Gender Composition of Tertiary Education and Early Fertility

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Abstract

The gender composition of peer groups has been shown to affect marriage market outcomes, but there is no evidence on whether the gender composition of tertiary education across fields of study affects graduates' fertility, even though the college field-of-study peer group is a natural source of potential mating partners. We use variation in gender shares by fields of study implied by the recent expansion of tertiary education in 19 European countries and a difference-in-differences research design, to show that the share of women in study peer groups affects early fertility levels only little: Endogamous fertility by tertiary graduates from the same field of study is driven by the availability of potential partners in the peer group but non-endogamous fertility compensates for this effect for both genders. However, the availability of endogamous partners affects the probability of parenting with a less-than-tertiary educated spouse. We also show that the EU-wide level of gender segregation across fields of study has not changed since 2000, despite heterogenous country-level evolution.

JEL Codes: I23, J13, J16

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1 Introduction

Assortative mating based on education is strong among the college educated (Bredemeier and Juessen, 2013; Greenwood et al., 2014) and a major part of the first births of the tertiary educated takes place within a few years of graduation (Herr, 2012). Parental matches of college graduates are thus likely to have been formed during or shortly after their studies so that the gender composition of tertiary education may affect mating and fertility patterns. In particular, women continue to be unevenly represented across college fields of study, despite making up the majority of university graduates across developed countries (Charles and Bradley, 2002). The gender composition of college field-of-study groups can be important for mating and fertility if costs of partner search are lower within such groups, as Kaufmann and Messner (2013) imply for college programs. Further, Bruze (2011) suggests that assortative mating based on education is in large part based on preferences for marrying similarly educated partners (as opposed to low search costs or matching on earnings); by extension, one may also expect a preference towards mating and parenting within groups defined by one's field of study.

Yet there is no work to date measuring the extent of endogamous fertility among college graduates, defined as child births to couples graduating from the same field of study. There is also no causal evidence on whether the availability of potential partners in one's field-of-study group affects the level of fertility or the education composition of parental pairs. In fact, little is known at the descriptive level about the gender composition of the recent higher education expansion across fields of study.

In this paper, we therefore employ 1998-2010 population statistics on the gender composition of college graduates in eight fields of study in over 20 EU countries to track the evolution of the representation of women and to measure the implied changes in gender segregation by field of study. We then combine this variation in the share of women across country-year-field-of-study groups with over a decade of harmonized labor force survey data on the early fertility of tertiary graduates in 19 EU countries. Specifically, we study the occurrence of first childbirth within five years of graduation for students graduating between 1998 and 2006. We first ask whether partner availability in one's field of study affects fertility levels by gender. Next, we quantify the importance of the changing composition of tertiary education across fields of study for the endogamy structure of fertility and for the probability of parenting with a less-than-tertiary educated spouse. Our difference-in-differences regressions control for the country-specific evolution of pro-family preferences among college graduates and for the stable part of family-preference differences across fields of study.

Our analysis is related to three strands of literature. First, there is much research on the postponement of fertility among college graduates (e.g., Amin and Behrman, 2014), but most of this work does not consider field-of-study groups. Second, there is growing evidence on the marriage returns to attending college (e.g., Bruze, 2015), but again, this literature does not focus on field-of-study matching. Third, a well-established body of work suggests that the gender composition of peer groups affects marriage market outcomes, but this research focuses on the gender composition of the workplace (Svarer, 2007; McKinnish, 2007), occupations (Mansour and McKinnish, 2014a), or immigrant groups (Angrist, 2002; Lafortune, 2013) and it does not consider field-of-study peers, even though the college field-of-study group is a natural source of potential mating partners.

2 Related Literature

2.1 Women in Higher Education

A worldwide boom in higher education that started around 1970 coincided with major increases in the female representation in college education (Goldin, 2006; Becker, Hubbard and Murphy, 2010). There is a growing, mainly US literature asking about the driving forces behind this secular trend: Jacob (2002) and Hubbard (2011) study the importance of gender differences in returns to education, Goldin, Katz, and Kuziemko (2006) and McDaniel (2010) highlight the effects of work and education expectations, respectively, while Ge and

Yang (2013) point to rising divorce probabilities as an explanation for the increasing college enrollment of women. Another explanation is provided by Chiapori et al. (2015) who show that marriage returns to attending college have been increasing for women.

As women now form the majority of higher-education graduates in developed countries, gender segregation across fields of study, which could be related to mating patterns, represents the main remaining axis of gender differences in tertiary education (Charles and Bradley, 2002). There is much discussion about the sources of gender segregation by field of study (e.g., van Bavel, 2010; Charles and Bradley, 2009) or, relatedly, by occupation (e.g., Dolado, Felgueroso and Jimeno, 2002). Mastekaasa and Smeby (2008) and Morgan, Gelbgiser and Weeden (2013) are examples of studies that attempt to quantify the importance of individual-level determinants of the gender-specific choices of college major in the EU and the US, respectively. There is also a growing literature on gender differences in the college admission process with consequences for field-of-study choice, e.g., Jurajda and Münich (2011).[1]

However, there is surprisingly little evidence available to answer the basic question of whether the recent increase in the share of female tertiary graduates has been accompanied by a decline in segregation by field of study or not. The two major sociological studies of international differences in college field-of-study gender segregation, Charles and Bradley (2002, 2009), both use data from the 1990s and offer only cross-country comparisons. We know of no work tracking the recent evolution of gender segregation in college across a wide set of countries.[2] We therefore provide such evidence based on population data from 1998 to 2010 covering over twenty EU countries. This also introduces the source of variation we use in the subsequent fertility analysis.

[1] Without focusing on gender differences, Beffy, et al. (2012) imply that in the French context expected earnings are not a driving force of tertiary field-of-study choices, and Kirkebøen et al. (2014) estimate the payoffs to different fields of study in the US while correcting for selection bias.

[2] Barone (2011) is the only study we are aware of to follow the gender composition of higher education by field of study over time, but he does so only for four countries, and he uses measures based on the EU Labor Force Survey such that sampling error is a major concern in smaller fields.

2.2 Peer Group Composition and Fertility

There is a large literature, starting with Becker (1973), studying the implications of the gender composition of peer groups for marriage and fertility patterns. Angrist (2002) analyzes the flow of US immigrants from different nationality groups at the beginning of the 20th century and finds that a higher ratio of men to women in a group increases the likelihood of female marriage, consistent with an increase in female bargaining power in the marriage market. Svarer (2007) and McKinnish (2007) focus on the gender composition of the workplace and present evidence suggesting that those who work with a larger fraction of workers of the opposite sex are more likely to get divorced. Lafortune (2013) studies the reaction of pre-marital investments to varying gender shares.

Surprisingly, there is almost no work asking about the importance of school peers for marriage market outcomes. College graduates increasingly mate with other college graduates and their fertility is concentrated after graduation.[3] There are two potential mechanisms of how the gender composition of peer groups consisting of college graduates in the same field-of-study could affect matching into parenthood. First, potential partners in one's field-of-study group may be easier to meet, either in the same study program (as in Kaufmann and Messner, 2013, or Nielsen and Svarer, 2009) or outside of study programs if social links are stronger within field-of-study groups than across.[4] Second, members of field-of-study groups may be more desirable (on the country-wide matching market) in terms of their (possibly similar) tastes than potential partners outside of one's group.[5]

The available evidence on whether field-of-study gender composition affects fertility is

[3]Herr (2012) uses the NLSY79 data to show that in the US about half of first births by tertiary educated women occur within 6 years of graduation. In Section 6, we find similar evidence in our EU data.

[4]In a related line of work, Fletcher, Ross and Zhang (2013) and Arcidiacono, Aucejo, Hussey and Spenner (2013) study the implications of the composition of cohorts of US students for friendship formation.

[5]Bruze (2011) highlights the importance of preferences for similarly educated partners, but we know of no direct evidence on preferences for mating within field-of-study groups. In related work, Mansour and McKinnish (2014b) argue that highly educated individuals are especially likely to marry similarly-aged peers.

based on cross-field comparisons. Demographers and sociologists frequently point out that highly 'female' fields of study are typically characterized by higher fertility. For example, Van Bavel (2010) studies data on about three hundred graduates per country from the 2004 round of the European Social Survey and finds that a higher share of women among graduates is related to earlier female fertility. Since his analysis is based on a cross-section of fields of study, it cannot disentangle the causality-selection nexus. Unlike van Bavel (2010) and the literature he cites,[6] we track fields of study in several countries over time and can thus employ a difference-in-differences identification strategy. Given the negative effect of the share of women on marriage estimated in Angrist (2002) based on a quasi-random research design, it is plausible that the positive cross-field relationship between fertility and the share of women uncovered in earlier work is due to the pro-family 'nature' of these fields and to selection: Highly 'female' fields of study may have more supportive work-family culture or lower earnings potential in subsequent highly 'female' occupations and may attract women and men with strong pro-family preferences. If there is a higher share of such women than men in the population, this would lead to a higher share of women in these fields.

Our identification strategy, explained in detail in Section 5, controls for the country-specific evolution of fertility preferences and determinants among college graduates (by gender) and for the stable part of fertility preferences and determinants across fields of study (again, by gender). However, we assume that changes in the gender composition of fields of study occurring during the recent higher education expansion are not systematically related to changing labor market prospects by field of study or to the sorting of men and women into fields of study based on their family-formation preferences. This is a strong assumption and future research is needed on this issue.[7]

[6]Van Bavel (2010) discusses earlier related research, which is all based on a one-country design. Begall and Mills (2013) and Michelmore and Musick (2014) are recent additions to this one-country work offering cross-field-of-study fertility comparisons based on Dutch and US data, respectively.

[7]If some fields became more family-friendly over time relative to others and this attracted both more women and more family-oriented types across both genders into such fields, our differences-in-differences approach would provide an upper bound on the effect of the female shares on fertility. Given the increasing

2.3 Matching into Parenthood

To guide our specification choices in the estimation of the effect of gender composition of study peer groups on fertility, we need to consider the potential mechanisms of matching effects in unbalanced groups. That women marry faster and have children earlier when the share of men on the marriage market is high has been recognized at least since Becker (1973). Mortensen (1988) provided a search theoretical perspective for such patterns. Having a larger pool of potential partners increases one's chances of matching with a partner of desirable qualities, and the general prediction of matching theory is the short(er) side of the market is better off. Whether this implies higher fertility depends on gender-specific family-formation preferences: If women have stronger preferences for having children than men and if the female bargaining power is high when such is the share of men on the marriage market (Angrist, 2002), this will lead to higher fertility. Conversely, increasing the share of women above parity may increase male bargaining power—men may realize that the costs of drawing another match is lower and may be less willing to commit to parenthood.

When the share of either gender on the peer group is close to one, the potential for endogamous (within-group) matches is small. This will likely imply a search strategy focused on out-of-group search. In our case, women in highly 'female' groups of graduates and men graduating from almost fully 'male' fields of study are likely to look outside of the group to find non-endogamous partners with bargaining power implied by cohort-wide gender shares.

The shape of the relationship between fertility and gender shares in tertiary education are thus likely to be different for men and for women and may also be non-linear, i.e., exhibiting a different slope on either side of the 50 percent share and also towards the extreme ends of the gender share range. Unlike the existing analyses of field-of-study gender segregation and early fertility (discussed in Section 2.2), we therefore distinguish endogamous and non-endogamous fertility and use a non-linear empirical model (in Sections 5 and 6).

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marriage return to college (Chiapori et al., 2015), it is also possible that the choice of field of study is based on marriage prospects, i.e., to the gender composition of the field. Existing work on marriage expectations and college attendance (e.g., Ge, 2011) does not focus on the choice of the field of study.

3 Data Sources

To measure the gender composition of tertiary-level graduates by field of study, we use country population statistics for ISCED education levels 5 and 6 compiled by the UNESCO Institute for Statistics (UIS). The data cover eight fields of study (Education, Humanities, Social Sciences, Science, Engineering, Agriculture, Health, and Services) for 29 European countries from 1998 to 2010. After excluding countries with less than 6 years of information, the data allow us, in Section 4, to describe the recent evolution of gender segregation across fields of study in 23 EU countries using more than two thousand country-year-field of study group observations.[8]

Next, we merge the UIS data on the gender composition of fields of study groups with information from the EU Labour Force Survey (LFS) on tertiary graduates and their fertility in 19 EU countries. Specifically, we employ the 2012 release of the EU LFS covering reference years 2003 to 2011, when information on field of study is available in the data, and use information on individuals with ISCED education levels 5 and 6 who graduated between the ages of 20 and 44. The share of sampled individuals with missing data values generally does not exceed 5% in any of the country-year data cells. Fertility information for the sampled individuals is merged with UIS population statistics on the gender composition of tertiary education at the level of graduation year, country, and field of study, and the merged data are used in Section 6 to study the effect of the gender composition of one's group on fertility.

