Skills, Parental Sorting, and Child Inequality*

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Abstract

This paper studies the consequences of educational expansion on marital sorting, intergenerational mobility, and inequality. We first formulate a simple skill and education model to explain how better access to higher education leads to stronger assortative mating on skills of parents and a more polarized skill and earnings distribution of children. Using Swedish registry data, we provide evidence that more skilled students increasingly enrolled in college and ended up with more skilled partners and more skilled children. Finally, we provide causal evidence on the impact of college education on marital skill sorting and intergenerational skill transmission. Exploiting college openings and expansions as an exogenous source of spatial variation in college access, we find that better access increases both skill sorting in couples and skill and earnings inequality among their children. All findings are consistent with the view that rising earnings inequality is, at least in part, supply driven by rising skill inequality.

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1 Introduction

Two postwar trends have fundamentally changed labor markets throughout the Western world: a rising supply of college graduates, followed by rising earnings inequality. The leading explanation that reconciles the inequality surge with expanding college rates is skill-biased technical change. According to this explanation, rising inequality is demand driven; that is, new production technologies (encouraged by the increased supply of college-educated workers) shift relative demand in favor of skilled workers, which in turn leads to a higher skill premium and a more polarized earnings distribution. While skill-biased technical change, with ample empirical support (Katz and Autor, 1999; Goldin and Katz, 2009; Acemoglu and Autor, 2011), is a plausible explanation for increased inequality, the existing evidence is certainly not ironclad and leaves the door open for alternative explanations (Card and DiNardo, 2002).

In this paper, we propose a supply-side explanation for the rise in inequality. We connect expanding college rates to rising inequality through reinforced skill sorting in the marriage market and intergenerational skill transmission. The idea is quite simple; that is, we treat the rise in college attendance as an expanding marriage market for skilled men and women. If improved access to college increases the number of skilled men and women going to college, we should see stronger skill sorting among marriage partners because skilled men and women can more easily meet each other. In the context of intergenerational skill transfers, reinforced sorting on skills (enhanced by higher college attendance rates) should then also widen the skill distribution of individuals in the next generation, leading to a more dispersed earnings distribution.

To evaluate our supply-side explanation, we explore how educational expansion observed in Sweden in the 60s, 70s, and 80s affected skill sorting of spouses and the skill and earnings distribution of their children. We first formulate a simple theoretical model to explain how improved access to higher education leads to stronger skill sorting of partners and consequently causes a more polarized skill and earnings distribution of their children. We then use Swedish registry data on cognitive skills and education to show that more skilled students increasingly enrolled in college and ended up with more skilled partners and more skilled children. Finally, our study provides causal evidence on the impact of rising college attendance on skill sorting of parents and intergenerational skill transmission. In particular, we exploit college openings and expansions as exogenous source of spatial variation in college access and show that improved college access increases both skill sorting in couples and skill and earnings inequality among their children. These findings suggest that rising inequality is, at least in part, supply driven due to rising skill inequality.

Our paper connects three related literatures. A first, steadily growing, literature focuses on trends in positive assortative mating. Several empirical papers document how partners become increasingly more similar in terms of education since the 1940s (see e.g. Mare, 1991; Schwartz and Mare, 2005; Eika et al., 2019). There are a number of explanations that predict this rise in sorting; among these are rising skill returns, technological progress, and expanding marriage markets for skilled men and women. Fernández et al. (2005) claim that rising skill returns make skills also more valuable in the marriage market. Greenwood et al. (2016) argue that non-monetary considerations of marriage are increasingly important because home production has become less time consuming (due to improved technologies) and women have become less financially dependent (due to better education and higher labor force participation). Our paper takes a marriage market perspective and argues that higher assortative mating is, at least in part, driven by rising college attendance rates. If skilled men and women find it easier to meet their marriage partners in college, rising attendance rates can also lead to stronger assortative mating. Recent empirical studies confirm, like we do, the importance of colleges as marriage markets.[1]

The second literature focuses on the intergenerational effects of parental education. The related papers center around different instrumental variables to capture variation in parental education that is unrelated to the preferences and abilities of parents. While most papers exploit compulsory schooling reforms to identify parental effects (Chevalier, 2004; Black et al., 2005; Oreopoulos et al., 2006; Holmlund et al., 2011), fewer papers consider intergenerational transfers among higher educated parents. The studies closest to ours are Kaufmann et al. (2015) and Suhonen and Karhunen (2019). Using elite college admission thresholds in Chile, Kaufmann et al. (2015) show that attending elite colleges raises partner and child quality (as measured by test score outcomes). Suhonen and Karhunen (2019) use college openings and expansions in Finland as instrument and find that college graduates marry better educated partners and have

[1] Artmann et al. (2018) estimate how field-of-study choices impact partner choices using admission lotteries for four oversubscribed fields of study in the Netherlands. They find that lottery winners are much more likely to marry someone from the same field and conclude that fields of study operate as marriage markets. Kirkebøen et al. (2021) reach the same conclusion using admission thresholds into different institutions and fields of study in Norway; that is, institutions and fields of study significantly matter for partner choices.

better educated children.[2] This is in line with what we find. None of these studies examines how increased college access among parents impacts inequality in children's skills and earnings, however.

The last literature we connect to links assortative mating to earnings inequality. While most of the related papers study the impact of higher assortative mating on inequality within the same generation (Fernández et al., 2005; Greenwood et al., 2014; Eika et al., 2019), only a few studies take an intergenerational perspective and examine how educational sorting in one generation affects earnings inequality in the next generation (Kremer, 1997; Fernández and Rogerson, 2001). The results of these studies are divided. Kremer (1997) argues, like we do, that sorting likely improves the economic prospects for children in rich families while worsening them for children in poor families. Exploring US data up to the late 1980s, however, he does not find much evidence that stronger educational sorting among parents leads to greater earnings inequality among children. Kremer (1997) concludes that, as long as parental characteristics are only moderately heritable (such as education), changes in sorting cannot impact inequality in future generations in a meaningful way. Fernández and Rogerson (2001) provide an extended model where inequality among children depends on the extent to which parents sort on college education, as well as on the extent to which college-educated parents have fewer children, and face fewer borrowing constraints. When they calibrate their model to US data, they find that increased parental sorting significantly increases earnings inequality of children. Our paper takes a different route; that is, we explicitly focus on skills (which are arguably more heritable than education), treat college as a marriage market for skilled men and women, and test whether exogenous college openings and expansions led to stronger skill sorting among parents and more skill and earnings inequality among children.

The remainder of this paper proceeds as follows. Section 2 motivates the relevance of our model by illustrating long-run trends in education, assortative mating and earnings for the US and Sweden. Section 3 outlines the theoretical framework and discusses its assumptions and implications. Section 4 describes the data which we use in our analysis, presents our main results on postwar trends in education, skills, and earnings, and estimates the key parameters of our model. Section 5 backs up our previous findings

[2] Other empirical studies on the intergenerational effects of college education are Maurin and McNally (2008) and Carneiro et al. (2013). With instruments that are very different (county-by-year variation in tuition fees and college location in the United States versus year-by-year variation in the quality of entry exams in French universities), these studies find that parental college education matters in lowering repetition probabilities of children in high school.

with estimates on the causal effect of improved college access on martial sorting and intergenerational transmission. Finally, Section 6 concludes.

2 Descriptive evidence

The three key macroeconomic trends central to this study are educational expansion, persistent assortative mating, and rising earnings inequality. Before we discuss the underlying mechanisms, we first document these trends for Sweden and the United States. For trends in Sweden, we use administrative records which are available for the full population. For the United States, we use nationally representative survey data from the Panel Study of Income Dynamics (PSID).[3]

Figure 2a plots long-term trends in college attendance for men and women born between 1900 and 1980. In Sweden, we see a huge rise in attendance rates starting from 5 percent to 50 percent for the most recent cohorts. Initially fewer women attend college than men, but this pattern reverses over time. In the United States, there are similar trends, but also some differences. Compared to Sweden, college attendance rates are somewhat higher, and female students begin to outnumber male students about ten years later.

Figure 2b plots trends in assortative mating of spouses measured as the share of spouses who both attended college (by cohort of men). We compare the observed shares to the expected shares under random matching of spouses, where the latter corresponds to the product of the college attendance rates of women and men. In both countries, spouses match much more often on college education than random matching predicts. Moreover, differences appear to be stable across cohorts. The ratio of observed to random matches declines over time but still amounts to about 1.5 for the youngest cohorts.

Figure 2c plots trends in earnings inequality. Observations are restricted to men aged 35 to 55. Inequality is measured in terms of percentile ratios. The ratios for Sweden are calculated based on real annual total earnings before taxes.[4] Percentile ratios for the United States are based on real hourly earnings before taxes. As shown in the graphs, we see a steady increase in earnings dispersion in both Sweden and the

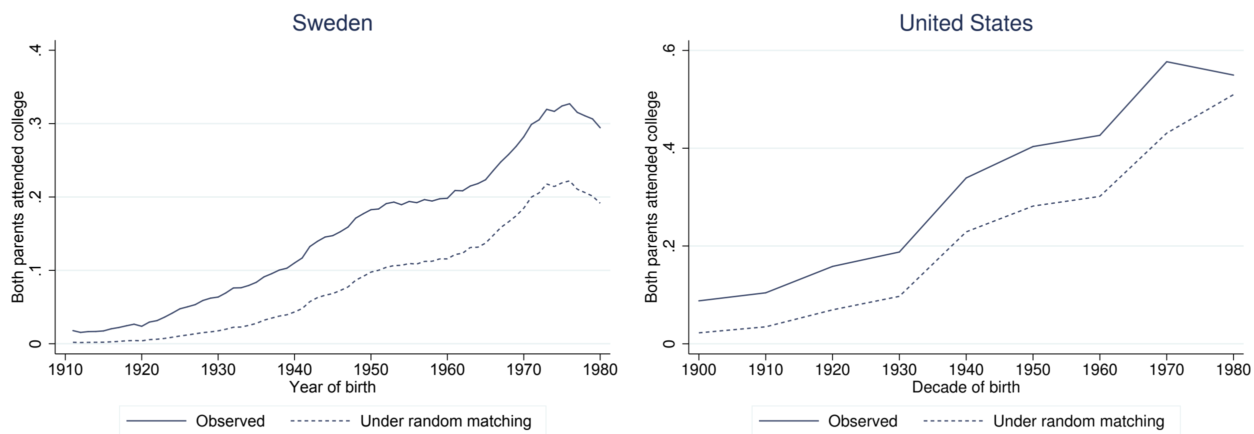
[3] Observations are weighted using household sample weights to account for sample attrition over time.

[4] All earnings are adjusted to 2014 prices. We exclude observations with very low income who presumably did not work throughout the entire year.

