The importance of nature-nurture interactions in skill formation: Evidence from a large sample of Swedish adoptees

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Very preliminary and incomplete

Abstract

In this study we estimate the importance of nature-nurture interactions for cognitive and non-cognitive ability and educational attainment, using data on adopted children and their adoptive and biological parents complied from Swedish registers. There exist very few studies of the importance of gene-environment interactions for skill formation and evidence from these studies is inconclusive. In this study, we use a large sample of adoptees, born during the 1930s, 1940s, 1950s and 1960s. Preliminary results suggest that interaction effects are non-positive. This is an important result as it suggests that positive environmental shocks will not exacerbate genetic inequality due to inherited differences among children. There is also some evidence of negative interaction effects, especially for sons, for the early periods, possibly indicating that the role of environmental interventions as an equalizer has decreased during the establishment of the Swedish welfare state.

1. Introduction

The existence of gene-environment interaction has enormous implications for how to optimally design public policies. If environmental inputs can compensate for initial differences in genetic endowment (genetic inequality), well-designed interventions will not only be beneficial for disadvantaged individuals, and as such increase equality of opportunity, but also be the most efficient way to raise productivity

The literature on the importance of genes-environment interactions, although not new, has become more prominent in recent years. Studies have shown that gene-environment interaction can be important for some outcomes, such as the development of mental disorders and alcoholism, although there are still a lot of inconsistent results across studies (see e.g., Rutter et al, 2006). Plomin et al (2016) lists 10 replicable findings in the behavioral genetics literature. However, genotype-environment interactions is not one of them.[1]

Using actual genetic markers, researchers have very recently been able to explain significant variation in some outcome like education (Rietveld et al, 2013). However, interacting these with environmental conditions can be problematic if these are not exogenously determined. Hence, interaction effects might be observed just because the environment is better for those with a positive genetic predisposition for some outcome. Combining polygenic scores with some exogenous variation in the environment is a literature still in its infancy (e.g., see Schmitz and Conley, 2016).

In this study we estimate the importance of nature-nurture interactions for cognitive and non-cognitive ability and educational attainment, using adopted children and their adoption and bio parents. More specifically, we regress the outcome for the adopted child on the outcomes for the adopted parent, the biological parent and the interaction between the two, where a negative interaction term is interpreted as environmental interventions potentially having a larger effect for individuals born with disadvantage genetic predisposition for the analyzed outcome. We perform separate estimations for sons/daughters and fathers/mothers. We argue that because of pre-natal environmental effects, the biological father is probably a cleaner measure of genetic endowment.

We believe that there are several reasons for why our study is a valuable one. There exist very few studies of the importance of gene-environment interactions for skill formation, and, as pointed out above, evidence from these studies is inconclusive. An earlier study for Sweden (Björklund, Lindahl and Plug, 2006) used a smaller sample of Swedish adoptees born in the early 1960s and estimated interaction effects for education and income. However, results were inconclusive as some interaction terms was positive and some insignificantly different from zero with fairly large standard errors.[2] In this study, we use a much larger sample of adoptees. We also look at new outcomes, such a cognitive and non-cognitive ability measures, and at separate effects across daughters and sons. We are also able to look for separate effects over time, where a hypothesis is

[1] "Fifth, our goal is to describe big behavioral genetic findings that replicate, rather than describing results that have not shown sufficient replication to be included in our list. Examples, which may become more convincing with more research, include (….) "genotype-environment interaction (attempts to show that heritability differs as a function of environment)." (Plomin et al., 2016, page 4)

[2] Other authors have also who used this decomposition approach to also investigate the importance of nature-nurture interaction effects for other outcomes; Hjalmarsson and Lindquist, Labour Economics, 2011, have looked at the criminal convictions, and Cesarini, Johannesson and Oskarsson, APSR, 2014, have looked at voting outcomes.

that the room for environmental interventions possibly has decreased during the establishment of the Swedish welfare state.