Several features of our data deserve to be mentioned. First, this appears to be the first data combining extensive panel information on the gender composition of fields of study with marriage and fertility measures.[9] Second, we use data on graduates, which means that observed patterns of sex segregation reflect gender differences in both initial choices of field of

[8]The Data Appendix provides details on all our data sources and procedures, in particular on how missing data cells were treated in our analysis.

[9]Recently, Altonji, Kahn, and Speer (2014) compile an even richer panel for the US to study the gender-specific interplay of field-of-study choices and labor-market conditions. They do not consider fertility.

study and in the completion rates (Alon and Gelbgiser, 2011). Third, unlike in, for example, Wei and Zhang (2011), our gender shares are not estimated off survey data and are therefore not affected by sampling error that could lead to attenuation biases in regression estimation (Aydemir and Borjas, 2011).

Our analysis could be affected by a different source of measurement error, however, namely by potential differences in the coding of education in the two data sources. To verify that both data collection efforts use the same coding of education fields, we have correlated the UIS population shares of women in each year-country-field cell with those measured with sampling error in the LFS. The correlation (measured at the year-country-field cell level) is 0.97. When we measured this correlation separately for our eight fields of education, the small field of Services (800) was a clear outlier with a correlation of only 0.33 (the median correlation across the other fields being 0.83). In a robustness check, we therefore drop this field from the regression analysis.

4 Segregation Evolution

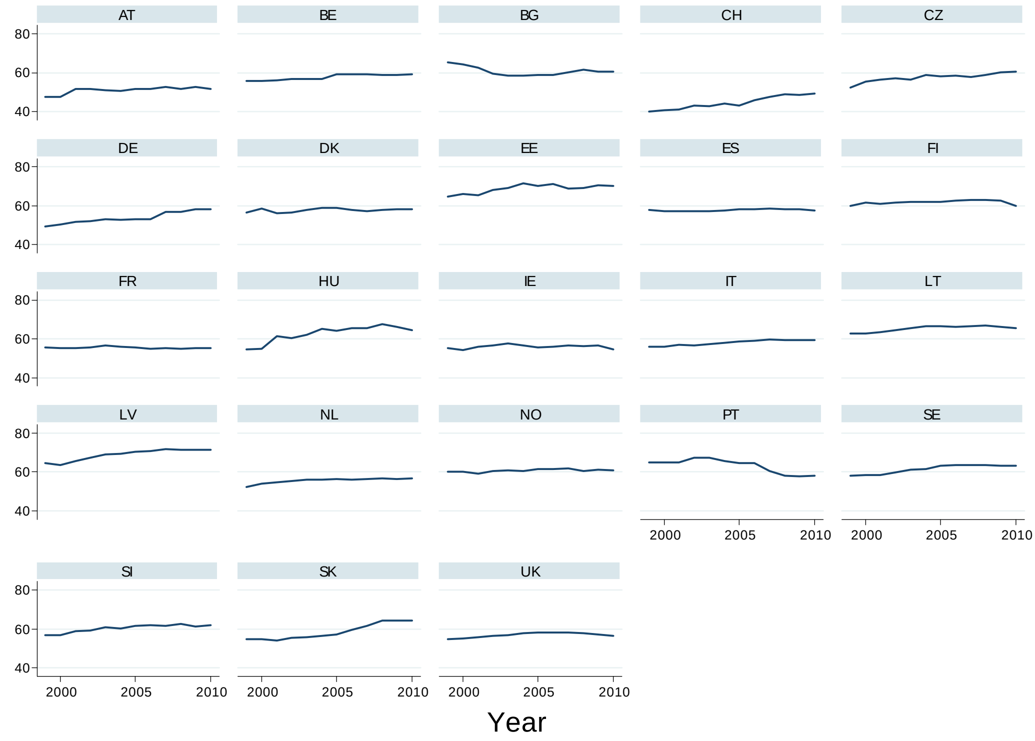
During the first decade of the 21st century, the share of women in higher education graduates has increased in most, but not all, of the 23 EU countries covered by the UIS data, as Fig. 1 attests.[10] The share of female graduates varies from a low of 40 percent in Switzerland in the early 2000s to about 70 percent in the Baltic countries recently. While the share rose by about ten percentage points in seven countries including, e.g., Germany and Slovakia, it declined in Portugal and changed little in France, Spain, or the UK. The overall share of female graduates across all of these countries rose from 55% to 58% between 2000 and 2010.

As shown in Fig. 2, the increasing share of female graduates means that most fields of study with above-parity shares of women (at the level of all of our 23 countries) as of 2000 have actually witnessed further increases in their share of female students. Among fields with

[10] The figure is based on 2,208 country-year-field observations, of which 220 missing values and outliers were imputed using neighboring years. See the Appendix for details.

Figure 1: Percentage of Women in Tertiary Graduates by Country

Note: Graduates with tertiary-level education (ISCED level 5 and 6) from eight fields of study (see Fig 2).



low initial shares of women, Engineering and Agriculture move toward parity while no such change occurs in Science. These simple statistics suggest segregation across fields of study is not generally declining.

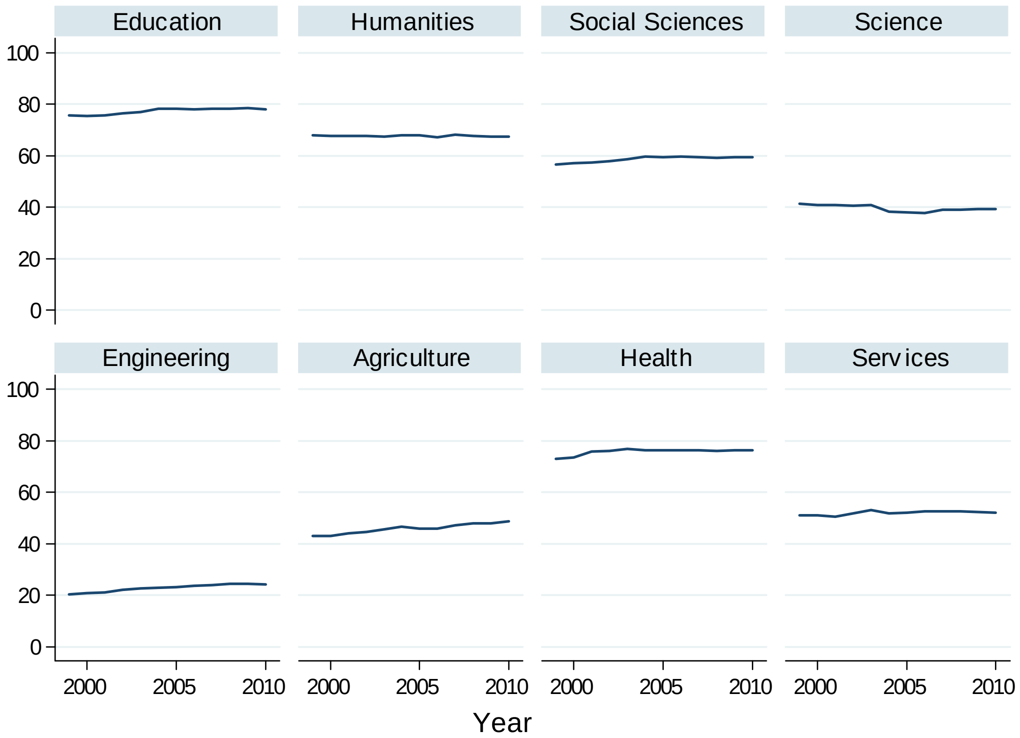
To quantify the change in the extent of higher-education field-of-study gender segregation at the country level, we apply the widely used Duncan segregation index (Duncan and Duncan, 1955). For a given country c and year t, the index is defined as

$$D_{ct} = \frac{100}{2} \sum_{f=1}^{8} \left| \frac{M_{fct}}{M_{ct}} - \frac{F_{fct}}{F_{ct}} \right|,$$

where M_{fct} denotes the number of males in a field of study f, F_{fct} is the corresponding number of females in a group, and where M_{ct} and F_{ct} represent the total number of males and females in higher education, respectively. The index can be interpreted as reflecting the

Figure 2: Percentage of Women in Tertiary Graduates by Field

Note: The share of women by field on the total sum of graduates from the 23 EU countries of Fig 1.

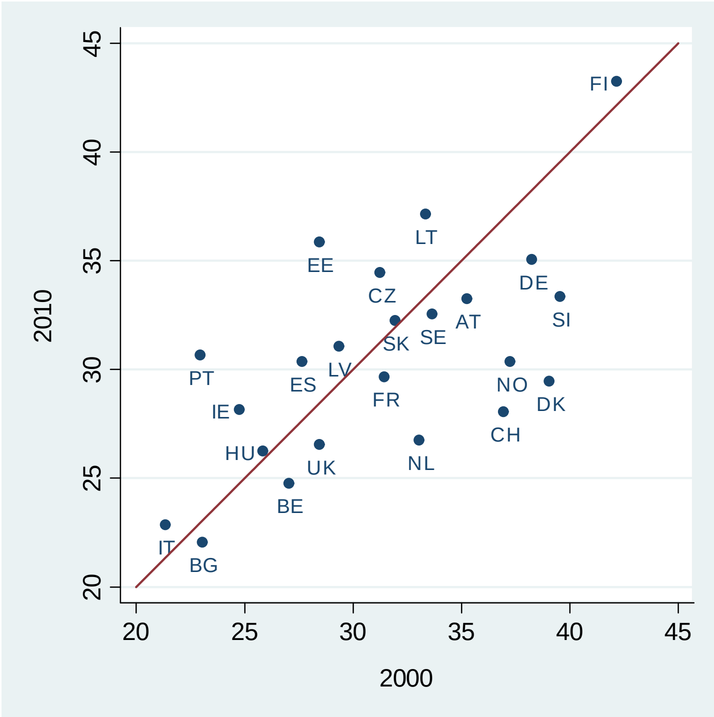


percentage share of the total body of graduates that would have to change the field of study in order to equalize the gender composition across fields; it ranges between 100 (complete segregation) and 0 (complete integration).

Figure 3 shows Duncan segregation index values calculated for each country in 2000 and in 2010 (or in the nearest available year) against the 45-degree line. It implies that field-of-study higher-education segregation changed by over 5 percentage points in seven EU countries. It declined by about 10 percentage points in Switzerland, where the share of women increased from a very low initial level, and in Denmark, where it stagnated at a high level of about 60 percent. The other three countries experiencing sizeable declines in segregation were similar to Denmark in this respect. On the other hand, segregation increased rapidly in Portugal, where the share of women declined, and in Estonia, where it kept on increasing from a high

Figure 3: Field-of-Study Gender Segregation, 2000 and 2010

Note: The Duncan segregation index in 2010 (2009 in BE, FR, PT, SI and 2008 in IT) and 2000 (1999 in IE, IT, SI and 2001 in HU, UK).



initial level. The other two Baltic countries where the share of women also grew much above 60 percent also experienced increases in segregation.

These statistics suggest that improvements in segregation are achieved by either increasing the share of women from low levels or by altering the allocation of students to fields of study once a high share of women in aggregate has been achieved, and that very high levels of the female share on tertiary education come at the cost of women increasingly enrolling in highly 'female' fields of study.

While there is clearly much heterogeneity in segregation evolution at the country level, Figure 3 also implies that there has been little change in the extent of segregation at the EU level over this decade. Summarizing the segregation index changes across the 23 countries using an average of country-specific index values weighted by the country-specific number of tertiary-level graduates, the overall extent of field-of-study gender segregation changed from

30% in 2000 to 29% in 2010.

Our next goal is to exploit the variation in the country-specific changes in the gender composition of fields of study to ask whether it can explain early fertility patterns among recent tertiary graduates. In the next section, we introduce the econometric specifications used in the fertility analysis, which is presented in Section 6.

5 Econometric Methodology

We use individual-level data to measure the impact of the changing gender composition of fields of study on early fertility choices of tertiary graduates. Yet, the mechanism we test for operates at the group level defined by country, field of study, and graduation year. In order to reflect the group-level nature (degrees of freedom) of the estimation, we follow the simple two-level procedure suggested by Donald and Lang (2007) separately for each gender.[11]

In the first step, we aggregate the individual-level EU LFS fertility data to the relevant country-field-graduation year group level whilst controlling for any age compositional and survey year effects, thus abstracting in our analysis from any EU-wide trends in fertility as well as potential survey-round-specific data issues. Specifically, we aggregate individual fertility measured as the presence of first childbirth at the most one year prior to and within five years after graduation[12] using the following least squares regression

$$y_{icfts} = \omega_{cft} + \beta age_{icfts} + \gamma_s + \varepsilon_{icfts}, \tag{1}$$

where $y_{icfts} = 1$ if a first child was born to individual i from country c, who graduated from field of study f in year t, and who was interviewed in a survey conducted in year s and

[11] All of our regression analysis is conducted separately for each gender. However, to simplify the exposition of the analysis, we drop the gender subscript from the regression specifications presented in this section.