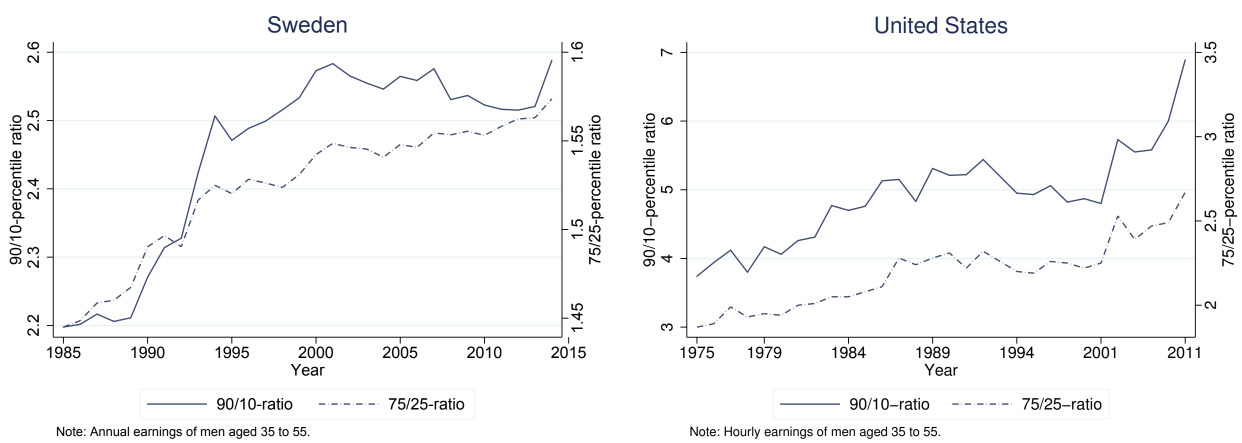
United States. Again, there are also some differences. Compared to Sweden, overall percentile ratios are much higher and trends are steeper in the US, indicating that there is much more inequality, which also grows at a faster rate.

Figure 1: Trends in college education, marriage sorting, and earnings inequality in Sweden (left) and the US (right)

(a) College attendance by gender



(b) Match in college attendance of spouses



(c) Earnings dispersion

Sweden and the United States are very different countries in terms of education (educational costs) and labor market institutions (tax incentives, returns to education and skills). Trends in higher education, marriage sorting and earnings inequality, however, are remarkably similar. We therefore think that the results of our study can also be generalized to other developed countries.

3 Theoretical model

3.1 Skills, education and earnings

To examine the intergenerational effects of educational expansion on earnings inequality, we propose a simple theoretical model that links skills to college attendance. For ease of exposition, we consider a two generations model. Skills of women and their (male) spouses are denoted by a_f and a_m, respectively. Both are drawn from a skill distribution $F(\cdot)$ with mean μ and variance σ^2. Assuming that skill transfers from the mother and the father are equally important, we define the skills of children a_c as a linear combination of the parents' skills and a random skill component ε:

$$a_c = \eta \frac{a_f + a_m}{2} + (1 - \eta)\epsilon.$$

Parameter η measures the extent to which skills are linked across generations. The random component ε has expected value μ to ensure that the expected skill level is the same across generations. The variance of a_c is then given by

$$\mathrm{var}(a_c) = \frac{\eta^2}{4}[\mathrm{var}(a_f) + \mathrm{var}(a_m) + 2\mathrm{cov}(a_f, a_m)] + (1 - \eta)^2 \mathrm{var}(\epsilon).$$

If mating of parents is random ($\mathrm{cov}(a_f, a_m) = 0$), the skill distribution remains stable over generations and the variance of the random component becomes $\mathrm{var}(\varepsilon) = (1 - \eta^2/2)/(1 - \eta)^2\sigma^2$.[5] If there is positive assortative mating on skills ($\mathrm{cov}(a_f, a_m) > 0$), the variance in skills of children is higher than that of their parents.

Next, we focus on parents and discuss how changes in college attendance can cause stronger assortative mating on skills. Variable e takes value one if an individual attends college and value zero otherwise. Individuals have sufficient skills to go to college as long

[5] Our model specification implies that, in case of random matching, at most 50% of the variance in children's skills are due to parents' skills. If η converges to 1, it is easy to see that $\eta^2/4(\mathrm{var}(a_f) + \mathrm{var}(a_m))/\mathrm{var}(a_c)$ equals 0.5.

as their skill level a is above some threshold $\bar{a}$. The latter is determined by academic requirements of college education, which we assume to remain unchanged over time. Not all individuals with sufficient skills ($a \geq \bar{a}$) actually attend college because there are other factors that influence the decision to attend college. We call these external factors education frictions, which may vary over time. Education frictions impose that only fractions p_f, p_m and p_c of women, their spouses and their children also attend college if they qualify. In our model, parameters p_f and p_m are the key policy parameters linking reduced frictions to the rise in college attendance, as documented in the previous section. We assume that education frictions decline for reasons unrelated to skills; among these are changing cultural norms in favor of college education, expanding colleges and new college openings.[6] Without loss of generalization, we write $p_m = p$ and $p_f = \alpha p$ with $0 < p < 1$ and $0 < \alpha < \frac{1}{p}$. If p increases, education frictions decline for both women and their spouses, while if α increases, education frictions only reduce for women. For women and their spouses, the share of college attendees is given by $q_f = \alpha p[1 - F(\bar{a})]$ and $q_m = p[1 - F(\bar{a})]$.

Skills and college education jointly determine earnings on the labor market. We define earnings as

$$y = (1 + \pi e)wa,$$

where labor market parameters w and π represent a uniform wage rate and a college premium. We assume that the wage rate and college premium are the same for women and men and the same for both generations. This earnings specification allows for complementarities between college education and skills; that is, the earnings differential between workers with and without college education is increasing in skills.

3.2 Assortative mating

We are particularly interested in how a reduction in education frictions of parents affects earnings inequality of children. Because earnings depend to a large extent on skills, the

[6] Such frictions are extensively discussed in the sociology literature, where increasing levels of schooling are partly attributed to changing attitudes towards education and better access to educational institutions (Schofer and Meyer, 2005). Because higher education used to be the privilege of a small elite in the past, many potential students did not consider college as a feasible career choice but rather followed role models in their social environment. When in the course of the 20th century new social norms promoted educational equality to foster economic success independent of social origin, these attitudes changed steadily and contributed to the increase in enrollment rates. Concurrently, the expansion of colleges and new college openings led to better access to educational institutions.

skill correlation between parents is crucial in explaining skill and earnings dispersion.[7] To model skill matching of parents, we consider a relatively simple matching function of men and women in which college attendance plays an important role as a marriage market. The marriage match parameter λ characterizes the relative likelihood that a college-educated man meets a college-educated woman. λ is defined between 0 and 1: if $\lambda = 1$, a college-educated man only meets college-educated women; if $\lambda = 0$, he only meets women without college education; and if $\lambda = 1/2$, he is equally likely to meet a woman with and without college education, which describes the case of random matching on the marriage market. The marriage match parameter may represent marriage frictions, marriage preferences, or both. A college-educated man then meets the following women, defined by $\lambda q_f + (1-\lambda)(1-q_f)$, from which he randomly chooses one to become his partner. As a result, the probability that a college-educated man matches with a college-educated woman is

$$\frac{\lambda q_f}{\lambda q_f + (1-\lambda)(1-q_f)}.$$

Multiplying this term by the share of college-educated men leads to the fraction of couples where both partners are college educated:

$$\pi_{11} = q_m \frac{\lambda q_f}{\lambda q_f + (1-\lambda)(1-q_f)}.$$

Due to supply constraints, π_{11} is bounded between $\max(0, q_m - (1-q_f))$ and $\min(q_f, q_m)$, meaning that λ is bounded between $\max(0, \frac{q_m-(1-q_f)}{q_f+q_m-(1-q_f)})$ and $\min(1, \frac{(1-q_f)}{(q_m-q_f)+(1-q_f)})$. Most likely λ is larger than $1/2$, which implies positive assortative mating on college education.

All individuals in the marriage market eventually match.[8] College-educated men who do not match with a college-educated woman consequently match with a woman without college education. The corresponding fraction is given by $\pi_{01} = q_f \frac{(1-\lambda)(1-q_f)}{\lambda q_f+(1-\lambda)(1-q_f)}$. Using the same argument, the fraction of couples where only women attended college is $\pi_{10} = q_f - q_m \frac{\lambda q_f}{\lambda q_f+(1-\lambda)(1-q_f)}$. The remaining fraction, $\pi_{00} = 1 - q_m - q_f + q_m \frac{\lambda q_f}{\lambda q_f+(1-\lambda)(1-q_f)}$, then describes the share of couples where none of the spouses went to college.

[7] We assume that the number of children per family is unrelated to skills or education of parents.

[8] Alternatively, we can introduce a second marriage match parameter describing how women meet men. If resulting matching shares do not align, some individuals remain single. This would cause more assortative mating in education among the matched couples.

3.3 Predictions

We use these fractions to derive the covariance of skills between women and their spouses, which is given by

$$\mathrm{cov}(a_f, a_m) = \frac{((\mu_1 - \mu_0)F(\bar{a}))^2}{(1-q_m)} \frac{(2\lambda - 1)q_f q_m}{\lambda q_f + (1-\lambda)(1-q_f)},$$

where $\mu_0 = \mathrm{E}[a_j | a_j \leq \bar{a}]$ and $\mu_1 = \mathrm{E}[a_j | a_j > \bar{a}]$ for $j = f, m$. This expression allows us to analyze the determinants of assortative mating in skills.

