.p. for sons and 12 for daughters). The magnitude of these figures is almost as large as the overall gender gap in STEM university degree completion. The extent of intergenerational transmission is also sizeable for mothers. Having a mother with a STEM degree increases a student's probability of graduating from a post-secondary STEM program by 11 p.p. (8 p.p. for sons; 12 p.p. for daughters).

Our findings on the intergenerational persistence of educational attainments in STEM fields are consistent with previous empirical evidence on the intergenerational transmission of education in Italy (Checchi, Fiorio, and Leonardi 2013). Intergenerational persistence in STEM is not affected by whether parents practice a liberal profession, although the intergenerational persistence of graduating in non-STEM fields does appear to be largely driven by parents holding a liberal profession. Notably, and somewhat surprisingly, the intensity of the intergenerational transmission of fields of study at university remains sizeable at a much narrower level of field classification. At this more disaggregated level, we show that the differential influence of parents holding a liberal profession, conditional on field of graduation, is highest in the disciplines of economics and legal studies, where barriers to entry in the profession are likely to be considerable (Aina and Nicoletti 2018).

Our measures of parental educational qualifications can be seen as proxies of role models. We believe that the same-gender pattern we observe in the intergenerational persistence in certain fields of study—i.e., mothers to daughters and fathers to sons—supports our interpretation. The results related to the role of parents practicing a liberal profession on the transmission of some non-STEM fields, in contrast, speaks in favor of channels of intergenerational transmission more related to the transfer of endowments and non-trivial interactions with the institutional setting, as discussed in Section 6 (see the taxonomy reported by Bjorklund and Salvanes (2010)).

The novel patterns we uncover on the persistence of educational achievements in STEM fields suggest that the roadmap for future research on intergenerational transmission of education indicated by Holmlund and Lindhal (2011) should be a broader one. Since not only parental schooling, but also parental field of study passes to the next generation, more research is needed to understand the mechanisms generating also the second type of transmission. This is relevant for policy makers concerned with equality of opportunity across genders and occupations and with the shortage in the supply of STEM related skills, particularly among women.

Could students' outcomes be improved by parents becoming aware of these patterns? Though an answer is beyond the scope of this paper, we suggest that parental influence is likely to be an important mediator in interventions that aim at promoting STEM fields among middle school and high school students. Though parents may potentially be less malleable, they are not always fully informed and aware of their influence, suggesting that they might also be targeted by interventions seeking to improve educational outcomes. Further research might also explore whether programs that promote STEM fields directly among students have the unintended effect of reducing the intergenerational transmission of choice of academic discipline.

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