[12] We do not observe the exact age of the child, only a three-year age range and use the mid-point of the age interval as our age proxy to compare with the year of graduation. This implies that a small random part of the children we classify as born within five years after and one year before graduation are, in fact, born in the two years adjacent to this interval.

$y_{icfts} = 0$ otherwise; ω_{cft} are the country by field of education by year of graduation fixed effects, age_{icfts} is the age of the individual at graduation, and γ_s are the survey-year fixed effects.[13] As the outcome variable is censored for individuals who graduated less than five years ago, we focus only on individuals who are at least 5 years out of school such that the last graduation year in our estimation-ready sample is 2006.

In the second stage, we relate the fertility aggregates from the first stage, i.e., the estimated fixed effects $\widehat{\omega_{cft}}$, to the share of women and other control variables measured at country by field of education by graduation year level. The theory discussion in Section 2.3 implies that the share of women may have a non-linear effect on early fertility. We therefore estimate the second-stage relationship using a semi-parametric regression in which the key variable of interest – the share of women on a field-of-study group – enters non-parametrically. We also control (parametrically, using a linear specification) for the size of the group (the total number of graduates) and a set of fixed effects corresponding to our identification strategy.[14]

The panel data we employ covers fertility choices of graduates in 8 fields of study across 19 EU countries from 1998 to 2006. The extent of variation in our data allows us to consider two parsimonious identification strategies: First, we ask about the effect of the gender composition within the field of study on early fertility whilst assuming that the sorting into fields of study based on pro-family preferences is the same across our 19 EU countries and allowing for country-specific time evolution of fertility, which could be potentially correlated with the country-specific time evolution of the share of women in tertiary education. Alternatively, we assume that there are no country-specific time shocks to fertility (on top of the EU-wide common evolution, which we control for in equation (1)) and allow for country-specific sorting into fields of study based on pro-family preferences that could be potentially correlated with field-of-study differences in the representation of women across countries. The two alterna-

[13] The regression is estimated without a constant (with a full set of fixed effects) and with age demeaned.

[14] We use the `semipar.ado` command in `Stata` developed by Verardi and Debarsy (2012), which implements the double-residual estimator proposed by Robinson (1988).

tive specifications corresponding to these two identification assumptions are presented in the following two equations: In equation (2), we condition on country by field of education (δ_{cf}) and graduation year (δ_t) fixed effects, while in equation (3), we use country by graduation year (δ_{ct}) and field of education (δ_f) fixed effects:

$$\widehat{\omega_{cft}} = \alpha_0 + \alpha_1 ln(graduates_{cft}) + \delta_{cf} + \delta_t + \Gamma(fshare_{cft}) + \nu_{cft}, \tag{2}$$

$$\widehat{\omega_{cft}} = \alpha_0 + \alpha_1 ln(graduates_{cft}) + \delta_{ct} + \delta_f + \Gamma(fshare_{cft}) + \nu_{cft}. \tag{3}$$

In both equations, $ln(graduates)$ is the logarithm of the total number of graduates in a given country, field of education, and graduation year; $fshare_{cft}$ is the share of women among graduates in a given country, field of education, and graduation year; and where $\Gamma(.)$ is an unknown function estimated non-parametrically.

Equations (2) and (3), together with equation (1), can be thought of as corresponding to a production function aggregating the number of men and women in a group into a single factor affecting fertility. We measure the gender composition of peer groups using the share of women as opposed to the sex ratio—the ratio of men to women. Angrist (2002) is a prominent example of a study of matching on marriage markets that uses the sex ratio. He analyzes situations where the share of men and women is not too far from balanced. In his specification of a matching function, the logarithm of the sex ratio can thus be approximated with a linear term. Given the wide variation in gender shares across the field-of-study groups presented in Section 4 and the theoretical arguments supporting non-linear effects, this strategy is not attractive in our case. Studies of workplace segregation effects, which also work with variation in the share of women that ranges almost from 0 to 1, also typically condition on the share of women, not on the sex ratio.[15] Similar to Angrist (2002), we also condition on the logarithm of the group size to allow the probability of finding one's preferred match to depend on the pool of potential partners, as in any standard matching function.

[15] See, e.g., Svarer (2007) and McKinnish (2007) for studies of divorce patterns and Macpherson and Hirsh (1995) or Baker and Fortin (2001) for work on the gender wage gap. There are also matching studies that use the shares of demographic groups as their main explanatory variable (e.g., Fletcher et al., 2013).

6 Fertility Analysis

In Section 4, we summarized variation in the gender composition of peer groups across the three principle dimensions of our data, namely year, country, and field of study. In this section, we ask about the effect of this variation on early fertility patterns.[16] Our analysis-ready sample includes 92,154 female graduates and 72,795 male graduates from 156 country-reference year LFS samples graduating between 1998 and 2006. This data covers 2,103 country-graduation year-field of education data cells (1,058 for women and 1,045 for men), for which we can form group-level fertility aggregates (using equation (1)).

We measure early fertility based on the presence of first childbirth at most one year prior to and within five years after graduation.[17] An endogamous child is a child born to a tertiary-educated couple[18] who graduated from the same field of study within at most five years from each other. A non-endogamous child is born either to a couple where one of the parents is not tertiary educated or to a tertiary-educated couple who graduated from different fields of study or from the same field of study more than five years apart.

Table 1 shows average fertility rates by type and gender for the entire data. About one fourth (sixth) of early fertility is endogamous for men (women). A summary fertility outcome ('Any child') includes not only childbirths identified as endogamous or non-endogamous, but also any children born to individuals without a partner and (the few cases of) individuals

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[16] Figures 7 and 8 in the Appendix document that much of this variation is independent of the increasing size of higher education across countries. In other words, there is variation in gender shares conditional on the growing size of the field-of-study peer groups. We illustrate the extent of available *annual* variation in the gender composition of fields of study below.

[17] In our data, 60% of children born to a parent with tertiary education who graduated in 2000 were born within this interval. Similar to, e.g., van Bavel (2010), we exclude from this calculation, and our subsequent analysis, those who already had children before our fertility window, in which one can expect fertility decisions to be affected by gender composition of peer groups.

[18] We define partners (couples) using the EU LFS data, which record the presence of "spouses or cohabiting partners in the same household."

Table 1: Average Fertility Rates

Endogamous	Non-endogamous	Any child
	Women	
0.038	0.200	0.267
	Men	
0.046	0.152	0.207

Notes: Fertility rates corresponding to the presence of first childbirth at most one year prior to and within five years after tertiary graduation. Endogamous couples graduated from the same field of tertiary education within at most five years from each other. 'Any child' fertility covers endogamous (same education) and non-endogamous (different education) couples and also children born to individuals without a partner.

with a partner but with missing information about spouses' level of education, field of study, or year of graduation.[19] Table 2 shows that the female endogamous fertility rate reaches over 0.1 in fields where women represent less than a quarter of graduates and is lowest in fields where women represent more than three quarters of graduates, i.e., where there are fewer available potential endogamous partners. The male endogamous rate exhibits a similar, but less pronounced relationship with the male representation on fields of study.

Table 2: Average Endogamous Fertility Rates

	Women	Men
Highly 'male' fields of study	0.104	0.023
Balanced fields of study	0.040	0.049
Highly 'female' fields of study	0.032	0.053

Notes: Endogamous fertility rates corresponding to the presence of first childbirth at most one year prior to and within five years after tertiary graduation by couples graduated from the same field of tertiary education within at most five years from each other. Balanced fields of study are those with shares of women between 25 and 75%.

[19] The share of first-born children that we cannot classify as either endogamous or non-endogamous is small (10% for women and 5% for men); this provides an upper bound on the number of cases of endogamous or non-endogamous parents who do not live in the same LFS household.

Next, we use the identification strategy outlined in Section 5 to quantify the effect of the availability of potential endogamous partners on early fertility. Our sample countries differ dramatically in the evolution of early fertility of tertiary graduates. In three (five) out of the nineteen countries covered by the merged UIS-LFS data, female (male) early fertility rates have changed on average by more than 1.4 of a percentage point a year with several countries experiencing strong growth and several others sizeable declines. Given these differences in country-specific fertility trends, our preferred specification corresponds to equation (3), which allows for country-specific evolution of fertility and conditions on the stable part of the selection of students with strong pro-family preferences into highly 'female' fields of study. Within robustness analysis, we compare the key estimated parameters across the alternative identification approaches (specifications (2) and (3)).

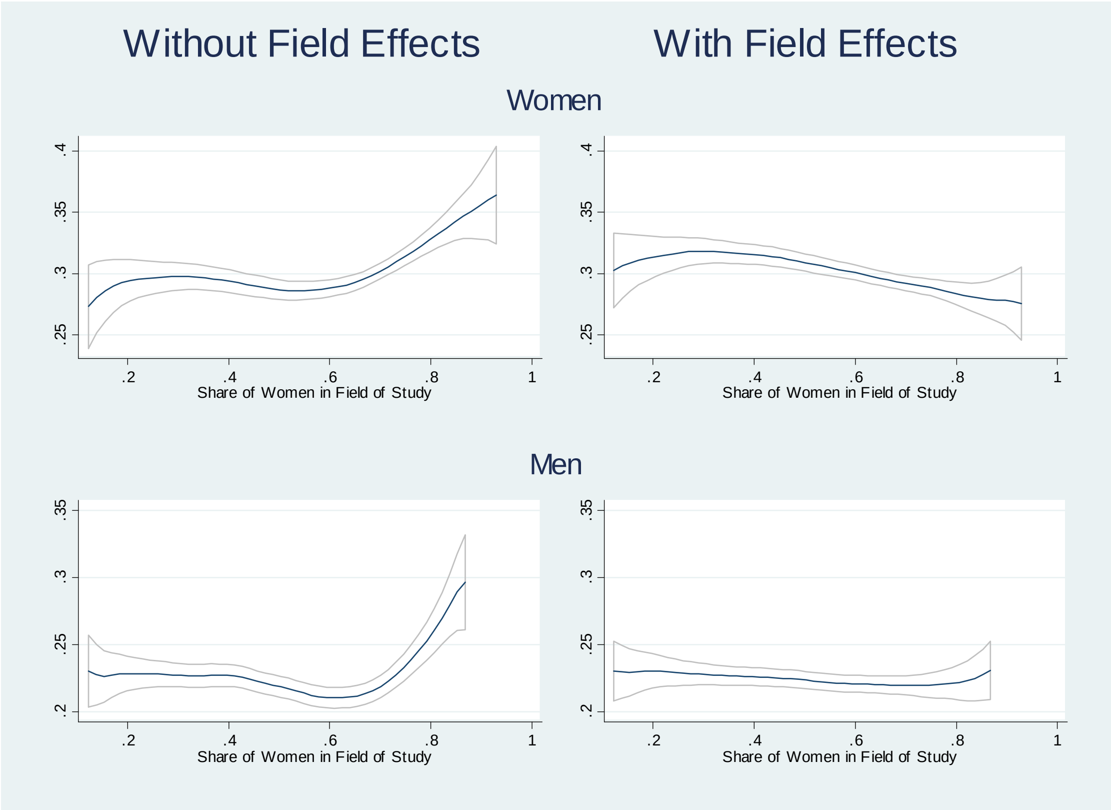
In our first analysis, we confirm the earlier findings of a positive relationship between the share of women on a field of study in tertiary education and fertility. This is born out in the two left-side graphs of Figure 4, which rely, in large part, on cross-field of study comparisons as they are based on estimating equation (3) separately for each gender without the field-of-study fixed effects (δ_f). The plotted lines correspond to the estimated non-parametric effects Γ of the share of women in a field-of-study peer group on fertility;[20] they suggest fertility (of any type) is high in highly 'female' fields of study. In contrast, the right two graphs of the Figure, which are also based on estimating equation (3) but this time with field-of-study fixed effects included, i.e., based on difference-in-differences comparisons, suggest a starkly different picture—one of only a limited effect of gender composition of field-of-study groups on fertility.[21] Hence, the positive cross-field association between fertility and the share of women is likely driven by selection of students with strong pro-family preferences to highly 'female' fields of study.

[20] These estimated effects would correspond to predicted group fertility levels $\widehat{\omega_{cft}}$ if one were to add the effect of mean groups size and the estimated fixed effect coefficients from equation (3).

[21] The top-right graph suggests early female fertility is decreasing as the share of women increases, but the magnitude of this decline is small, and it is not robust to some of the robustness checks we perform below.

Figure 4: Effects of Share of Women in Group on Fertility Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted together with the non-parametrically estimated effects.