Proposition 1. *(a) If λ increases, then $\mathrm{cov}(a_f, a_m)$ increases. (b) If $\lambda > \frac{1}{2}$, then $\mathrm{cov}(a_f, a_m)$ increases in p and α.*

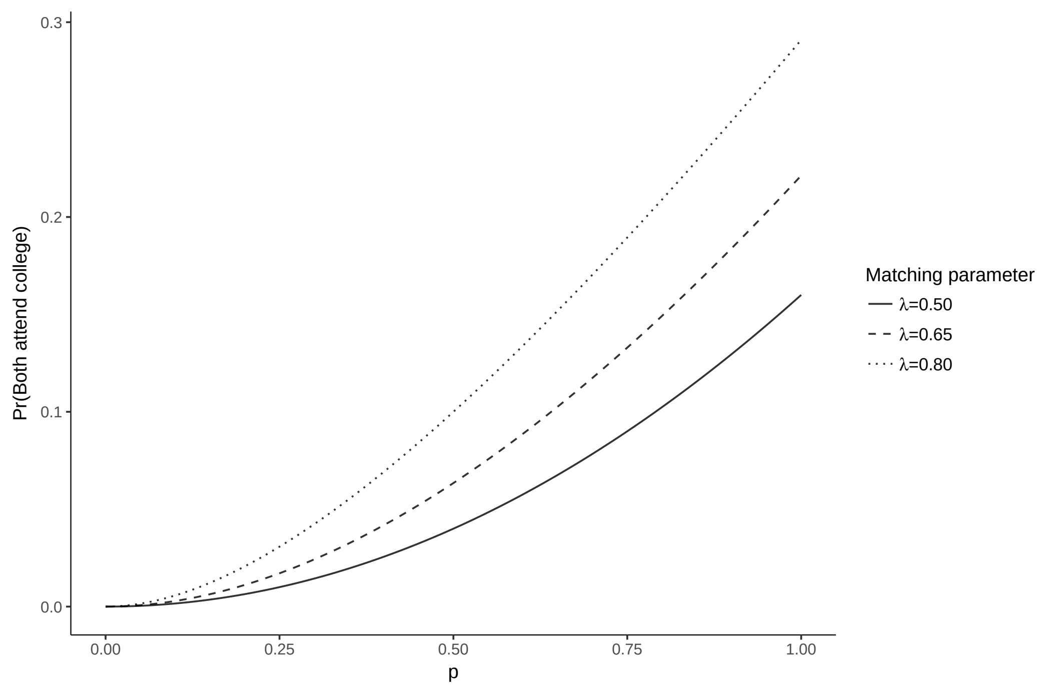
The proposition shows two results.[9] First, if the relative rate at which college-educated men meet college-educated women (compared to women without college education) increases, assortative mating as measured by the covariance of skills between partners becomes stronger. Second, if education frictions decline, there is a higher degree of assortative mating. Above we showed that the skill distribution widens over generations if there is positive assortative mating of parents. Together with Proposition 1, this implies that diminishing education frictions of parents increase dispersion in the children's skill distribution.

Our theoretical model is illustrated in Figures 2 and 3. Figure 2 plots the share of couples where both partners attended college as a function of friction parameter p. The solid line shows the case of random matching in the marriage market ($\lambda = 1/2$), while both other lines are associated to positive assortative mating. The share of couples with two college-educated partners increases monotonically in both λ and p, showing that reduced education frictions lead to more matches between college-educated individuals.

Figure 3 illustrates for different values of λ how the variance of children's earnings changes when education frictions diminish for their parents. If matching on the marriage market is random ($\lambda = 1/2$), the earnings distribution of children is unaffected by college education of their parents. However, if there is assortative mating on education, rising college attendance of parents due to lower frictions increases earnings inequality of children. For larger values of λ, the impact on earnings inequality of the next generation becomes stronger.

[9] The derivation of the covariance and the proofs of the proposition are shown in the Appendix.

Figure 2: Education frictions and assortative mating of spouses

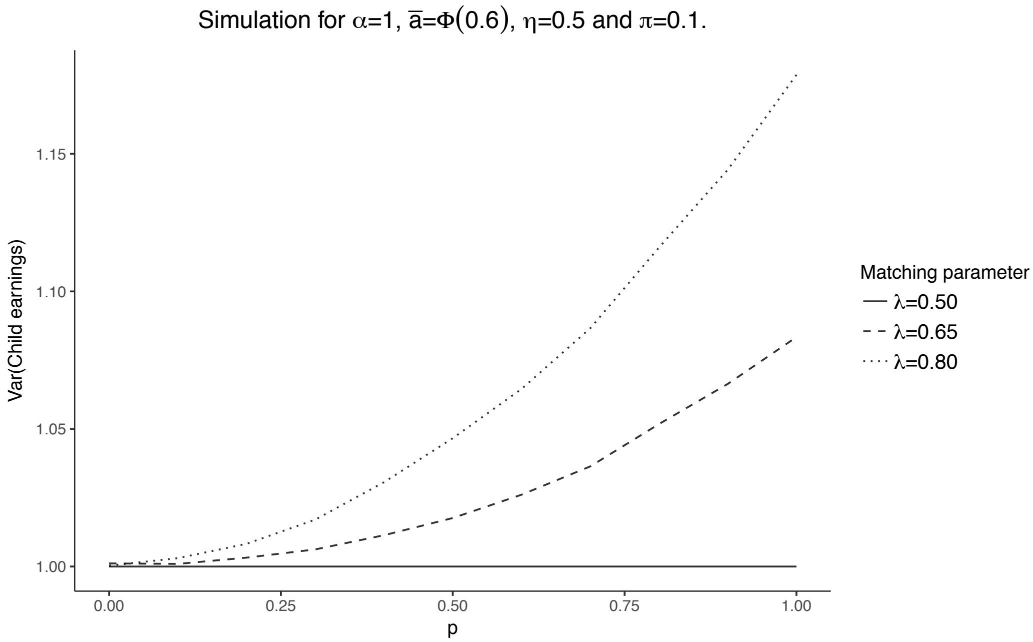


Note: The share of individuals above threshold $\overline{a}$ is 40%. α is set to 1.

Our theoretical model makes a few assumptions on the determinants of higher education and matching on the marriage market. We assume that rising college attendance rates for younger birth cohorts are the consequence of reduced education frictions, while entry thresholds on skills remain constant. We test this empirically in Section 4, where we also test whether marriage market parameter λ implies positive assortative mating on college education ($\lambda > 1/2$) and remains constant over time.

Furthermore, we provide empirical evidence on skill sorting of partners and the intergenerational transmission of skills. Our model predicts that women who attend college due to reduced education frictions are more likely to marry a high-skilled spouse and have therefore higher skilled children. We test these predictions using data on cognitive skills and exploiting exogenous variation in college attendance.

Figure 3: Education frictions and earnings dispersion of children



Note: Variance under random matching (λ=0.5) normalized to 1.

4 Empirical analysis

4.1 Data

Our empirical analysis requires data on skills, education, and earnings for women, their spouses, and their sons, covering multiple decades. For this purpose, we combine various administrative registers in Sweden. We use the military enlistment register for skill records, the education and tax registers for education and earnings records, and the population register for partner and children records, complemented with municipality-of-residence records.

Our primary measure of cognitive skills comes from military enlistments, which were compulsory for all Swedish men until 2010. Enlistment tests are taken at age 18 and are available for about 90 percent of all males. The total cognitive skill score represents an aggregated score from several subtests that measure verbal, logical, spatial and technical skills. Importantly, this cognitive skill score has been shown to strongly predict future labor market outcomes, such as wages, earnings and unemployment, in previous research (e.g., Lindqvist and Vestman, 2011; Edin et al., 2021).

Data on these raw scores are available for the years 1969 to 1994. In 1980, the test procedure underwent some minor revisions (see Grönqvist et al. (2017) for more details). We therefore convert the raw test scores into cohort-specific percentile ranks (divided by 100), which are more robust to test revisions. Since ranks are scale-invariant, we only have to assume that the relative position in a cohort did not change because of the revision. This follows the recent practice of using rank measures in intergenerational transmission studies (see, for instance, Dahl and DeLeire, 2008; Chetty et al., 2014).

There are two limitations of our skill measure. First, skill scores are not available for females. Instead we proxy the skills of women with the skill measure of their brothers. This reduces the sample to spouses who have at least one drafted brother during the period of observation, which corresponds to about 40 percent of all families. Because skills of siblings are not perfectly correlated, estimates of skill sorting (skill correlations between spouses) and intergenerational skill transmission (skill correlations between mothers and sons) based on the proxied skill measure are biased downward in our subsequent analysis. To assess the size of the bias, we can use the skill rank correlation between drafted brothers. Assuming similar skill rank correlations among same-sex and different-sex siblings, we conclude that the actual skill correlations between spouses, and mothers and sons are probably twice the size of the correlations that we estimate.[10]

The second limitation is that the skill rank measure is not informative about skill inequality. Rank distributions remain by construction the same over time. Instead we detect changes in skill inequality through changes in skill rank correlations. In line with the predictions of our model, we infer a greater inequality in absolute skills of children whenever the skill rank correlations between mothers, fathers, and sons are positive. If skills of both parents are transmitted across generations, positive assortative mating in ranks improves the skills of children whose parents are higher ranked while worsening the skills of those whose parents are lower ranked.

The test score data are matched to education and earnings records, which are available for the full sample. We define college attendance as having at least some post-secondary education. Earnings are gross annual earnings from work including self-employment and sickness benefits at age 35.

Our primary data source includes all women who were born between 1930 and 1980. Table 1 provides descriptive statistics of these women, their spouses, and sons. We

[10] Appendix Figure A.1 shows that the rank of one brother closely maps the rank of the other brother with a correlation of about 0.46. Moreover, we do not observe large changes over time; between the first and last cohorts in our sample, the correlation only slightly increases by approximately 2 percent (not shown).

then draw the appropriate sample to test the three main predictions of our model. First, educational expansion is driven by diminishing education frictions. Second, the expansion leads to stronger positive assortative mating in skills. Third, higher skill sorting of parents induces a widening of the children's skill distribution and in turn increases earnings inequality. The different tests rely on different subsamples depending on the available skill, education, and earnings information on women, spouses, and sons. For each subsample, we report the sample means and standard deviations for each outcome we use in our estimations at the bottom of the estimation tables.