We use a data set based on all adoptees born in Sweden 1932-1970, where we can identify the children as well as their adoptive and biological parents. It is compiled from several Swedish registers and contains information on the children's educational outcomes and on the same characteristics of both their adoptive and biological parents. For adopted sons born 1951-1970 we also have information on cognitive and non-cognitive results from military tests and evaluations. The intergenerational estimations for the adoptive samples are also compared with a representative sample of all (nonadopted) children born in Sweden in these periods.

2. Theoretical framework

How does parental endowment and investments impact the production of offspring's skills? To understand this with respect to our setting, we here lay out a slightly modified version of the model of skill formation in Cunha and Heckman (2007).[3]

The skills production function is defined as:

$$\theta_{t+1} = f_t(\theta_t, h, I_t)$$

where θ_t and θ_{t+1} are the skills at the beginning of the time periods t and t+1; h is the stock of skills of the parents (when they have finished their education); and I_t are the parental investments in the child's skill formation in period t.

In this simple model we think of investments being possible in 2 periods, in-utero and in childhood, and where the stock of skills (θ_t) exists at the beginning of period 1, 2 and 3: θ_1 is the stock of skills at conception, hence constituting the genetic endowment of the biological mother and father; θ_2 is the stock of skills when the child is born, which depends on the genetic make-up, investments during pregnancy, as well as from interactions between these (pre-natal environmental induced changes in gene expression), and θ_3, which is the stock of skills formed when investments in skills are done, hence $\theta_3 \equiv h'$ which is the stock of skills of the child, when the child has become an adult. θ_3 depends on the factors determining θ_2 as well as investments during childhood by the adoption family and interactions between these investments and earlier investments and/or with the genetic endowment. The stock of skills of parents, h, is assumed to (passively) influence the stock of skills in each period.

Hence, this three-period framework leads to

$$\theta_3(\equiv h') = m_2(\theta_1, h, I_1, I_2)$$

In the Cunha and Heckman (2007) model, two features of the concept of skill formation are emphasized: Self-productivity, which means that the stock of skills θ_t are causally related across t:s, so that a high stock of skills in one period (for instance via investments during the earlier period) leads to a higher stock of skills in the next period; Dynamic complementarities, where a high stock of skills in the beginning of a period raises the

[3] In Conti and Heckman (Perspective sin Psychological Sciences, 2010), they set up a framework for estimating nature-nurture effects with adoptions data in a latent variable framework.

returns to investments made during this (or later) time periods. In our setting, self-productivity means a positive effect of initial genetic endowment on the stock of skills in later periods, whereas dynamic complementarity means positive nature-nurture interactions, as a high genetic endowment raises the returns to investments in utero or in childhood. Negative nature-nurture interactions, or dynamic substitutability, means that the lower initial genetic endowment, the higher are the returns to investments in later periods.

So what can we estimate with our data?[4] We can estimate self-productivity and dynamic complementarity with respect to initial genetic endowment, but only under some strong assumptions. Years of schooling of the biological parent is a proxy for the initial genetic endowment, θ_1 and investments in utero (possibly h^{bp} if the stock of skills of the biological parents influence in utero conditions), while years of schooling of the adoptive parent is a proxy for the adoptive parent's stock of skills, h^{ap}, and investments during childhood/upbringing, I_2. However, if we are willing to assume that biological fathers of the adopted children have very limited influence on the prenatal environment of the adopted child, years of schooling of the biological father is a better proxy for the initial genetic endowment, θ_1. A positive estimate for years of schooling of the biological father would then indicate self-productivity, and a positive (negative) estimate for the interaction between years of schooling of the biological father and the adoptive parents would indicate dynamic complementarities (substitutability). Note that the later result only holds if adoptive parent's stock of skills, h^{ap}, and the investments of adoptive parents, I_1or I_2 are uncorrelated. The reason is that these factors are not empirically distinguishable (without additional information on, say, some exogenous reform that increases adoptive parents' propensity to invest in their children's skills).[5] If there instead is, as is likely, a positive correlation between these factors, dynamic complementarities/substitutability will be overestimated (biased away from zero).