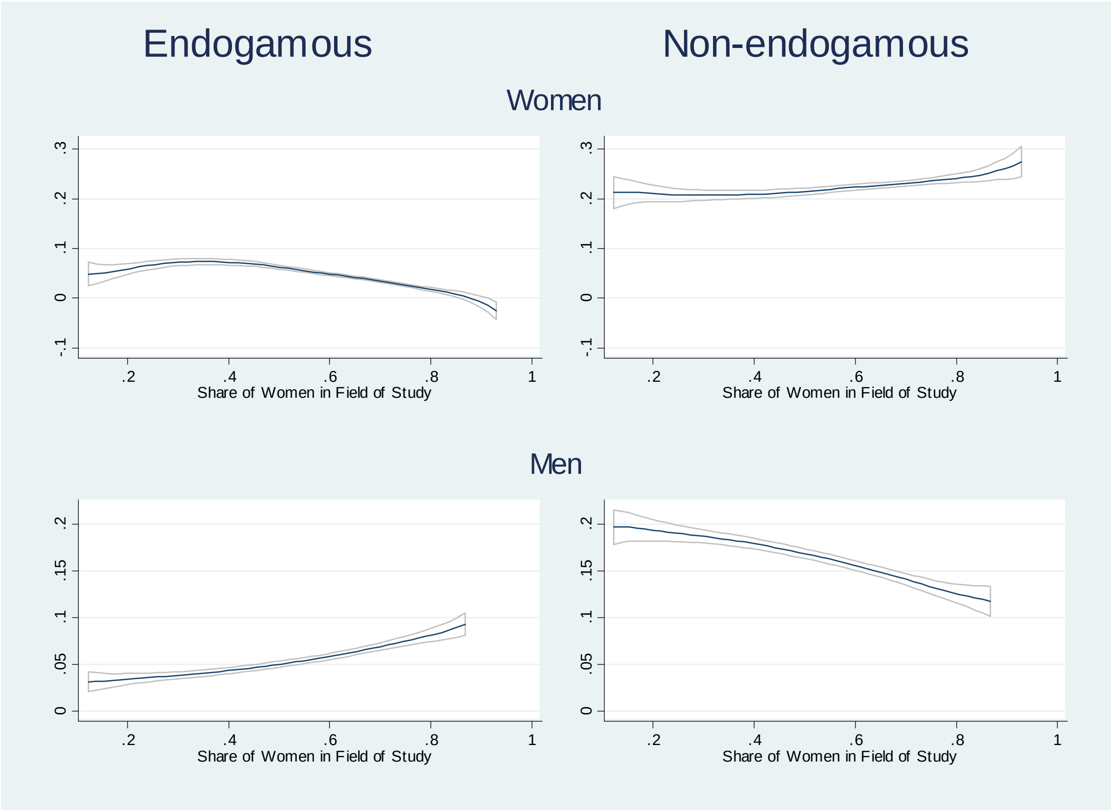
Next, we decompose the effects on overall fertility from the two right-side graphs of Figure 4 into their endogamous and non-endogamous parts. Figure 5, which is also based on estimating equation (3) separately for each gender,[22] plots the estimated non-parametric effects of the share of women in a field-of-study peer group on two types of fertility outcomes: endogamous first childbirth and non-endogamous first childbirth.

The two graphs in the left column of Figure 5 paint a consistent story: For men, endogamous fertility is higher when the share of men is lower, and endogamous fertility of women

[22]We again aggregate fertility of each type by re-estimating the corresponding version of equation (1).

Figure 5: Effects of Share of Women in Group on Fertility by Type Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted together with the non-parametrically estimated effects.



declines, as expected, when the share of women increases, at least when the share of women is above one-third where the effects are less noisy for women. When there are almost no members of the opposite sex in a peer group, there can be only few endogamous children. The simplest interpretation of the slopes of the endogamy effects is that they correspond to varying availability of potential partners; that they are 'mechanical' artifacts of matching in unbalanced groups.

It is not surprising that the slopes of the endogamy fertility effects for men and women are roughly equal (in absolute value): They are based on the same children in the data—children born to endogamous couples in the LFS-sampled households.[23] However, that the endogamy effect is close to linear can shed light on gender differences in pro-family preferences: If men had lower preferences for having children, they would have disproportionately (relative to the 'mechanical' matching effect) fewer children as their bargaining power increased in highly female fields of study—the endogamy effects would be non-linear. Similarly, endogamous fertility of women is not particularly high when their share is low.[24] Furthermore, the earlier comparison (in Figure 4) of cross-field and within-field estimates suggested strong selection into fields of study based on pro-family preferences. We thus view the endogamy estimates as consistent with similar pro-family preferences of men and women who chose the same field of study and with partner availability being a key driver of endogamous fertility.[25]

Given the effects of gender shares on endogamous fertility and the low impact of gender composition of peer groups on overall fertility shown in Figure 4, it is clear that those men as well as women who face a highly gender unbalanced peer group manage to 'compensate' for the lack of suitable potential partners in the group by successfully forming non-endogamous parenthood matches. The right column graphs of Figure 5 bear this out.[26] Our fertility decomposition thus provides an underlying mechanism for the low impact of gender composition of peer groups on overall fertility of both genders shown in Figure 4.

The estimates shown in Figures 4 and 5 are based on defining peer groups (pools of potential partners for matching into parenthood) as corresponding to all those who graduated in the same year (in the same field of study and country). Also, since some of our

[23]The minor differences between the estimated effects are driven by gender differences in coefficients corresponding to control variables in equations (1) and (3).

[24]It may be that their bargaining power does not increase when their shares are low because most men in the group have focused their search for partners outside of the group.

[25]This set of findings could also be generated through more complicated labor-market mechanisms, such as changes in pro-family culture or gender-specific wages in occupations linked to fields of study with changing gender shares. The joint analysis of the marriage-market and labor-market implications of the gender composition of tertiary education across fields of study is an important avenue for future research.

[26]Unlike with the endogamous fertility effects, there is no 'mechanical' explanation for these estimates.

country-graduation year-education field data cells contain only few individuals such that the corresponding fertility rates are noisy, our preferred specifications shown in Figures 4 and 5 are based on a sub-sample of data cells with at least 10 graduates.[27] Within this sub-sample, there are 773 (717) data cells for women (men) with on average 89 (75) individuals.[28] In the Appendix section 9.2, we show that our results are not sensitive to these choices and that applying the alternative identification strategy based on equation (2) does not qualitatively affect our main findings.[29] We also present the coefficients for age at graduation from equation (1) and for group size from equation (3) in the Appendix. As expected, the group size coefficients are positive for endogamous fertility specifications, where the larger the pools of individuals to be matched, ceteris paribus, the higher the probability that the match occurs.

In sum, we find that the high fertility rates in highly 'female' fields of study observed in earlier work are not robust to difference-in-differences comparisons. We uncover only a limited effect of changing gender composition on fertility. For women, overall early fertility is highest when women represent about a third of the group, and fertility may be particularly low in almost fully 'female' groups although the estimates are noisier at both extremes of the 'female' share where there are fewer observations in the data. These effects are small in magnitude in any case, such that search frictions generated by the availability of potential partners in college are unlikely to be among the key explanations for the low fertility levels of college graduates.[30]

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[27] For a similar approach, see Altonji, Kahn, and Speer (2014).

[28] To describe the extent of available annual variation in this estimation-ready sample, we have regressed the gender shares across the country-year-field of study groups on the fixed effects defined in equation (3). The residuals from this regression correspond to the variation, which we use to estimate fertility effects. For both genders more than 50% of these group-level residuals are larger in absolute value than 3 percentage points. The 90/10 percentile range goes from plus to minus 6 percentage points.

[29] Fertility aggregates across the various samples we employ are almost identical to those presented for the entire data in Table 1.

[30] To assess the magnitudes of the fertility structure implications of our estimates, we use the estimated relationship presented in Figure 5 together with the (UIS) observed change in the gender composition of

Our main finding thus far is that the availability of potential partners in college field-of-study group does not affect the level of fertility for either gender since non-endogamous fertility 'compensates' for the lack of endogamous partners when gender shares are not balanced. However, the availability of endogamous peers may still affect the 'quality' of non-endogamous parental couples, specifically their education structure. We now therefore use our preferred specification to estimate how the share of women in one's field of study affects the probability that a tertiary graduate with a non-endogamous child parents with a non-tertiary spouse as opposed to a tertiary-educated spouse from a different field of study. (This simply continues the decomposition of fertility education structure that we started by looking at the share of fertility that is endogamous.) The ability of those who do not form endogamous parental couples to find tertiary educated partners is likely to be related to the aggregate share of women among college graduates, which varies widely across countries as shown in Fig. 1. We therefore provide separate evidence on the education structure of non-endogamy for countries where the average share of women on all college graduates in our data was above/below the overall median, which is 57%.

First, Table 3 shows the average shares, within non-endogamous fertility, of parental couples where a college graduate is matched to a less-educated partner.[31] There is a difference in the education structure of non-endogamous fertility between countries where the average share of women on all college graduates is relatively high (above 57%) and those where it is

fields of study between 2000 and 2010 to predict fertility change by type separately for each country. These simulations confirm that predicted increases or declines in endogamous fertility are largely compensated by balancing changes in non-endogamous fertility. The largest country-specific implied change of endogamous fertility (in absolute value) is 0.01 for both women and men, i.e., about one-fourth and one-fifth of the sample-average endogamous fertility rate. Correspondingly, none of the implied country-specific changes of non-endogamous fertility were higher than 0.01 (in absolute value) for both genders, which means they were only one-twentieth and one-fifteenth of the sample-average non-endogamous fertility rates.

[31] The table is based on all LFS data, similar to Table 1. Before constructing the table, we drop those men and women who are in a non-endogamous parental couple and have graduated from the same field of study more than five years apart. As a result, less than 5% of observations for either gender was omitted.

Table 3: Average Share of Non-Tertiary Parental Partners (as Opposed to Tertiary Partners) in Non-Endogamous Fertility

	Women	Men
Countries with High Aggregate Share of Women	0.55	0.30
Countries with Low Aggregate Share of Women	0.53	0.48

Notes: Non-endogamous fertility corresponds to couples where either one of the parents is not tertiary educated or both parents are tertiary educated who graduated from different fields of study within at most five years from each other. Countries are divided based on their aggregage share of women on college graduates being above/below 57%.

low. In the former set of countries, men with non-endogamous children are much less likely to end up parenting with a less educated partner and the opposite is true for women, if to a lesser extent.

Next, Figure 6 presents estimates based on our identification strategy[32] asking how the share of women in one's field of study affects the probability that college graduates who do not manage to form endogamous parental couples parent with less-educated partners. There is a general pattern shared by both genders in both settings: As the share of one's own gender on one's field-of-study group increases above 40%, that is as the availability of potential endogamous partners declines, the chances of parenting with a less-educated partner increase by at least 10 percentage points.

For both genders these effects are larger in countries where the aggregate share of women is high (above 57%). For women, this is not surprising—female graduates who do not form endogamous parental matches are likely to be more constrained in their ability to find non-endogamous partners with college diplomas when the aggregate share of women among all college graduates is high. However, the effect of peer group gender composition on the education structure of male non-endogamous fertility is also stronger when the aggregate

[32]The estimates are based on the same sample and specification that were used to generate the right two graphs in Figure 4, except that we drop graduates who are in a non-endogamous parental couple and have graduated from the same field of study more than five years apart. As a result, less than 5% of observations for either gender was dropped and the number of fertility data cells used for estimation was not affected.

share of women is high, consistent with search frictions playing a role even in environments where there are plenty of potential partners.

Our estimates become uninformative when based on the few (203, to be exact) women in the data who graduate in highly 'female' countries in fields where the share of women is below 0.3. We also uncover a surprising effect for the sub-set of men in highly 'female' fields of study:[33] as the share of women nears 100%, the subset of these men who do not form endogamous parental couples is more likely to end up parenting with a less educated woman. This effect is particularly strong in countries where the aggregate share of women is high. We believe it could be driven by selection on preferred fertility type: If a constant share of males in every field of study prefers to parent with less educated women, this sub-group will represent a larger share on the field's non-endogamous fertility the easier it is for men to form endogamous parental couples.

7 Supplementary Evidence on Marriage

To shed additional light on the fertility evidence presented in the previous section, we now provide a brief analysis of couple formation.[34] Unfortunately, our data do not provide information on when couples were formed. The analysis of fertility presented in the previous section focused on first childbirth occurring at most one year before graduation so as to link gender composition during study to subsequent fertility outcomes. In contrast, it is possible that some of the marriage/cohabitation matches we study in this section were formed prior to the choice of field of study in college. We thus consider the marriage estimates tentative and tantalizing.

Estimating equation (3) with marriage/cohabitation replacing fertility as the outcome variable implies that endogamous marriage/cohabitation depends on the availability of en-

[33]25 % of men in our data are in fields of study where the share of women is above 0.8.