Table 1: Descriptive statistics

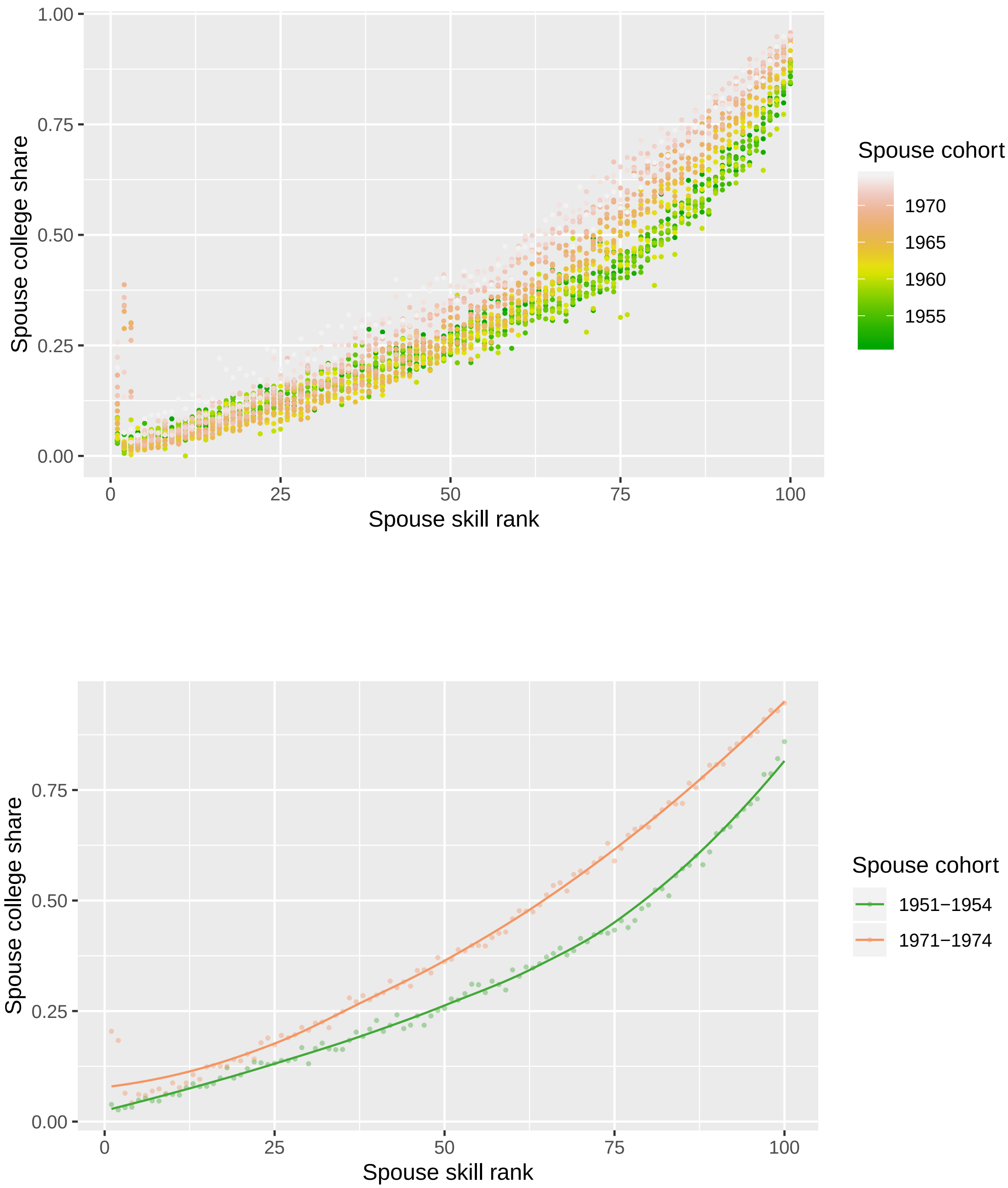
	Mean	SD	Observations
Women			
Year of birth	1956.44	14.14	3,403,472
Highest level of education	3.63	1.70	3,403,472
College attendance	0.34	0.47	3,403,472
Skill rank (proxied)	0.48	0.29	845,874
Spouses			
Year of birth	1952.80	14.75	2,820,141
Highest level of education	3.50	1.70	2,820,141
College attendance	0.29	0.45	2,820,141
Skill rank	0.51	0.29	933,565
Sons			
Year of birth	1969.02	8.00	1,489,821
Highest level of education	3.90	1.42	1,489,821
College attendance	0.33	0.47	1,489,821
Log(earnings)	12.48	0.82	1,265,717
Skill rank	0.50	0.29	880,081

NOTE – The sample consists of all women born between 1930 and 1980. Education is classified into seven levels ranging from primary school (1) to post-graduate education (7). Skill rank indicates the cognitive skills percentile rank (1-100) within a cohort divided by 100. Skills of women are proxied by their closest brothers. Earnings are annual figures measured at age 35.

4.2 Frictions, skills, and college education

To examine the role of education frictions as determinant of the secular rise in college attendance, we first look at the skill composition of college attendees. If rising attendance rates are due to diminishing education frictions, there should be an increasing number of college attendees among higher skilled individuals. If, on the other hand, rising attendance rates are due to lower skill requirements, the number of low-skilled college attendees should increase. Figure 4 plots attendance rates by cognitive skill ranks for the different cohorts of spouses in our sample for which we observe the skill measure (1951-1974).

Figure 4: College attendance by skill rank and cohort



It shows that college attendance rates tend to increase over time for most ranks. When we compare attendance rates between the first four and last four cohorts, we see that increasing attendance rates are much more driven by the higher skilled than by those with lower skills. Figure A.2 in the Appendix shows comparable trends in college attendance by skill rank for women.

Table 2 reports corresponding estimates from regressions that link college attendance to skill rank, while controlling for cohort years (measured with either dummies or a linear trend). The coefficients confirm that cognitive skills are a strong predictor for college attendance. As shown in column (4), being 10 percentage points higher in the cognitive skill distribution raises the likelihood of attending college by about eight percentage points in the sample of spouses. When we interact skill rank with cohort years, we find a small positive but significant interaction term, suggesting that over the years college education attracts increasingly more skilled individuals. These patterns are comparable for women although the estimates are much smaller because we proxy their skills with the skill rank of their brothers. Together these results are most consistent with an education friction story.

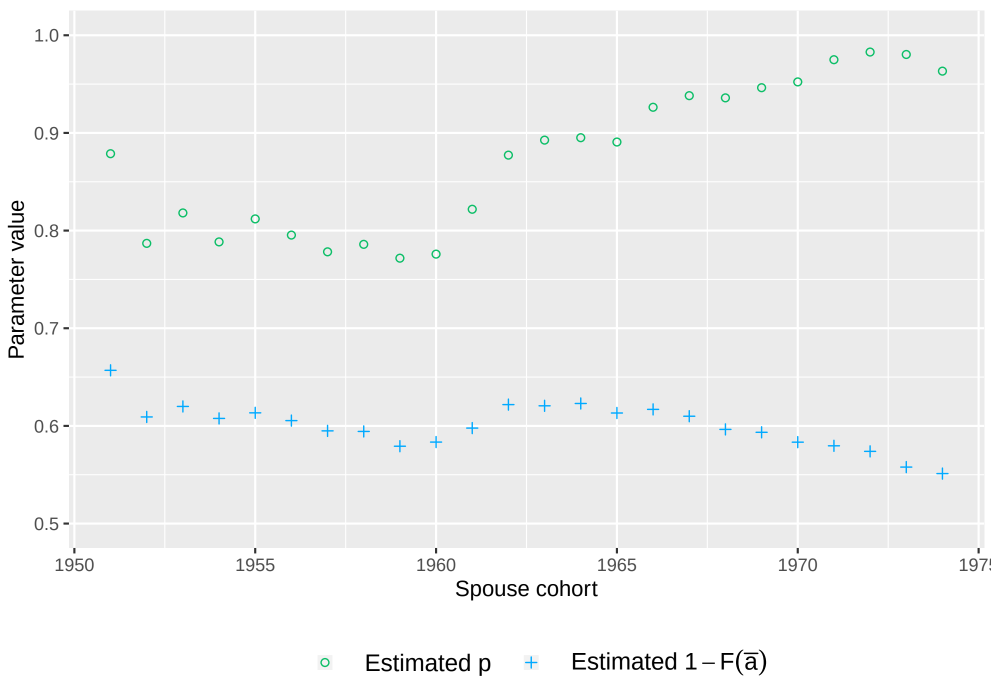
Table 2: The link between cognitive skills and college attendance

	Women college attendance			**Spouses college attendance**		
	(1)	(2)	(3)	(4)	(5)	(6)
Skill rank	0.462***	0.463***	0.368***	0.806***	0.807***	0.589***
	(0.002)	(0.002)	(0.012)	(0.002)	(0.002)	(0.007)
Skill rank× Birth year			0.003***			0.006***
			(0.000)			(0.000)
Birth year (1930=0)		0.007***	0.006***		0.004***	0.000***
		(0.000)	(0.000)		(0.000)	(0.000)
Cohort dummies	Yes	No	No	Yes	No	No
Mean (SD)		0.429 (0.495)			0.348 (0.476)	
N		509,450			933,565	

NOTE – The sample consists of all women born between 1930 and 1980 with spouses born between 1951 and 1974 for whom skill data are available. The dependent variable is a college attendance indicator. Skill rank indicates the cohort-specific cognitive skills percentile rank (divided by 100). Skills of women are proxied by the skills of their closest brother. Standard errors are reported in parentheses. * significant at 10% level, ** significant at 5% level, and *** significant at 1% level.

The data on college attendance by skill rank and birth year allow us to estimate the fraction of individuals who qualify for college $(1 - F(\bar{a}))$ and the education friction parameter (p), for each cohort of spouses. Figure 5 plots these two model parameters. The fraction estimates move around 0.6 for all cohorts, implying that the upper 60 percent of the skill distribution meet the qualifications to go to college. The friction estimates indicate that for cohorts born before 1960, about 20 percent of all individuals with sufficient skills did not go to college. For cohorts born after 1960, the education friction steadily decreases to zero. This suggests that higher attendance rates are mainly driven by disappearing frictions whereas relative skill requirements for college remained similar over time.

Figure 5: Estimated college attendance parameters p and $1 - F(\bar{a})$



4.3 Assortative mating on skills and college education

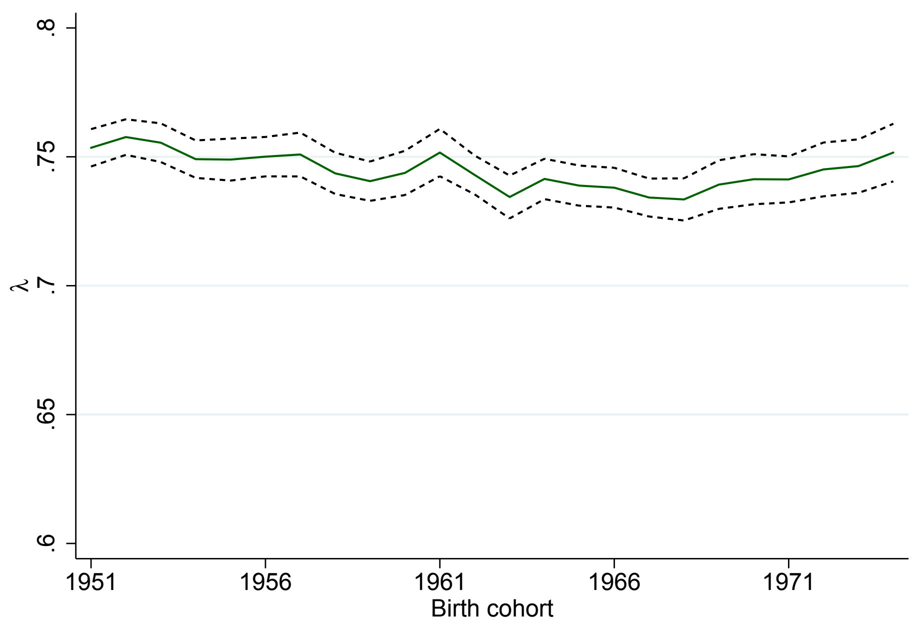
We next analyze how partners sort on college education and skills. According to our model predictions, the rise in college rates should reinforce partner sorting on skills as long as partners sort on college education. To test this, we run regressions of women's college education on their spouses' college education, as well as women's skills on spouses' skills, while controlling for cohort effects. Table 3 reports these assortative mating estimates.

Table 3: Assortative mating in college attendance and skill ranks

	Women college attendance			**Women skill rank**		
	(1)	(2)	(3)	(4)	(5)	(6)
Spouse col. attendance	0.387***	0.387***	0.356***			
	(0.001)	(0.001)	(0.004)			
Spouse col. attendance × birth year			0.001***			
			(0.000)			
Spouse skill rank				0.207***	0.207***	0.144***
				(0.002)	(0.002)	(0.008)
Spouse skill rank × birth year						0.002***
						(0.000)
Spouse birth year		0.007***	0.007***		0.001***	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Spouse birth year dummies	Yes	No	No	Yes	No	No
Mean (SD)	0.429 (0.495)			0.484 (0.289)		
N	1,337,800			417,541		

NOTE – The sample consists of all women born between 1930 and 1980 with spouses born between 1951 and 1974 for whom skill data are available. The dependent variables are the women's college attendance (in columns 1, 2, and 3) and skill rank (in columns 4, 5, and 6). Skill rank is the cohort-specific cognitive skills percentile rank (divided by 100). Skills of women are proxied by the skills of their closest brother. Standard errors are reported in parentheses. * significant at 10% level, ** significant at 5% level, and *** significant at 1% level.

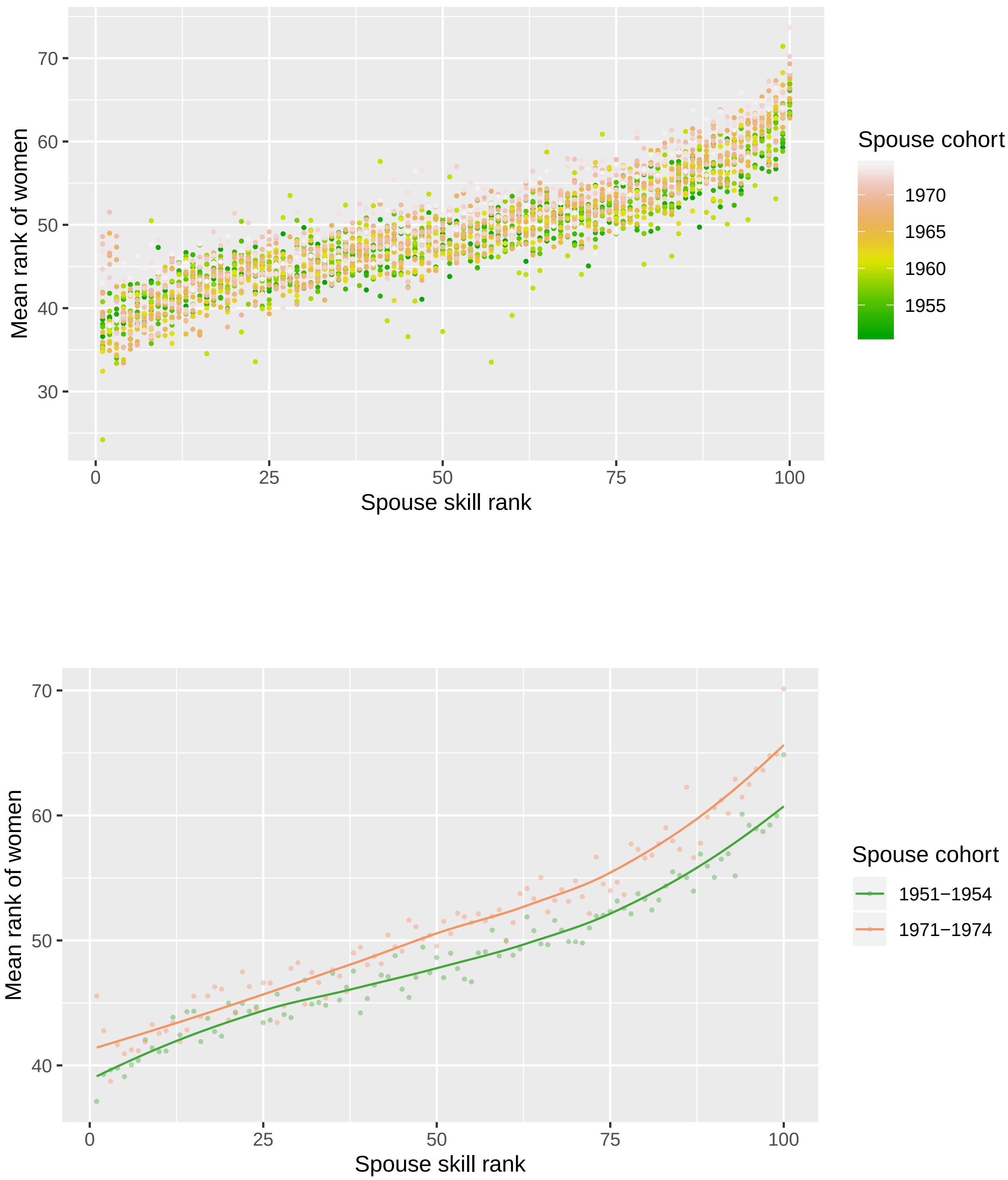
Figure 6: Estimated marriage match parameter λ



Note: Dashed lines indicate 95%-confidence interval.

When we examine sorting on college, we find that college-educated men are 39 percentage points more likely to match with college-educated women. The interaction term (in column 3) further indicates a small increase of 0.1 percentage points per cohort. Based on observed matches and overall college attendance rates of spouses, we can also estimate the marriage match parameter λ for each cohort. Figure 6 shows that the parameter estimates fluctuate around 0.75, suggesting that men who went to college are three times ($\frac{0.75}{1-0.75}$) more likely to match with women who attended college as well. When we look at sorting on skills, we observe, consistent with our model predictions, positive assortative mating. The estimates indicate that men who are 10 ranks higher in the skill distribution are married to women who are on average two ranks higher. The positive interaction between skill rank and cohort year suggests that sorting on skills gets slightly stronger over the years. Figure 7, which plots the mean skill rank of women by the skill rank of their spouse for each cohort, illustrates this trend.

Figure 7: Assortative mating in skill ranks of spouses



4.4 Intergenerational transmission

To examine the impact of these changes on children, we next focus on the intergenerational transmission of skills. Regression results in Table 4 indicate that skilled parents have more skilled sons.[11] For fathers, the estimates are large, positive, and statistically significant: a 10 percentage point increase in the skill rank is associated with a three to four percentage point increase in the skill rank of sons. For mothers, the estimates are also positive and statistically significant but, as we discussed above, biased downward and therefore smaller than the estimates for fathers. Importantly, both estimates do not change much when we additionally control for the other parent's skills. This emphasizes the relevance of assortative mating, suggesting that stronger sorting on skills of parents leads to a more dispersed skill distribution of children.

Table 4: Intergenerational mobility of skills

	Son skills rank			**Son college attendance**			**Son log(earnings)**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mother skill rank	0.203***		0.174***	0.244***		0.195***	0.093***		0.070***
	(0.011)		(0.011)	(0.007)		(0.007)	(0.011)		(0.011)
Father skill rank		0.341***	0.324***		0.385***	0.357***		0.179***	0.169***
		(0.011)	(0.011)		(0.007)	(0.007)		(0.011)	(0.011)
Mean (SD)	0.429 (0.275)			0.312 (0.463)			12.64 (0.695)		
N	7,537			59,220			52,438		

NOTE – The sample consists of all sons of women born between 1930 and 1980 for whom skill data on both parents are available. The dependent variables are skills (in columns 1, 2, and 3), college attendance (in columns 4, 5, and 6) and the logarithm of earnings (in columns 7, 8 and 9). Skills represent cohort-specific cognitive skills percentile rank (divided by 100). Skills of women are proxied by the skills of their closest brother. Earnings are annual figures measured at age 35. All regressions include mother cohort dummies. Standard errors are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

When we instead use earnings (measured at age 35) as outcome variable, we find that more skilled parents have more successful children in terms of labor market earnings. Although the impact is smaller compared to the direct transmission of skills, estimates are still sizeable.[12] If we assume that the intergenerational link between skills of parents and child earnings remains stable over time, we can compute expected earnings for future generations based on the skill rank of parents.

[11] Because skill data on both parents and sons are only available for a few families, the sample size is smaller compared to previous regressions.

[12] This pattern is consistent with a returns-to-skill story; that is, we should see similar patterns of intergenerational skill transfers if more skilled children earn more because of positive skill returns. We have estimated the relationship between earnings, skills, and college attendance in the sample of sons (see Appendix Table A.1). Being 10 percentage points higher in the skill distribution corresponds to an earnings increase of 4 percent. This compares to 15 percent higher earnings for individuals who attended college. When we include both variables in the regression, we find that skill returns dominate.

Figure 8: Standard deviation of predicted log(earnings)