[34]I.e., we study the incidence and endogamy composition of couples as defined in the EU LFS by the presence of "a spouse or a cohabiting partner in the same household."

dogamous partners similarly as fertility does, only more strongly.[35] The estimated effects for non-endogamous marriage/cohabitation and for any form of marriage/cohabitation are also fully consistent with the pattern uncovered for fertility. A simple interpretation of this set of findings is that the availability of endogamous partners drives the structure of match formation (couples) and that within couples bargaining power implied by group-specific gender shares plays little additional role for fertility.

Next, we ask whether the availability of potential partners in one's field-of-study group affects the education composition of non-endogamous couples.[36] Except for estimates for women in countries where the aggregate share of women is above the country median, we find marriage/cohabitation effects that broadly mirror the corresponding fertility estimates: the share of couples that involve a non-tertiary educated partner increases as the share of one's own gender increases above 40%, but these increases are less pronounced.

The main difference in comparison to the fertility estimates is that women in countries where the aggregate share of women is high are less likely to cohabit with a less-educated partner as their share on the field-of-study group increases, not more likely as was the case with parenting. Whether this corresponds to a tradeoff between cohabiting with a less-educated partner versus parenting with an equally educated man, or whether this difference is a consequence of our noisy definition of marriage/cohabitation could be subject of future research with data better suited for the study of couple formation.

[35] These estimates are presented in Appendix Figure 13. They are based on the same sample and econometric specifications that was used to generate Figure 5 and the right two graphs in Figure 4.

[36] I.e., we provide the marriage/cohabitation evidence corresponding to fertility estimates presented in Figure 6. The marriage estimates are shown in Appendix Figure 14. They are based on the same sample and econometric specifications that was used to generate Figure 6.

8 Conclusions

As of 2010, the EU-wide share of women studying education (engineering) in college is still close to 80 (20) percent. Gender segregation by field of study in higher education has not changed much in many of EU countries since the start of the 21st century despite the continuing expansion of university education driven by an influx of women into universities. In other words, the 'additional' women on average make field-of-study choices that are similar to those made by the earlier smaller cohorts of women in higher education. However, segregation declined dramatically in five countries, including Denmark and Norway, and grew strongly in Estonia and Portugal. It may be that increasing the share of women on tertiary education much above 60 percent comes at the cost of increasing segregation.

We use the corresponding variation in the changes in gender composition of country-field-of-study groups to ask about the impact of field-of-study gender mix on early fertility of the tertiary educated. Our results based on a decade of data covering 19 EU countries suggest that the effects on fertility levels are generally small with some evidence of slightly higher fertility for women when their share on a group is close to one-third. In particular, the estimates imply that a man who studies engineering in college manages to have children (within five years of graduation) at the same rate as if he were studying education, despite the dramatic difference in the availability of easy-to-sample potential partners. Search frictions generated by the availability of potential partners in college field-of-study groups are thus unlikely to be among the key explanations for the low fertility levels of college graduates. Future research could explore how search frictions are minimized in highly gender-unbalanced fields-of-study groups. For example, college students may adopt different mating strategies (social life activity) depending on the availability of potential partners in their field of study.[37]

Our evidence based on a difference-in-differences research design also implies that most of the positive cross-field association between fertility and the share of women, which was highlighted by previous studies, is driven by selection of students with strong pro-family

[37] Bellou (2015) suggests internet access increases marriage rates for groups facing thinner markets.

preferences to highly 'female' fields of study and/or by the work-family culture of occupations linked to these fields of study.[38]

Underneath the small effect of one's peer-group composition on fertility levels lie significant shifts in the *education structure* of fertility. First, about one fourth (sixth) of early fertility of male (female) college graduates is endogamous, i.e., occurs to tertiary-educated couples graduating from the same field of study, and endogamous fertility is strongly affected by the gender composition of the field-of-study groups. Our endogamy findings, which are based on country-wide field-of-study groups, could correspond to matching within as well as across colleges based on preferences for partners with not only the same level of education (as in Bruze, 2011), but also the same field of study. Alternatively, they could correspond to matching into parenthood driven by low costs of partner search within study programs. Two recent analyses of matching into marriage are consistent with the latter interpretation. Kaufmann and Messner (2014) find that the probability of marriage between students attending the same college is higher for men in programs with a higher share of women. Mansour and McKinnish (2014a) show that married couples are disproportionately formed from spouses who share their occupation. They then use wage information to ask whether this pattern is driven by partner search costs being lower within occupations or by within-occupation spousal preferences. Their findings are consistent with the search cost mechanism. Future research could relate the field-of-study endogamy patterns to occupational endogamy.

We also find that even though non-endogamous fertility almost fully compensates for the varying ability to form endogamous parenting couples, the gender shares by field of study affect the education structure of non-endogamous parental couples, specifically the

[38] Our difference-in-differences approach is based on the assumption that changes in the gender composition of fields of study did not systematically affect the sorting of men and women into fields of study based on their pre-tertiary-education family formation preferences. If some fields, in fact, became more family-friendly over time relative to others and this attracted both more women and more family-oriented types across both genders into such fields, one would expect the differences-in-differences approach to overestimate the effect of the female shares on fertility. It is therefore unlikely that violations of our identification assumption would mask an underlying positive effect of the share of women on field of study on overall early fertility.

probability of a college graduate parenting with a less educated partner: As the share of one's gender on a peer group increases (above 40%), so does the probability of forming a parental couple with a less educated partner. These effects are larger in countries where the aggregate share of women is higher. Our findings thus point to the importance of the gender composition of peer groups in higher education for the education structure of parenthood. Future research could relate field-of-study endogamy of couples to marital stability (as Schwartz and Han, 2014, do for education-level endogamy) and other family outcomes (such as intra-household bargaining or child investment).

There are other avenues of future research. Little work thus far examines the importance of field-of-study gender segregation for labor market outcomes. One recent exception is Lindley (2012) who studies the implications of the gender differences in the labor supply structure due to degree subjects relative to the labor demand evolution driven by technical change. Future work could also ask, for example, about the importance of gender field-of-study segregation for gender differences in youth unemployment rates.

Compliance with Ethical Standards

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9 Appendix

9.1 Data Appendix

9.1.1 UNESCO Data Description, Missing Data and Outliers

To measure the gender composition of tertiary-level graduates by field of study, we use data from public reports provided by the Data Centre of the UNESCO Institute for Statistics (UIS, www.uis.unesco.org). These are based on statistics submitted by national authorities, which UNESCO then harmonizes over time. Specifically, we have downloaded data corresponding to Table 16 ("Graduates by broad field of education in tertiary education"), which covers graduates with ISCED education levels 5 and 6, from the October 2012 release through the following link: http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx. The following eight fields of study are recorded in the data (with their ISCED codes and descriptions):

Education	100	Teacher training and education science
Humanities	200	Humanities, languages and arts
Social sciences	300	Social sciences, business and law
Science	400	Science, mathematics and computing
Engineering	500	Engineering, manufacturing and construction
Agriculture	600	Agriculture and veterinary
Health	700	Health and welfare
Services	800	Services

The UIS data cover a total of 29 countries. We have excluded Luxembourg, Iceland, Malta, Greece, Poland, and Romania, for which less than 6 years of information on all eight fields is available. We also do not use information on the number of graduates from unknown fields of study. With two exceptions (CZ in 2003 and the UK in 2000, where it reaches 10%), the share of graduates with missing fields of study never exceeds 6%.

Out of the maximum possible total of 2,392 country-year-field observations (for 23 countries, 8 fields, and 13 years from 1998 to 2010), there were 382 (15%) missing values, and we have further dropped 38 outlier data cells (1.5%). For this purpose, we defined outlier values as those corresponding to hard-to-verify large changes in the total number of graduates (i.e., not in terms of changes in the share of women). Specifically, we dropped a data cell whenever the number of all graduates in a given country-year-field differed from one of the two neighboring years by more than 50%. Excluding 1998 and focusing on the 2,208 maximum possible number of data cells from 1999-2010, the number of missing and dropped data cells decreases to 220 (10%).

Missing data cells were treated in our analysis as follows: For the purpose of Figures 1 and 2, we have excluded the year 1998 and imputed the values for all 220 missing and dropped data cells from neighboring year values, starting with the previous year, continuing with the following year when the previous year was not available, and using information from two years ago (ahead) when no neighboring year was available. For the purpose of Figures 3, 7 and 8, we have replaced missing country-year information with neighboring years as indicated in the graph legend. In addition, there are country-year cells where we have valid information for some but not all fields; these are used in the regression analysis presented in Figures 4 and 5, but are excluded from the descriptive graphs (Figures 1 and 2) or the segregation index calculations (Figure 3).

9.1.2 EU LFS Data Description, Missing Data and Outliers

We use the 2012 release of the anonymised EU Labour Force Survey (LFS) for the reference years 2003-2011. More specifically, we use the annual samples ("yearly files") except for Finland, where the annual sample does not contain information about children, so we use the specific household data file where this information is available. We do not use data from before 2003 since no information about the field of education was asked until then.

The EU LFS is a collection of national labor force surveys from EU countries. While most of the underlying surveys are collected as short rotating panels, the publicly available version of the data does not allow linking of individuals within surveys. In order to ensure that we do not use repeated observations for the same individuals, we use data from a single annual interview wave (wave 1 in all cases when multiple waves are available in the data).

We exclude country-year samples with missing information on graduation year, graduation field, or the presence of children. We also exclude Denmark where the annual sample does not contain information about children, and the information on educational attainment in the specific household data file is limited only to the reference person in the household. The share of missing values in educational attainment does not exceed 5% of prime-aged individuals in any of the country-year data cells. There are only few exceptions where the share of missing graduation year or field exceeds 5%.

9.2 Robustness Analysis

In this section, we assess the robustness of the main fertility estimates from Figures 4 and 5. First, there is little sensitivity to using data cells with more than five or more than fifteen (as oppose to more than ten) individuals. These results are available in the Appendix Figure 9.

The sample size increases to 922 (861) data cells for women (men) when only the cells with fewer than five individuals are dropped, and it declines to 668 (606) data cells for women (men) when we alternatively drop cells with fewer than 15 individuals.

Second, as highlighted in Section 3, there may be measurement error in the assignment of students to field of study in the small field of Services. Hence, we ask whether dropping this field affects the results and find that it has only a small effect. A related issue is whether we may be defining peer groups (pools of potential partners) too broadly in some large fields of study, which may in fact correspond to several effectively distinct sub-fields. We therefore alternatively drop the largest fields of study. Specifically, we order country-field-of-study groups (summed up across all years and normalized by the total number of graduates in a given country) by size and exclude from the analysis the largest decile. Again, we find only limited sensitivity. These results are available in the Appendix Figure 10. The number of data cells used in the estimation is similar for both of these robustness checks at about 700 for women and 650 for men.

Third, we consider alternative definitions of peer groups in terms of the year of graduation. Our preferred and simplest choice was to pool into a peer group all those who graduated in the same year (and field of study and country). To assess sensitivity to this definition of peer groups, we also define the share of women using a three-year moving window centered around the same graduation year for both genders and, alternatively, using a two-year window shifted forward for men by one year to allow for the fact that within couples, men may be older.[39] None of these alternatives resulted in quantitatively large changes in the estimates for women, but there is now a discernibly higher overall fertility predicted for men in fields where the share of women is high. These results, which are presented in the Appendix Figure 11, are, however, based on a substantially smaller number of data cells: 554 for women and 512 for men, i.e., about 30 percent less data compared to our favoured specification. The data loss is the result of the fact that we now need population statistics on the gender composition of graduates for each country and field of study for three consecutive years.

Fourth, we apply the alternative identification strategy based on equation (2). Given the different evolution of fertility across our sample countries (discussed at the start of this section), we attempt to homogenize fertility trends by dropping countries with the highest change (in absolute value) of overall fertility during the sample years: We drop the three countries for women and the five countries for men where the average annual fertility change

[39] The median age gap of partners with endogamous children in our sample (i.e., in partnerships formed within peer groups) is zero years. Further, about 50 % of both women and men with an endogamous partner have a partner whose age is within one year of their own.

exceeds 1.4 of a percentage point. The alternative identification approach leads to qualitatively similar results with the exception of a higher overall fertility of women and a lower overall fertility of men in almost fully 'female' groups, where the estimates are noisier. These results are presented in the Appendix Figure 12. The sample size is 661 (624) for women (men). Given the heterogeneity in fertility evolution across sample countries and the general robustness of our preferred specification, we take these results as a confirmation of the two main findings, namely of a small effect of the gender composition of field-of-study groups on overall early fertility and of a strong effect on the endogamy composition of fertility.

9.3 Appendix Figures and Tables

Table 4: Equation (1) Estimation: Fertility Aggregation

	Age (demeaned)		R^2	N
Fertility Outcome	coeff.	s.e.	adjusted	
Women				92,154
Endogamous first childbirth	0.0008	0.0002	0.06	
Non-endogamous first childbirth	0.0049	0.0003	0.24	
Any first childbirth	0.0071	0.0003	0.31	
Men				72,795
Endogamous first childbirth	0.0023	0.0002	0.08	
Non-endogamous first childbirth	0.0135	0.0003	0.20	
Any first childbirth	0.0166	0.0004	0.26	

Notes: OLS estimates with survey year and country by field-of-study by graduation year fixed effects included.