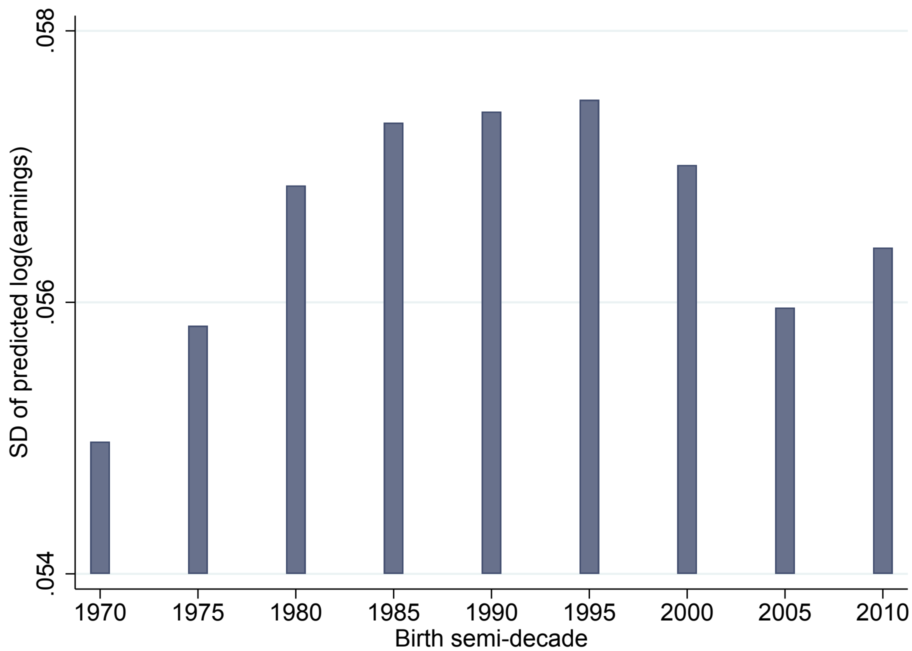
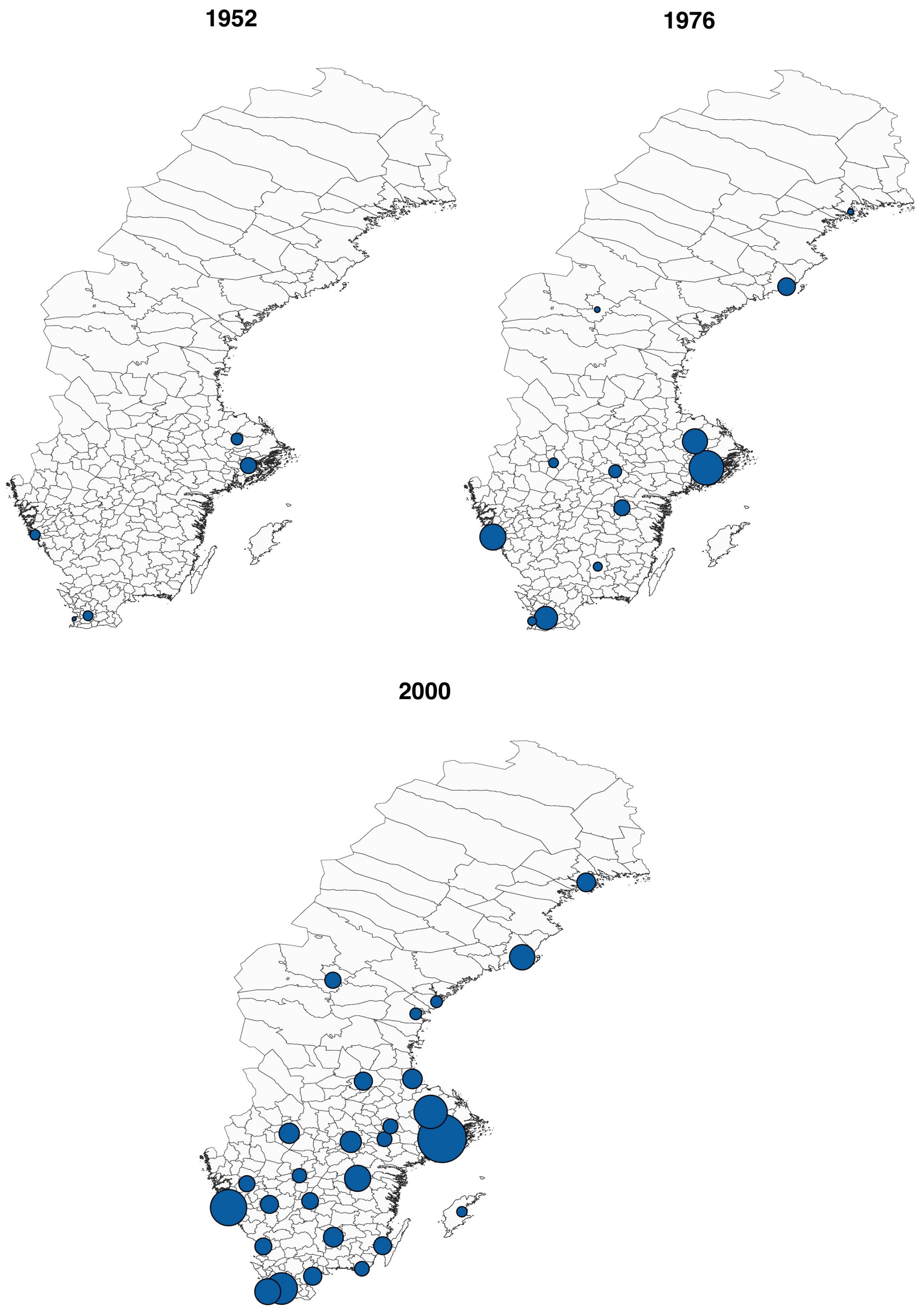


Figure 8 plots the standard deviation of predicted log earnings for each cohort of sons for whom data on skills of parents are available. Due to changes in assortative mating, the standard deviation increases by approximately 7 percent up to cohort 2000 and decreases again somewhat afterwards.

5 Causal evidence from university openings and expansions

Above we argued that the expansion in college attendance is due to reduced education frictions, and we showed how this expansion is associated to skill sorting on the marriage market and intergenerational skill transmission. In this section, we exploit the opening of new universities and the expansion of existing universities in Sweden as natural experiment to provide causal evidence for the effects of increased college attendance on skill and earnings inequality of the next generation. We argue that education frictions reduce exogenously for individuals who live near a location where either a new university is opened or an existing university has expanded its capacity.

Figure 9: Growth of first-year college student numbers in Sweden



Currently there are 16 universities located in 12 different municipalities in Sweden. There are also a number of more field-specific and/or regional colleges, covering an additional 15 municipalities. Figure 9 shows the location and sizes (in terms of student numbers) of these institutions over the course of the second half of the 20th century.[13] Sweden has four old universities (Gothenburg, Lund, Uppsala and Stockholm) that opened before our analysis window, while most of the other institutions opened in some form between the mid-1960s and the mid-1980s. We exploit that university openings and expansions affect the decision for university education of individuals living in the municipality of either a new or expanding university.[14]

Our model predicts that skill sorting in the marriage market increases whenever education frictions decline. In terms of skill inequality, stronger skill sorting (due to declining frictions) then implies an increasing skill gap between partners of college and non-college educated women. The same holds for the (expected) skill gap between children of college and non-college educated women, as well as for the difference in their (expected) earnings.

To empirically link rising inequality to reduced education frictions, we focus on the difference in skills between partners of women with and without college education. For woman i, the skill level of her partner can be expressed as

$$a_i^m = a^{m0*}(1 - e_i^f) + a^{m1*} e_i^f + v_i = a^{m0*} + (a^{m1*} - a^{m0*}) e_i^f + v_i,$$

where v_i is an error term, and a^{m1*} and a^{m0*} denote the partner's average skills of women with and without college education. The key prediction of our model is that the average partner skill gap, $a^{m1*} - a^{m0*}$, should rise whenever education frictions fall. If we treat university openings and expansions as a reduction in eduction frictions that increased university access in different regions at different times, the average skill gap between partners in region r at time period t can be written as

[13] Institutions in Sweden are typically separated into universities and colleges, where the former are more research oriented and have a general right to award doctorate degrees. We do not differentiate between these types of institutions in our analysis, and use the terms university and college interchangeably. Information on student numbers (registered first-year students) for the years 1952-1979 and 1984-1985 is obtained from official printed publications from Statistics Sweden (SCB, 1959b; 1959a; 1960; 1974; 1977; 1979; 1995); information starting from 1986 is obtained electronically through Statistics Sweden's website (SCB, 2020). We lack information for 1980-1983 and interpolate these years linearly.

[14] Figure A.4 in the appendix illustrates trends in college attendance of women. While attendance is always lower in municipalities without college access (*Never*-municipalities), we observe that the attendance rate in municipalities which have experienced an opening (*Opening*-municipalities) converges towards the level in municipalities which always had a university (*Always*-municipalities).

$$a_{rt}^{m1*} - a_{rt}^{m0*} = \eta_r + \gamma_t + \delta Z_{rt} + u_{rt},$$

where Z_{rt} is our measure for increased university access, η_r and γ_t are region and time fixed effects, and u_{rt} is an error term. The parameter δ captures the effect of education frictions. Similarly, we can write the partner's average skills of non-college educated women as $a_{rt}^{m0*} = \theta_r + \lambda_t + \phi Z_{rt} + w_{rt}$, where θ_r and λ_t are region and time fixed effects, and w_{rt} is again an error term. When we substitute the expressions for $a_{rt}^{m1*} - a_{rt}^{m0*}$ and a_{rt}^{m0*} into the previous equation, we can express the skill level of partners as

$$\begin{aligned} a_{rti}^{m} &= \theta_r + \lambda_t + \phi Z_{rt} + w_{rt} + (\eta_r + \gamma_t + \delta Z_{rt} + u_{rt})e_{rti}^{f} + v_{rti} \\ &= \theta_r + \lambda_t + \phi Z_{rt} + \eta_r e_{rti}^{f} + \gamma_t e_{rti}^{f} + \delta Z_{rt} e_{rti}^{f} + (w_{rt} + u_{rt} e_{rti}^{f} + v_{rti}). \end{aligned}$$

Our target of estimation is the parameter δ, which directly measures how education frictions impact partner skill inequality. There are two points to note about this regression model. First, consistent estimation of δ requires that conditional on the parameters capturing time and region fixed effects, our measure of university access Z_{rt} is uncorrelated with the sum of error terms $(w_{rt} + u_{rt}e_{rti}^{f} + v_{rti})$. One reason for such a correlation might be that location choices of university openings and expansion choices of existing universities are not random but relate to population characteristics and potential demand for university education, which are not captured by the year and region fixed effects. We consider this less problematic for our model because we are not interested in estimating the effect of women having higher education. Our focus is instead on the interaction effect for which the identifying condition is fulfilled as long as university openings and expansions are not the response to recent shocks in the average skills of partners. Second, we measure the skills of partners before they enter university, which means that any impact of improved university access must come from women changing their choice of partner. In this case, a positive estimate of δ indicates that reduced education frictions raise inequality in partner skills through enhanced skill sorting in the marriage market.

Because reduced education frictions experienced by women should translate into higher skill inequality in the next generation, we also expect a positive estimate of δ when we use the skill measure of their children as outcome variable. In this case, however, children of university educated women acquire more skills than children of women without university education for two distinct reasons. First, they benefit because their mothers married more skilled fathers. Second, their fathers are also more likely to be university graduates. The intergenerational transmission driven by these two effects is widening the skill gap between children of university and non-university educated women, creating even more inequality.

We consider several outcomes, including the skill rank and educational level of partners, and the skill rank, educational level, and earnings of sons. For all outcomes, we estimate the regression model following the specification for the skill level of the partner

$$Y_{icr} = \theta_r + \lambda_c + \phi Acc_{cr} + \eta_r Col_{icr} + \gamma_c Col_{icr} + \delta Acc_{cr} \times Col_{icr} + u_{icr},$$

where Y_{icr} is the outcome of the partner or the son of women i in cohort c in municipality r, Acc_{cr} is a measure for college access, and Col_{icr} an indicator for college attendance of women. For all outcomes, the coefficient of interest is δ, which describes how increased college access affects outcomes of college and non-college educated mothers differently. We are thus interested in the interaction effect, we takes into account that increased college access also changes which mothers will be college educated. It should be stressed that we are not interested in the causal effect of college education for a mother, but instead in how increased college access diverges outcomes for the groups of mothers with and without college access. So in line with out theoretical model we take into account that increased college access changes educational decisions of both males and females, which also has marriage market effects.

We consider four different measures for improved college access. The first measure is whether or not there exists a college or university in the municipality when women are 20 years old. The second measure is the number of first-year students in the municipality entering college in that year. As third measure, we divide the number of first-year students by the number of high school graduates in the same cohort and municipality. Our final measure is the gravity measure introduced by Suhonen and Karhunen (2019), which can be considered as a distance-weighted average of the student density around the municipality.[15]

[15]Here we provide a short motivation for the four college access measures. We make a distinction between college access measured at the extensive and intensive margin. The first measure is based on college openings. It is highly intuitive and captures the extensive access margin. The other measures capture the intensive access margin (in different ways). The second measure reflects on college capacity; because higher education in Sweden follows a numerus clausus principle, we believe that the number of first-year students entering college is an accurate proxy for college capacity. The third measure reflects

Table 5: Impact of college openings and expansions

	Spouses		Sons		
	Skill rank	Highest edu. level	Skill rank	Highest edu. level	log(Earnings)
(1) Any college in mun.	0.008	0.006	0.016**	0.034	0.023
Mean: 0.229, *SD*: 0.420	(0.005)	(0.012)	(0.008)	(0.026)	(0.015)
(2) Students ($\times 10^{-3}$) in mun.	0.002***	0.020***	0.004***	0.020***	0.004***
Mean: 1.302, *SD*: 3.435	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)
(3) Rel. students in mun.	0.003**	0.027***	0.007***	0.018**	0.001
Mean: 0.398, *SD*: 1.043	(0.001)	(0.004)	(0.002)	(0.008)	(0.004)
(4) Gravity-model measure	0.001***	0.011***	0.002***	0.011***	0.002*
Mean: 11.118, *SD*: 9.841	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
Observations	852,588	2,178,996	765,236	1,205,902	1,069,805

NOTE – The table reports estimates for coefficient δ. The sample consists of all women born between 1930 and 1980. Education is classified into seven levels ranging from primary school (1) to post-graduate education (7). Skill rank indicates the cognitive skills percentile rank (1-100) within a cohort divided by 100. Earnings are annual figures measured at age 35. Students refer to first-year college students. For every cohort of women c, 'Rel. students' are defined as the number of first-year students in a municipality in year c+20 divided by the number of high school graduates of this cohort born in this municipality. The definition of the gravity-model measure is provided in the text. Standard errors reported in parentheses are clustered by women's municipality $\times$ birth year. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 5 presents the estimated δ parameters for the different outcomes of women's partners and sons. We first take a look at the partner outcomes and examine whether improved college access affects skill sorting. For all four measures of college access, we find that reduced education frictions increase skill sorting on the marriage market. While the college access estimates are not always statistically significant, the estimates are all positive and confirm our theoretical model, which states that college attendance is important in the marriage market.[16] Individuals who attend college meet a different pool of potential partners and are therefore more likely to marry someone with higher

on possible college capacity constraints; because most first-year students enter college the same year in which they graduate from high school, the ratio between the number of first-year students and high school graduates (observed in the same cohort and municipality) is informative about the college's ability to take in their potential students. Low ratios, in this case, hint at restrictive college capacity (or selective college enrollment). The gravity measure also takes account of potential students (high school graduates) who live further away from the college municipalities. For municipality m in year t, it is defined as $Acc_{m,t} = \sum_{k=1}^{K} \frac{S_{k,t}}{C_{k,t} d_{km}^{\frac{1}{2}}}$, where $S_{k,t}$ denotes supply and $C_{k,t}$ denotes demand in municipality k. d_{km} is the kilometer distance between municipalities k and m. As measure for supply $S_{k,t}$, we use again the number of first-year students. Demand $C_{k,t}$ is given by $\sum_{l=1}^{L} \frac{N_{l,t}}{d_{kl}^{\frac{1}{2}}}$, where $N_{l,t}$ refers to the number of high school graduates who were born 20 years before t in municipality l.

[16] The least significant estimates are obtained when having a college or university in the municipality is used a measure for reduced educational frictions, which is not surprising. The openings of new colleges and universities is an indicator while enrollment of studens increases gradually after a new opening.

skills and more education. We next consider the child outcomes and examine whether improved college access for mothers also leads to more inequality in skills, education, and earnings (measured at the age of 35) of their children. We find that all estimates for the intergenerational effects of college access are positive and, by and large, statistically significant, regardless of how we measure college access. These estimates are again in line with the theoretical prediction that due to reduced education frictions the skill and earnings distribution gets more dispersed over generations. We therefore conclude that we can support our descriptive evidence from the previous sections with causal evidence on how improved college access increased skill sorting in couples, and skill and earnings inequality among their children.

6 Conclusion

Contributing to the growing literature on earnings inequality, this paper examines the intergenerational effects of rising college attendance. In a simple theoretical framework, we demonstrate that higher college attendance rates can lead to increased marital sorting on skills and causes a polarization of the next generation's income distribution.

The idea behind this mechanism is straightforward. If educational expansion is driven by better access to colleges, more students with sufficiently high skills attend college. Because improved college access operates as an expanding marriage market for skilled individuals, changes in the supply of college-educated individuals will impact the degree of assortative mating on skills. Even under very general assumptions on the intergenerational skill transmission, stronger assortative mating of parents then leads to a more dispersed skill and earnings distribution of their children.

Using unique data on cognitive skills which span multiple birth decades in Sweden, we test the predictions of our model on the composition of college attendees, assortative mating and intergenerational mobility. The observed trends are largely consistent with our model implications. Despite of rising attendance rates, cognitive skills are a consistently strong predictor of college education. Moreover, this paper exploits sibling data to proxy skill levels of women and documents an increasing degree of positive assortative mating in cognitive skills. Because the skills of both parents clearly have a positive impact on child earnings, our estimates suggest a further polarization of earnings in the future.

Exploiting exogenous variation in access to college education, this paper further provides causal evidence on the impact of educational expansion. Consistent with our previous findings, we estimate that improved college access leads to an increase in skill sorting in couples and an increase in skill and earnings inequality among their children.

Our model makes several simplifying assumptions. First, we abstract from borrowing constraints and assume that education is independent of parental income. Extending the model accordingly increases education inequality and the expected college premium but does not affect the assortative mating mechanism. Second, we assume that the number of children is independent of the parents' skill or education levels. Consistent with the idea that better prospects on the labor market increase the opportunity costs of childbearing, high-educated women often have less offspring. If family size has a negative effect on outcomes of children, this channel can further strengthen intergenerational inequality and amplify the effects of assortative mating. Third, we impose that every individual is matched on the marriage market. Empirical evidence shows, however, that the number of singles has been increasing in recent decades (see e.g. Stevenson and Wolfers (2007) for the US). It is possible that fewer matches reflect a change in marital preferences which may also contribute to stronger assortative mating.

In their seminal analysis of relative wage changes, Katz and Murphy (1992) identify the rapid growth of demand for higher skilled workers as an important determinant of rising wage inequality. While they argue that educational expansion can countervail this upsurge in inequality in the short run, we show that it may also come with repercussions in the long run. In fact, we argue that it is crucial to recognize that the educational expansion enforces sorting on the marriage market with substantial intergenerational consequences for inequality in the long run. To countervail such a polarization, it is not sufficient to adjust educational standards to the needs of changing labor markets. Policy makers should also focus on the support of children from low-educated households who are increasingly worse off compared to their peers from high-educated households.