Table 5: Equation (3) Estimation Corresponding to the Right Column of Figure 4 and to Figure 5

	ln(# of graduates)		R^2	N
Fertility Outcome	coeff.	s.e.	adjusted	
Women				773
Endogamous first childbirth	0.0091	0.0039	0.32	
Non-endogamous first childbirth	-0.0246	0.0076	0.47	
Any first childbirth	-0.0196	0.0079	0.62	
Men				717
Endogamous first childbirth	0.0021	0.0043	0.41	
Non-endogamous first childbirth	0.0040	0.0070	0.46	
Any first childbirth	0.0076	0.0080	0.55	

Notes: OLS estimates with country by graduation year and field-of-study fixed effects included.

Figure 6: Effects of Share of Women in Group on the Share of Non-Tertiary Parental Partners (as Opposed to Tertiary Partners) in Non-Endogamous Childbirth Conditional on Country-Year and Field-of-Study Fixed Effects

Note: 'High aggregate share of women' countries are those where the share of women on all college graduates is above 57%. Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted together with the non-parametrically estimated effects.

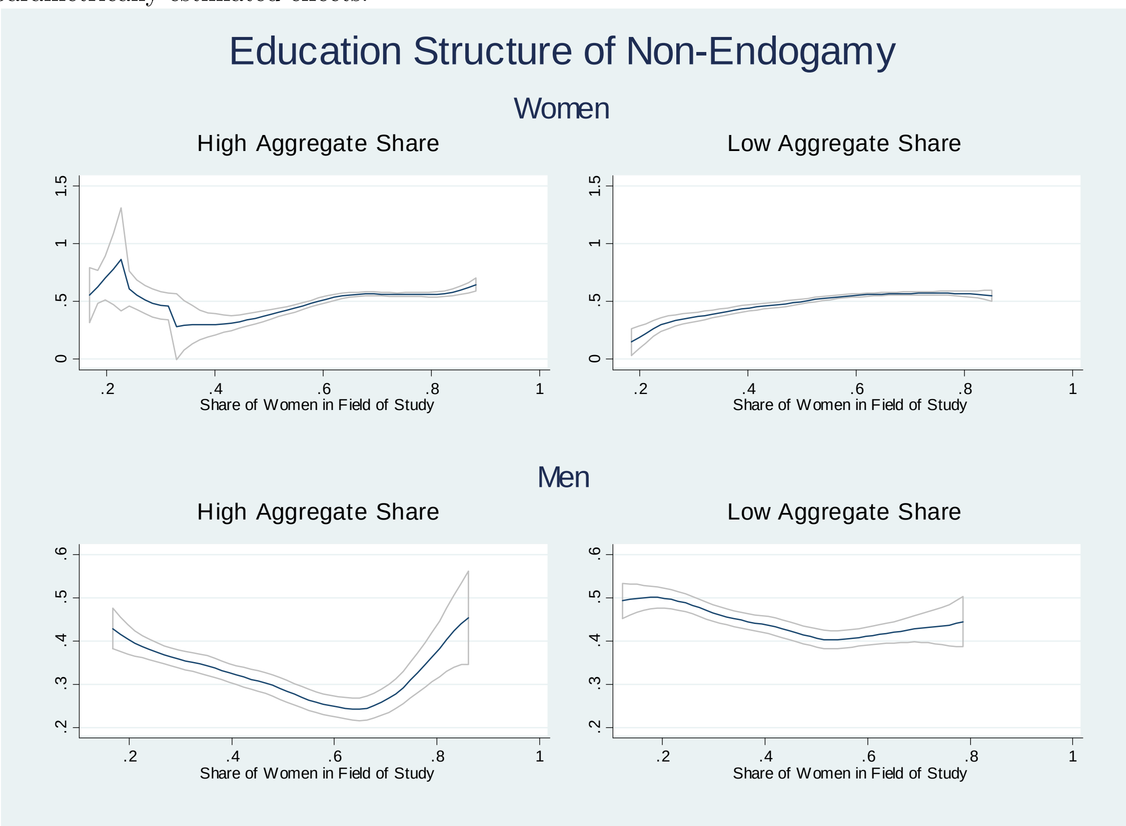


Figure 7: 2010-2000 Change in Share of Women and Total Number of Graduates by Country

The percentage-point change in the share of women among graduates against the change in the logarithm of total graduates between 2010 (2009 in BE, FR, PT, SI and 2008 in IT) and 2000 (1999 in IE, IT, SI and 2001 in HU, UK).

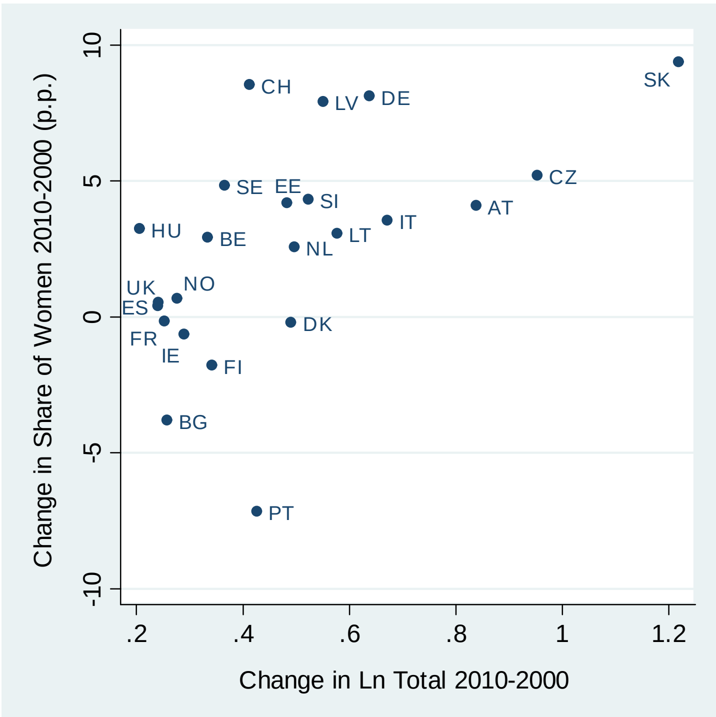


Figure 8: 2010-2000 Change in Share of Women and Total Number of Graduates by Field

Note: The percentage-point change in the share of women among graduates against the change in the logarithm of total graduates between 2010 and 2000 for the 23 countries (and year exceptions) of Fig 7. The relative size of the circles corresponds to the field-specific sum of graduates across these countries in 2000.

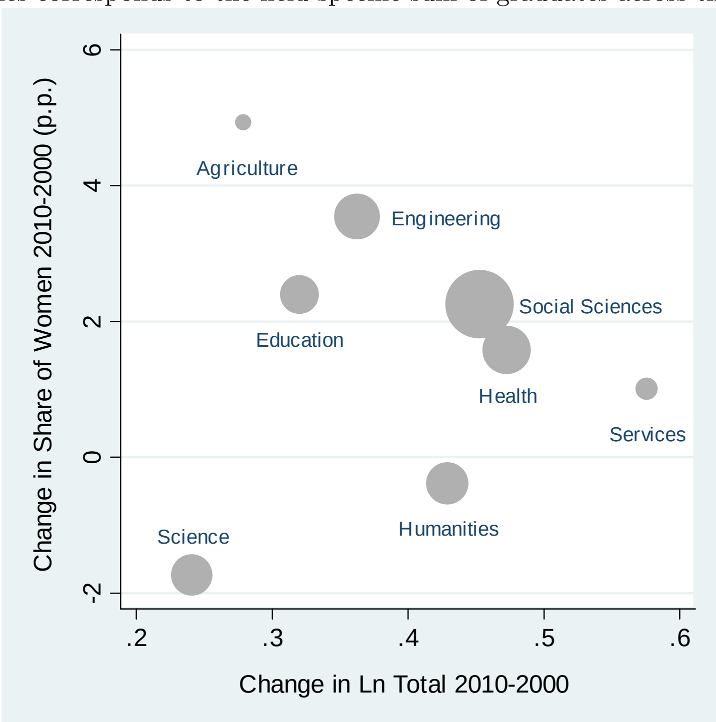


Figure 9: Effects of Share of Women in Group on Fertility by Type Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 5 or 15 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted.

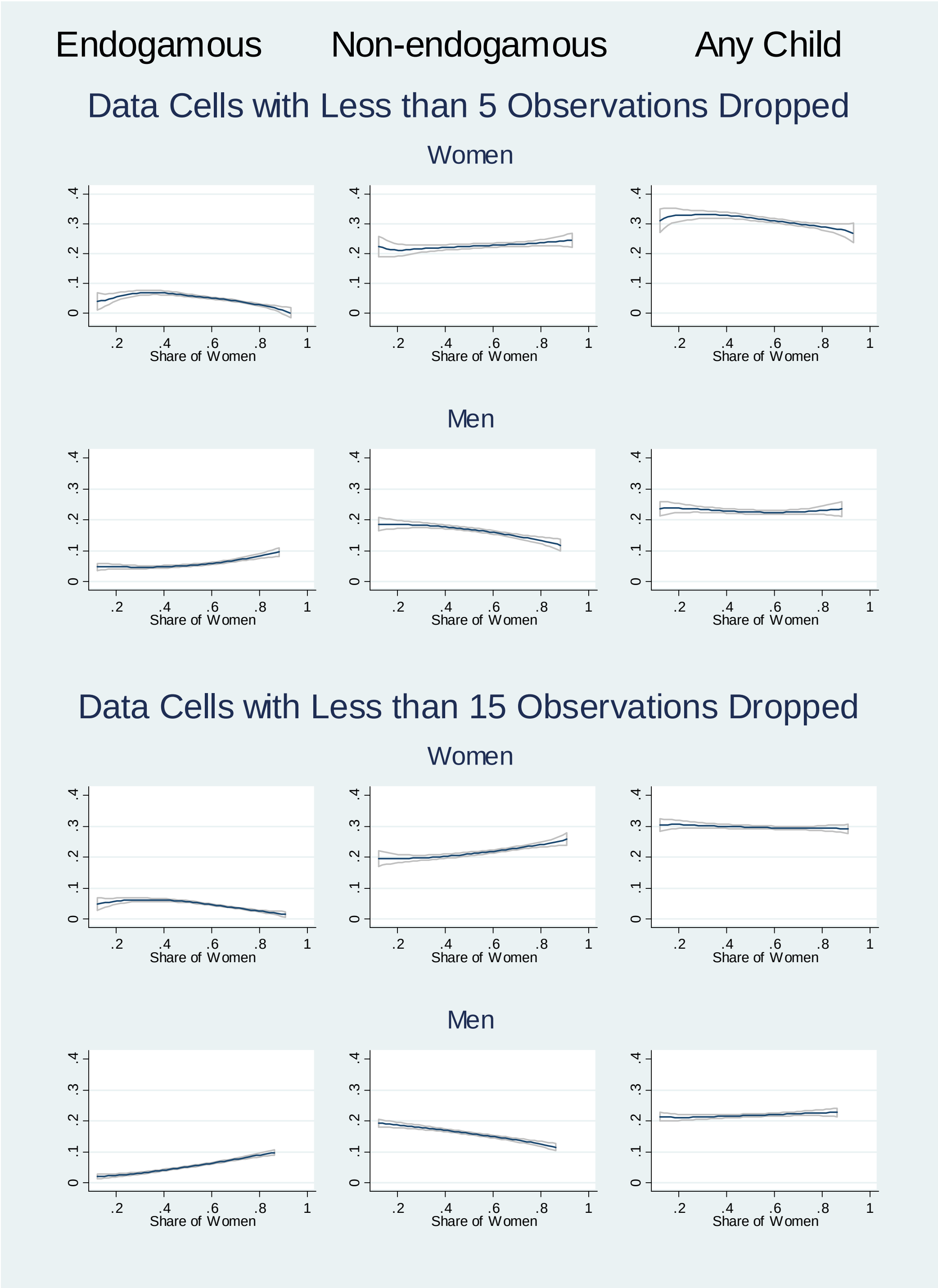


Figure 10: Effects of Share of Women in Group on Fertility by Type Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted.