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Appendix

Figure A.1: Skill rank correlation of spouses' brothers

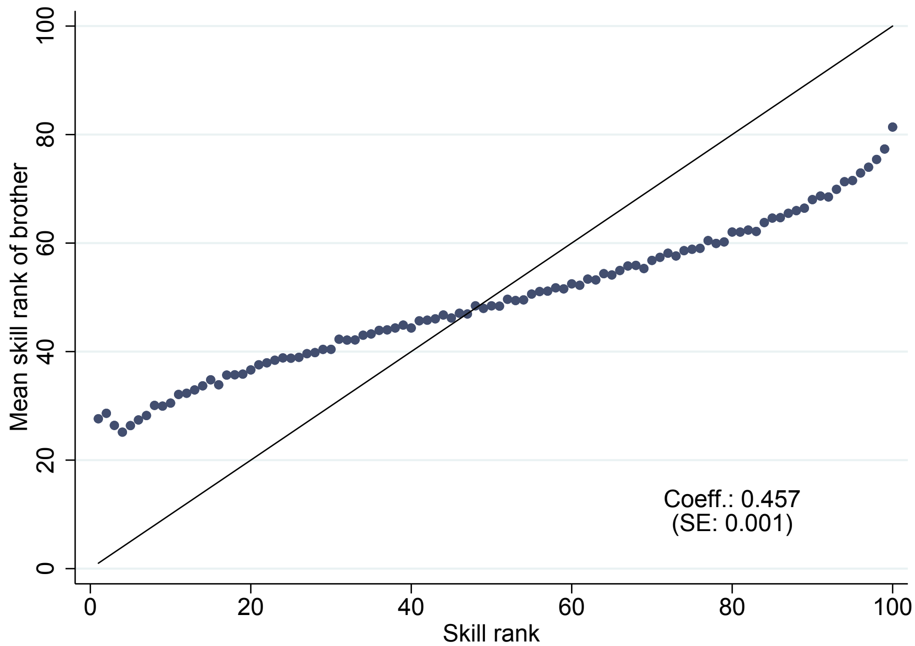


Figure A.2: College attendance by ability rank and cohort of women

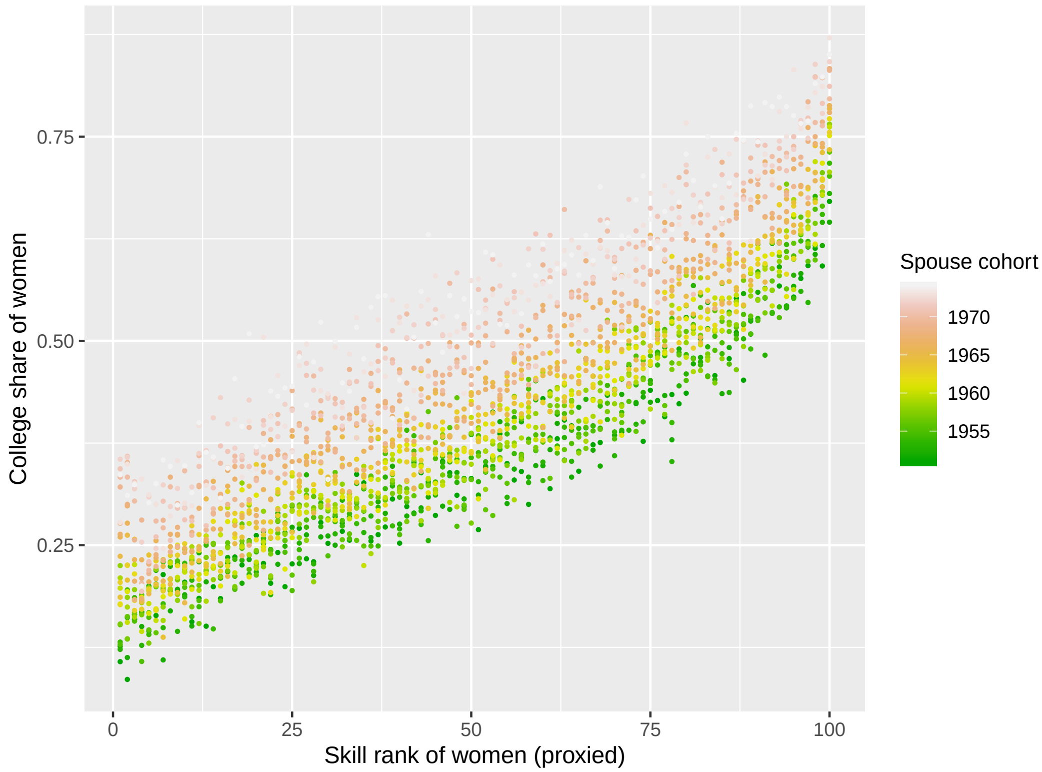


Figure A.3: Mean rank of child by rank of parents

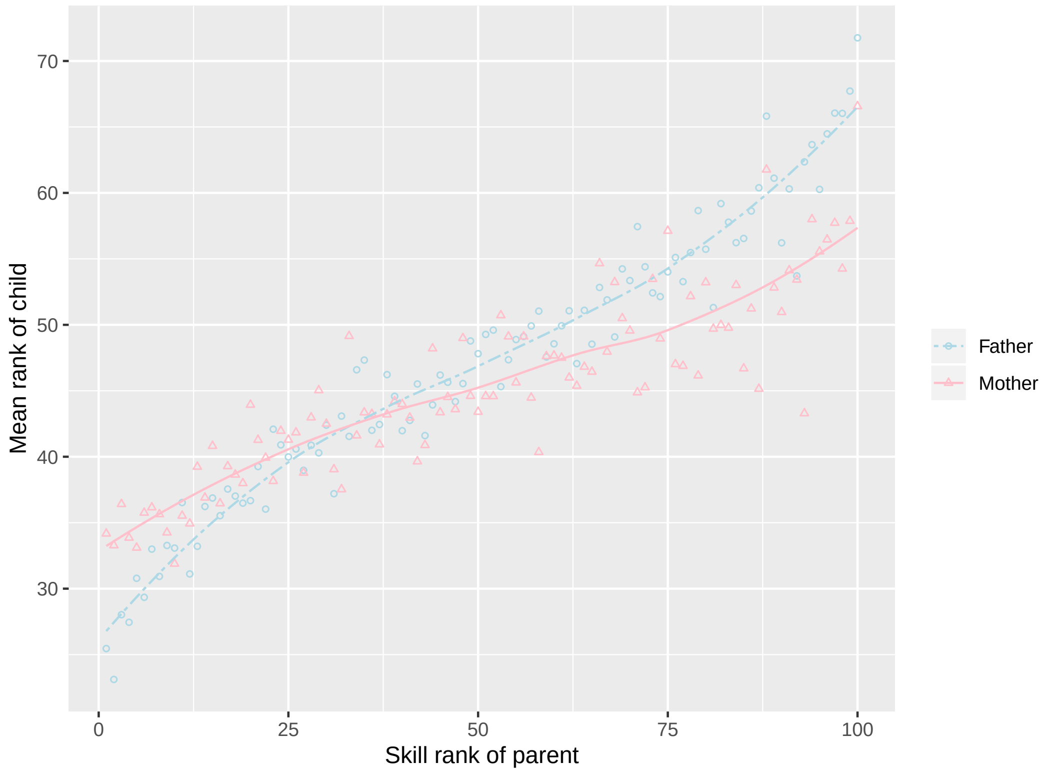
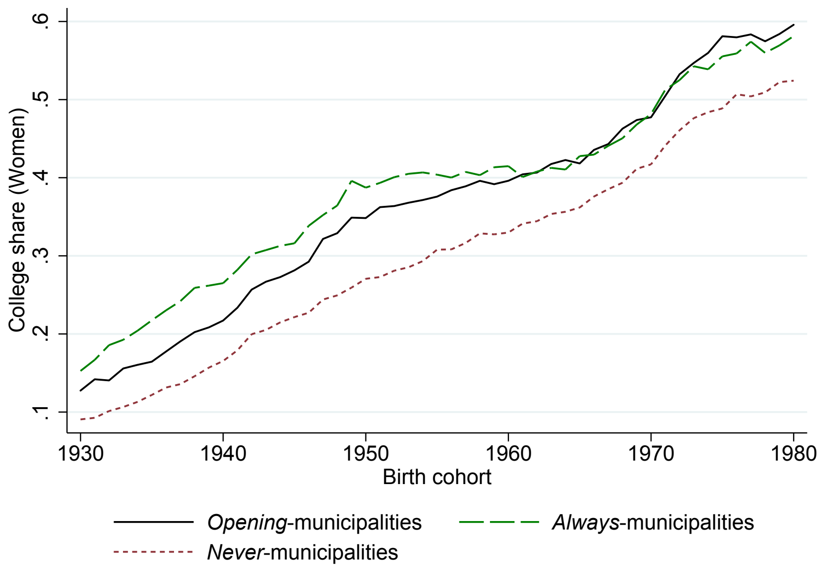


Table A.1: Earnings regressions with cognitive skills and college attendance

	log(earnings)			
	(1)	(2)	(3)	(4)
College attendance	0.150***		0.046***	-0.009
	(0.012)		(0.014)	(0.030)
Skill rank		0.418***	0.385***	0.356***
		(0.020)	(0.022)	(0.026)
College attendance × skill rank				0.100**
				(0.049)
N	20,481			

NOTE – Effects are estimated for all sons in our estimation sample. Earnings are annual figures measured at age 35. Skill rank indicates the cognitive skills percentile rank (1-100) within a cohort divided by 100. Standard errors are reported in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Figure A.4: College attendance of women by cohort and college access



Derivation of ability covariance $\mathrm{cov}(a_f, a_m)$

We first define $\theta_{ij} = \mathrm{E}[a_j|e = i]$ for $j = 0, 1$ and $i = f, m$, which denote expected ability levels of women (f) and their spouses (m) who did $(e = 1)$ and did not $(e = 0)$ attend college. Because, conditional on education, matching of spouses is random, the covariance of ability is given by

$$\mathrm{cov}(a_f, a_m) = \theta_{0f}\theta_{0m}\pi_{00} + \theta_{1f}\theta_{0m}\pi_{10} + \theta_{0f}\theta_{1m}\pi_{01} + \theta_{1f}\theta_{1m}\pi_{11} - \mu^2.$$

Substituting the shares of couple types (π) into this equation gives

$$\begin{aligned}\mathrm{cov}(a_f, a_m) = \quad & \theta_{0f}\theta_{0m} + \theta_{0m}(\theta_{1f} - \theta_{0f})q_f + \theta_{0f}(\theta_{1m} - \theta_{0m})q_m \\ & + (\theta_{1f} - \theta_{0f})(\theta_{1m} - \theta_{0m})\frac{\lambda q_f q_m}{\lambda q_f + (1-\lambda)(1-q_f)} - \mu^2.\end{aligned}$$

The average skill level can be written as $\mu = \theta_{i0} + (\theta_{1i} - \theta_{0i})q_i$, which yields

$$\mathrm{cov}(a_f, a_m) = (\theta_{1f} - \theta_{0f})(\theta_{1m} - \theta_{0m})\frac{(2\lambda - 1)q_m q_f(1-q_f)}{\lambda q_f + (1-\lambda)(1-q_f)}.$$

We next define $\mu_0 = \mathrm{E}[a_j|a_j \leq \bar{a}]$ and $\mu_1 = \mathrm{E}[a_j|a_j > \bar{a}]$. It follows that $\theta_{1j} = \mu_1$ and $\theta_{0j} = \frac{\mu_0 F(\bar{a}) + \mu_1 p_j(1-F(\bar{a}))}{F(\bar{a}) + p_j(1-F(\bar{a}))}$ for $j = f, m$. Substituting this into the equation for the covariance and using that $F(\bar{a}) + p_j(1 - F(\bar{a})) = 1 - q_j$ gives

$$\mathrm{cov}(a_f, a_m) = \frac{((\mu_1 - \mu_0)F(\bar{a}))^2}{(1-q_m)}\frac{(2\lambda - 1)q_f q_m}{\lambda q_f + (1-\lambda)(1-q_f)}.$$

Proof of proposition 1

(a) Using the above expression for the ability covariance, the first derivative with respect to λ equals

$$\frac{\partial \mathrm{cov}(a_f, a_m)}{\partial \lambda} = \frac{((\mu_1 - \mu_0)F(\bar{a}))^2}{(1-q_m)}\frac{q_f q_m}{(\lambda q_f + (1-\lambda)(1-q_f))^2}.$$

Because all terms in this derivative are positive, higher values of λ increase the ability covariance.

(b) First, we consider the first derivative of the covariance with respect to α. Recall that α only shows up multiplicatively in q_f, in particular $q_f = \alpha q_m$. Therefore, the derivative simplifies to

$$\frac{\partial \mathrm{cov}(a_f, a_m)}{\partial \alpha} = \frac{((\mu_1 - \mu_0)F(\bar{a}))^2}{(1-q_m)} \frac{(2\lambda - 1)(1-\lambda)q_m^2}{(\lambda q_f + (1-\lambda)(1-q_f))^2}.$$

Next, we calculate the first derivative with respect to p, which yields

$$\frac{\partial \mathrm{cov}(a_f, a_m)}{\partial p} = \frac{((\mu_1 - \mu_0)F(\bar{a}))^2}{(1-q_m)^2} \frac{(2\lambda - 1)((1-\lambda)(2-q_f-q_m) + \lambda q_f)(1-F(\bar{a}))q_f}{(\lambda q_f + (1-\lambda)(1-q_f))^2}.$$

Both derivatives are positive for $\lambda > \frac{1}{2}$ and negative for $\lambda < \frac{1}{2}$.