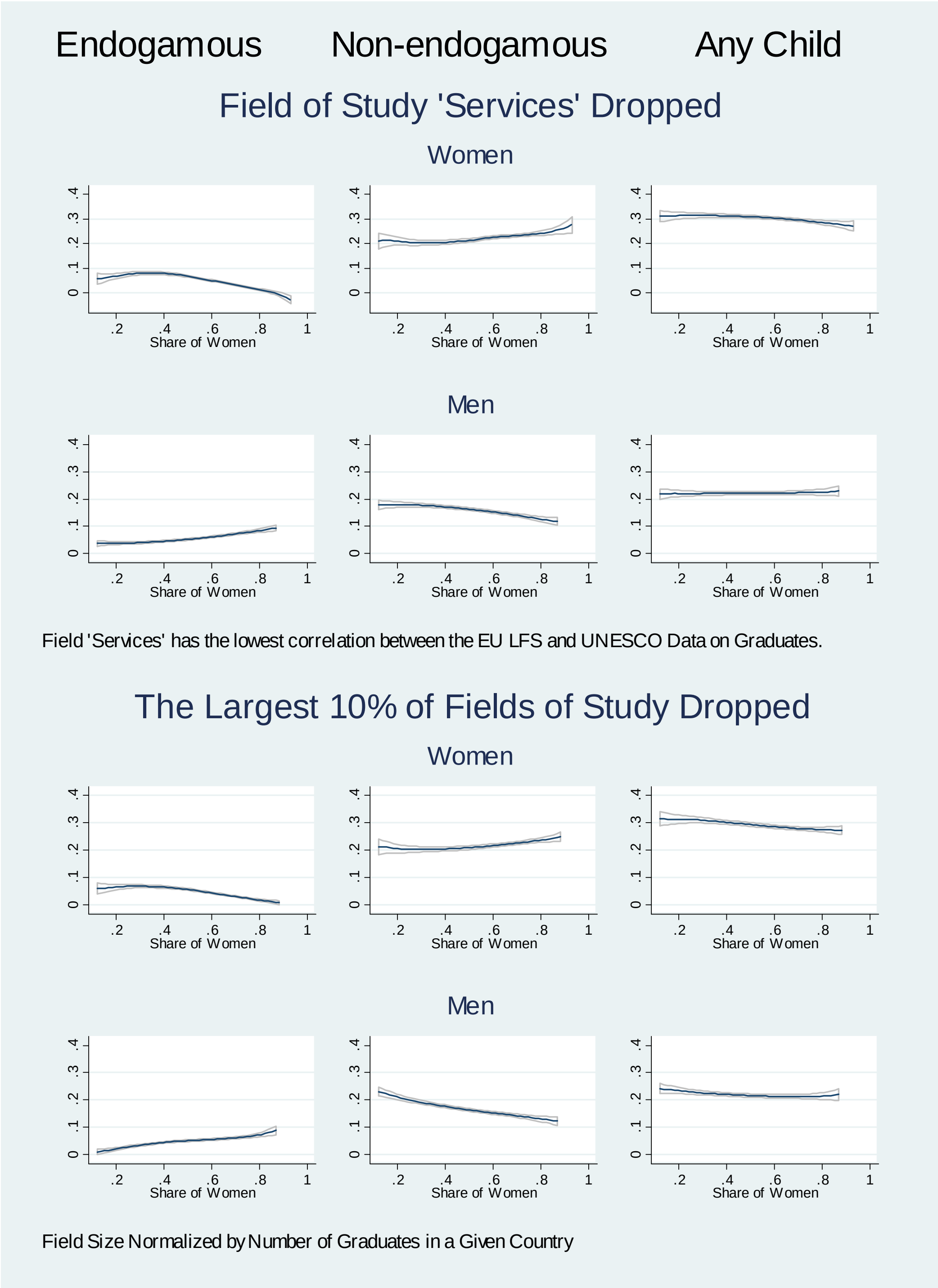


Figure 11: Effects of Share of Women in Group on Fertility by Type Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to peer groups as defined below. 95% confidence intervals are plotted.

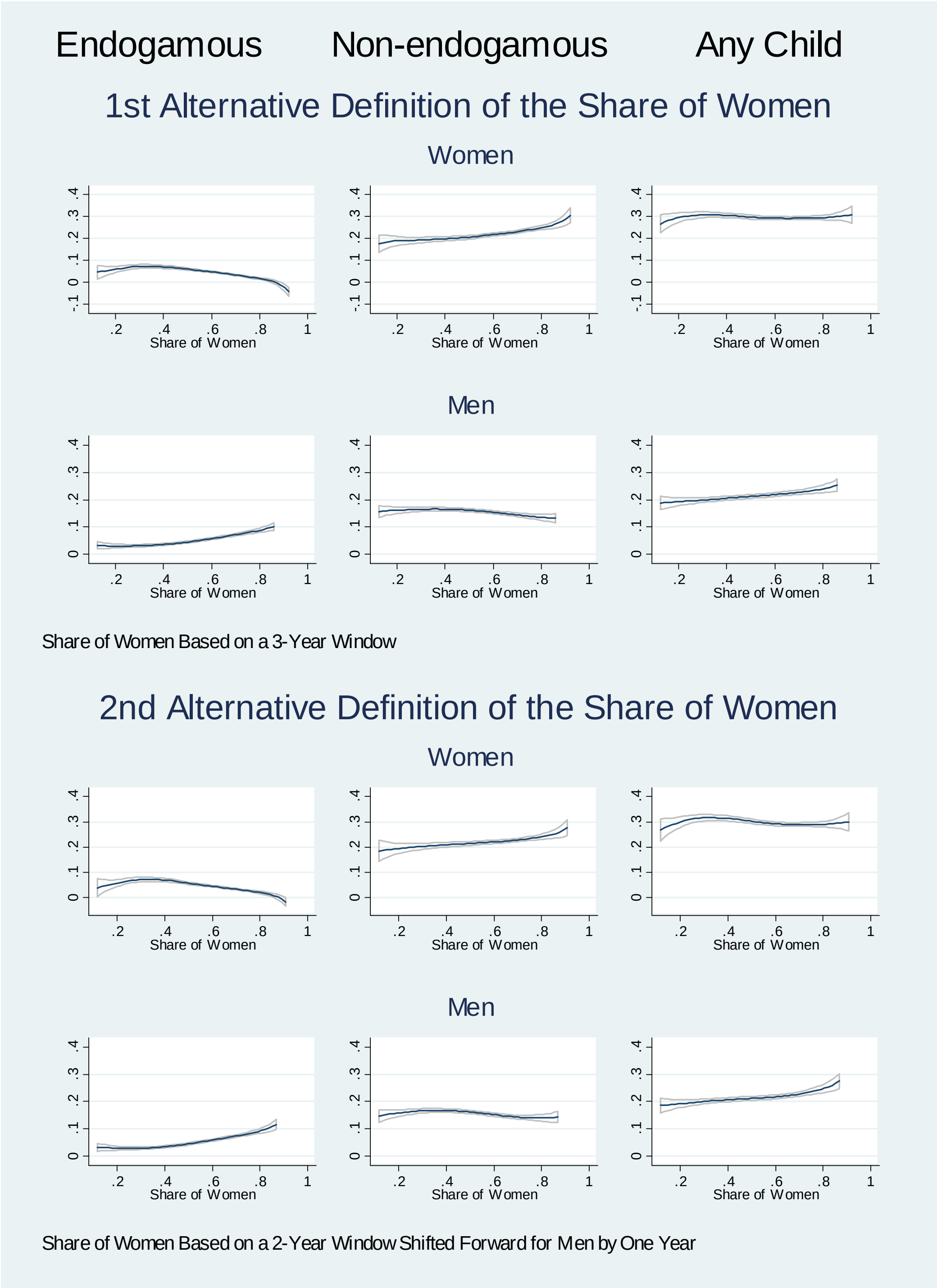


Figure 12: Effects of Share of Women in Group on Fertility by Type Conditional on Country-Field-of-Study and Year Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. Countries (three for women and five for men) with average annual fertility change exceeding 1.4 of a percentage point are dropped. 95% confidence intervals are plotted.

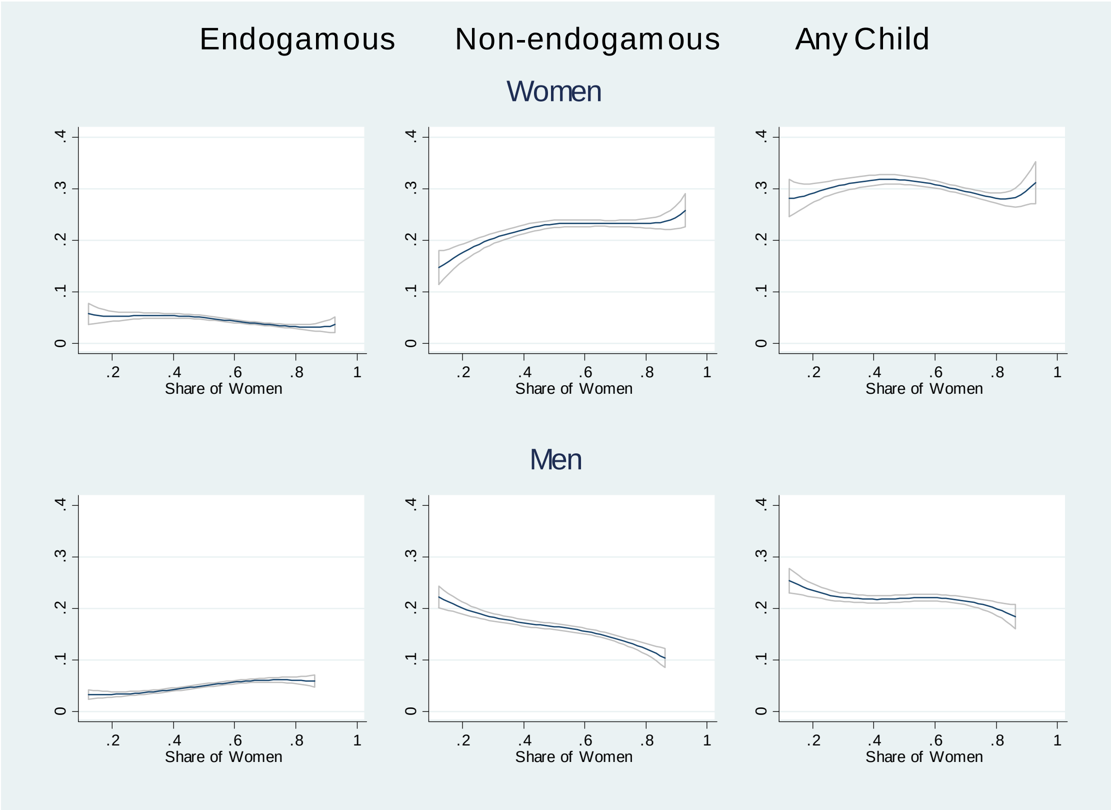


Figure 13: Effects of Share of Women in Group on Marriage/Cohabitation by Type Conditional on Country-Year and Field-of-Study Fixed Effects

Note: Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted together with the non-parametrically estimated effects.

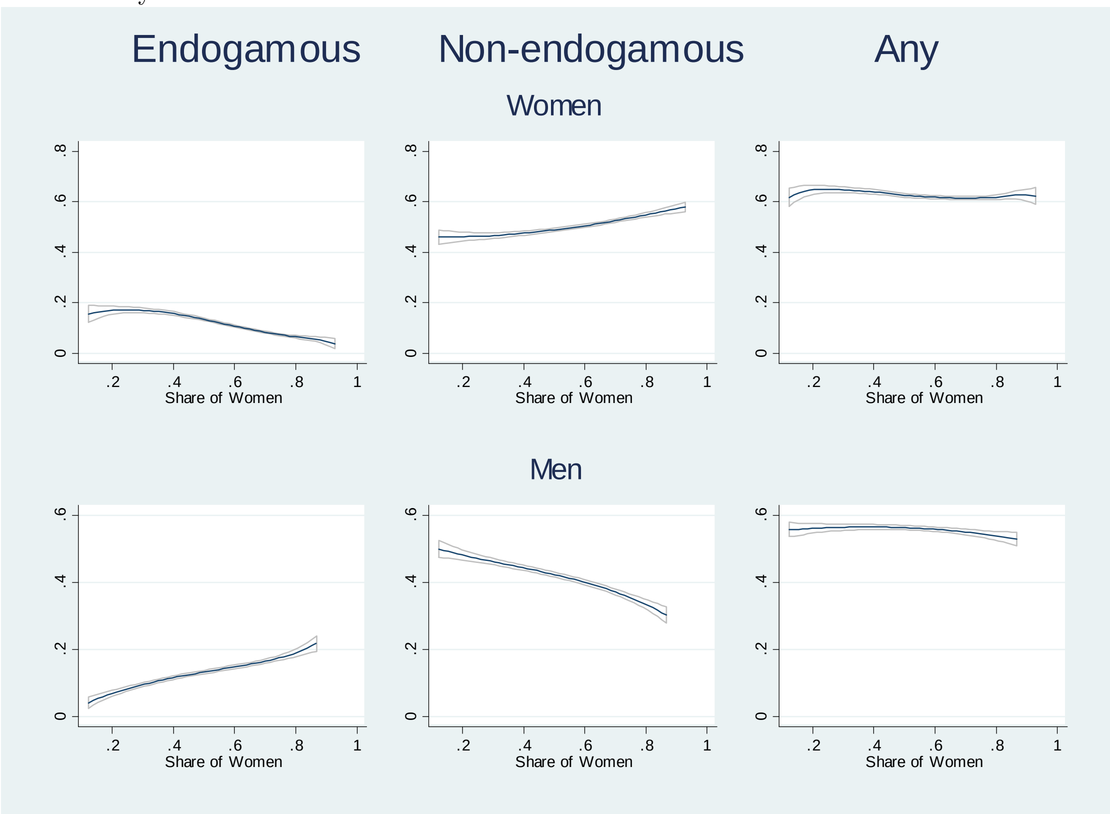
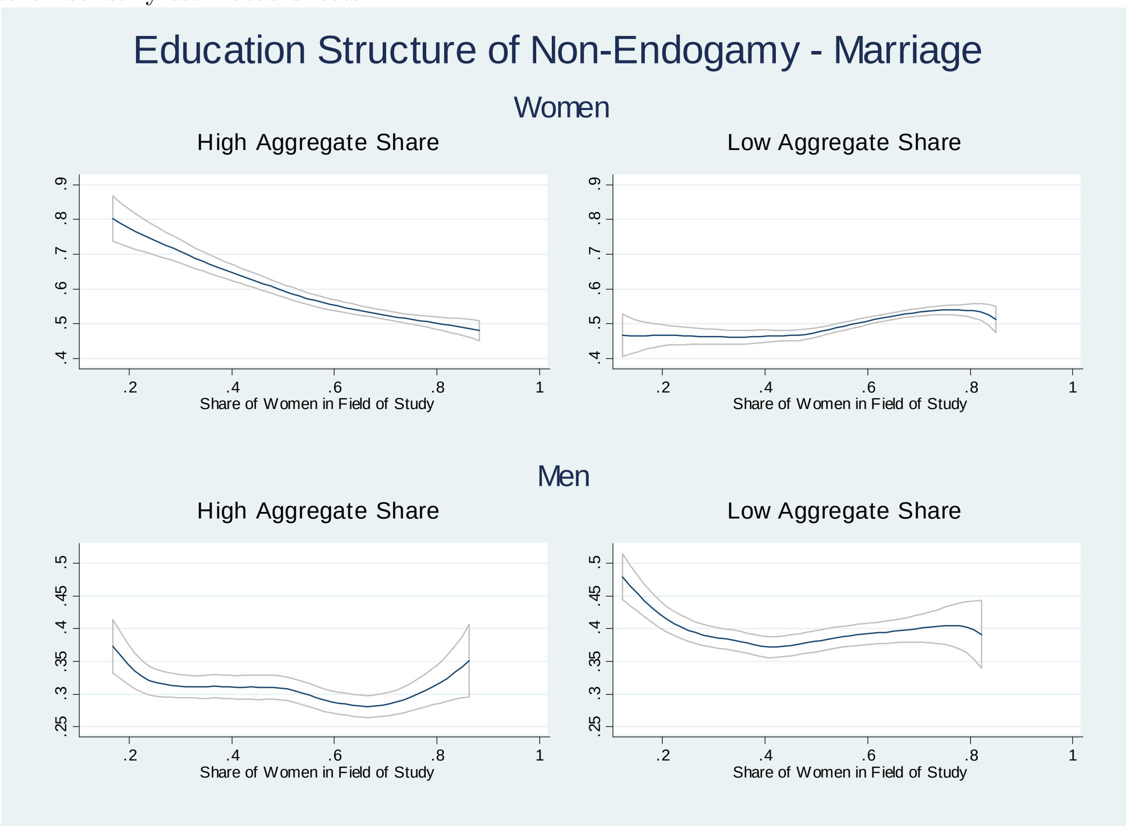


Figure 14: Effects of Share of Women in Group on the Share of Non-Tertiary Partners (as Opposed to Tertiary Partners) in Non-Endogamous Marriage/Cohabitation Conditional on Country-Year and Field-of-Study Fixed Effects

Note: 'High aggregate share of women' countries are those where the share of women on all college graduates is above 57%. Based on groups (field-of-study by country by year) with at least 10 individuals. The share of women corresponds to one's year of graduation. 95% confidence intervals are plotted together with the non-parametrically estimated effects.



Field-of-Study Homogamy

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March 2015

Abstract

This paper reports evidence on the strong tendency of college educated to match to partners who graduated in the same field of study—a dimension of assortative matching that has been overlooked thus far. Specifically, we employ Labor Force Survey data covering most EU countries to measure the extent of field-of-study homogamy in prevailing marriage and parental couples within several years of graduation. We also track the potential for field-of-study homogamy generated by the changing gender composition of higher education in Europe since 1998. Finally, to shed light on the underlying sources of field-of-study homogamy, we relate variation in the availability of homogamous partners in one's field of study in college to the extent of homogamous matching between college and high-school graduates across multiple marriage markets.

JEL Codes: I23, J13, J16

Keywords: Homogamy. Field-of-Study Gender Segregation, Tertiary Graduates, Marriage and Cohabitation, Fertility

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1 Introduction

Positive assortative mating is a central feature of marriage markets and subject of much research in evolutionary psychology, economics, sociology, and demography.[1] Educational homogamy—the tendency to match based on one's level of education—has received particular attention in the literature (e.g., Pencavel, 1998; Blossfeld, 2009) since it drives marriage returns to education (Goldin, 1997; Chiappori, et al., 2009) and affects inequality (Fernández, et al., 2005; Schwartz, 2013). Educational homogamy has increased since the 1970s (Siow, 2015) and is particularly strong among college graduates (Schwartz and Mare, 2005; Bredemeier and Juessen, 2013). Further, the rising marriage return to college for women (Ge, 2011; Chiappori et al., 2015) may help explain why women now represent the majority of college graduates across the developed world (Goldin, 2006; Becker, et al., 2010). A related, smaller body of work focuses on the tendency to match within occupations (Hout, 1982; Kalmijn, 1994; Mansour and McKinnish, 2014; McClendon et al., 2014).

The burgeoning literature on assortative matching has thus far ignored one potentially important dimension: matching on the field of study. This is again particularly relevant for college educated, for whom differences in wage returns across fields of study can be as large as the college wage premium (Kirkebøen et al., 2014), and where field-of-study choices have been linked to fertility (van Bavel, 2010). In this paper, we provide the first available estimates of the extent to which college graduates of each gender match into marriage/cohabitation and parental couples across fields of study. Since 2003, European Labor Force Surveys distinguish eight broad fields of study for each respondent and thus allow us to document field-of-study homogamy (hereafter FSH) trends for couples in prevailing marriages/cohabitations.[2]

[1] Schwartz (2013) provides a recent survey of the sociology and demography literature. Belot and Francesconi (2013) offer an extensive set of references to the theoretical work in economics on search and matching as well as to the evolutionary psychology literature studying assortative mating preferences.

[2] We thus capture matching patterns of newlyweds combined with the ramifications of separation patterns. Schwartz and Mare (2005) study educational homogamy based on prevailing marriages, arguing that these are relevenat for inequality and child-environment considerations. Schwartz and Han (2014) and Van Kammen

Specifically, the cross-sectional data allow us to track the entire post-college evolution of FSH for graduation cohorts starting in 2003; for earlier graduation cohorts, we map FSH patterns of prevailing marriages/cohabitations as of 2003 to 2012. For those graduating after 1998, we also provide evidence on homogamous fertility, defined as child births to couples from the same field of study occurring within five years of graduation. In most of our descriptive analysis, we focus on matches where both partners are college graduates, but we also study FSH patterns for college graduates matched to high-school graduates. In short, we measure FSH from the perspective of sampled college-educated respondents, separately by gender.[3]

During the period we study, the representation of women on college graduates was increasing in most EU countries and at different rates in different fields of study, implying large changes in the potential extent of FSH among college graduates. Our descriptive analysis provides a coherent picture of this development by tracking (i) a measure of FSH among matched college graduates that is free of supply effects (marginal distribution shifts), (ii) a measure of homogamy potential (a gender segregation index) based on the marginal distributions of *potential* partners (i.e., college graduates) across fields of study, and (iii) a measure of how well the potential for homogamy implied by the changing gender composition of tertiary education is used in observed matches. We also estimate homogamy parameters for two types of matching functions: the log-linear model (used by, e.g., Schwartz and Mare, 2005), which abstracts from supply effects, and the Choo and Siow (2006) model, which allows for supply as well as substitution effects across fields of study.

After presenting the extent of FSH across EU countries and over time, we turn attention to its underlying sources. In a matching market, positive sorting can arise as a result of preferences or it can correspond to costs of partner search being lower within groups sharing a common attribute. Existing evidence on educational homogamy is consistent with both channels playing an important role. The evidence on same-education-level preferences comes

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and Adams (2014) study marriage separations for educational and occupational homogamy, respectively.

[3]The use of LFS data for the purpose of studying matching as well as the homogamy dimension we measure both appear to be novel in the literature.

mainly from on-line dating or specific marriage markets;[4] we know of no direct evidence on same-field-of-study preferences. It is well established that search costs (meeting opportunities) play an important role for matching.[5] In particular, recent work focuses on the role of schools in structuring marriage markets and supporting educational homogamy (Blossfeld and Timm, 2003; Nielsen and Svarer, 2009; Kaufmann et al., 2013). Clearly, the chances to match to an equally educated partner are higher for those who meet daily within the same school and the availability of potential partners in the school or program drives the matching potential based on such low costs of meeting a potential partner. Kaufmann et al. (2013) use a regression discontinuity approach to shed light on the university-as-meeting-place matching mechanism. They show that being admitted to a particular study program increases the chances of marrying within that program and its university. But they also imply that quantitatively more important for matching is the effect that attending a particular university has on social networks that individuals access on the marriage market. Our analysis is based on country-wide groups of graduates in the same field of study and therefore asks about the combined channels of meeting potential partners in a study program and in market-wide social networks linked to one's field of study.[6]

There are large differences in meeting opportunities across these field-of-study groups

[4] Partner search costs are minimized in on-line dating, which is why it has been used to elucidate assortative mating preferences by, e.g., Hitsch, Hortacsu and Ariely (2010). Bellot and Francesconi (2013) find that in speed dating, both genders prefer partners of similar education. Chiappori et al. (2015) estimate a structural model off US marriage data to imply that preference for assortative matching by education among highly educated has increased significantly in the recent past. Bruze (2011) shows that Hollywood stars, whose wages do not depend on education, also match on education; this may suggest that educational endogamy is based in some part on preferences for marrying similarly educated partners.

[5] For example, Bellot and Francesconi (2013) highlight the importance of the composition of the participant pool at speed dating events in explaining patterns of dating proposals and matches. Hitsch et al. (2010) also suggest search frictions may be important for educational homogamy.

[6] Using a similar approach, McClendon et al. (2014) rely on US-wide measures of occupational education to ask how marriage market outcomes differ across occupations based on the occupation-specific share of college graduates.

as women continue to be unevenly represented across college fields of study (Charles and Bradley, 2009; Bičáková and Jurajda, 2014). This allows us to ask whether college graduates who face a limited pool of potential partners in their field of study in college are relatively more likely to accept as partners high-school graduates from the same field of study or college graduates from other fields of study.[7] There is much empirical evidence suggesting that favorable sex ratios lead to higher quality partners, i.e., make one less likely to 'marry down'[8] If same-field preferences are strong, college graduates will be willing to accept lower education of same-field spouses, particularly when there is few potential spouses available in their field in college.[9] Even if the same-education-level preference dominates the same-field-of-study preference, we would expect to observe a tendency towards FSH for women in countries, where there are relatively few men available on the aggregate college-graduate market (after homogamy pairs based on both education level and field are formed).[10] Throughout this analysis, we exploit the changing gender composition of field-of-study groups to condition on all time-constant determinants at the field-of-study level.

[7] To accurately measure the availability of potential partners within one's field of study, we employ 1998-2010 population statistics on the gender composition of tertiary education.

[8] See, e.g., Angrist (2002) and Abramitzky et al. (2011), who study ethnically and regionally defined marriage markets, respectively.

[9] Chiappori et al. (2010) provide a two-dimensional matching model with gender imbalances that motivates this question. See Mansour and McKinnish (2014) for a similar exercise focused on occupational matching. Their analysis, based on couples where both partners report an occupation, suggest that women accept lower wages of same-occupation husbands in occupations where men are plentiful. The timing of occupation versus partner choice is not clear in their data.

[10] In contrast, in fields and countries where there are plentiful potential partners available in college, a tendency towards FSH between college- and high-school-educated spouses could be observed only if the preference towards same-level-educated is weaker than the preference for same-field-educated and if search costs within field of study are substantially smaller than across, such that a college graduate would be willing to accept lower education of same-field spouse in order to benefit from such low costs.

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