3. Conceptual framework, econometric specifications and identification issues

A simple linear additively separable model of skill production would look like

$$Skills^{ac} = f(E, G) = \alpha + \delta \cdot E + \theta \cdot G + u$$

where E is the environment and G is the genetic background of the child. However, as many have argued, this model is over-simplistic. For instance, Cunha and Heckman (2007) argue that the nature and nurture distinction is obsolete because genes express themselves through the environment. There are also other possibilities for why genetic predisposition can impact skills differently depending on the environment experienced by the child. Therefore, the model should be modified to take this into account. An simple way to do this is to allow θ to depend on E, for instance through a linear relation so that $\theta(E) = \gamma_0 + \gamma_1 \cdot E$:

$$Skills^{ac} = \alpha + \delta \cdot E + \theta(E) \cdot G + \varepsilon = \alpha + \delta \cdot E + \gamma_0 \cdot G + \gamma_1 \cdot (E \cdot G) + u$$

As is clear from the discussion in the previous section, E contains "skills" of the family and other factors important for the child's skill formation, as well as direct investments and prenatal environmental factors, and G constitutes the genetic endowments of the

[4] Let us also abstract from the fact that we can observe a vector of skills for the child but not for the parent.
[5] If we extend I to include government investments in child's stock of skills, we can also think about effects through reforms that impact child's skill directly.

child. We will use years of education of the adoption parents to proxy for E and years of education of the biological parents to proxy for G.

$$Skills^{ac} = \beta_0 + \beta_1 \cdot Ed^{ap} + \beta_2 \cdot Ed^{bp} + \varepsilon$$

$$Skills^{ac} = \beta_0 + \beta_1 \cdot Ed^{ap} + \beta_2 \cdot Ed^{bp} + \beta_3 \cdot Ed^{ap} \cdot Ed^{bp} + \varepsilon$$

We are interested in estimating the parameters δ, θ, γ_0 and γ_1 through estimation of these two regression equations. Note first that we have to limit ourselves to estimating associations, as causal effects are unattainable simply because we are using proxies for E and G. Under ideal circumstances (see the assumptions stated below), an OLS estimate of β_1 will at best capture the effect of the education of the adoptive parent's education (Ed^{ap}), and of other characteristics in the adoption family correlated with Ed^{ap}. The same reasoning is true for β_2 (and β_3).

To arrive at unbiased estimates of these parameters we need to impose a few assumptions: i) Children are given up for adoption early and will be moved to the adoptive family shortly thereafter, ii) Prenatal and pre-adoption postnatal environment are not correlated with the genetic endowment of the child and not correlated with the postadoption environment of the child. iii) Children are randomly assigned to adoptive families, and iv) Adopted children (and the adoptive parents) do not interact with the biological parents post adoption.

Regarding assumption ii): Since adoption took place a few months after the child was born, years of education of the adoptive parents will only capture environmental factors post adoption, and years of education of the biological parent will, in addition to genetic endowment, also capture prenatal environment and early postnatal environment. We will argue that as the biological father of the adopted child had limited involvement during mother's pregnancy and during infancy of the child, years of education of the biological father is a better proxy for the genetic endowment of the child.

We will return to the other assumptions below, when we discuss sample restrictions and selective placement, but in shortwe will: i) show that most adopted children are adopted very early and move to the adopted families fairly quickly, iii) control for main effects of both biological and adoptive parents' education and simulate the likely direction and size of the remaining bias in the presence of positive selection (on unobservables) of children to adoptive families, and iv) restrict the sample of parents and children so as to limit the possibility for interactions.

Another issue specifically relevant for estimating the interaction term is that if there are non-linear effects present, but not included in the estimated model, they might be captured by the interaction term. We will therefore i) include quadratic terms in some of the estimations, and ii) estimate models using binary proxies for E and G.

Note also, that the regression-based adoption approach very easily is extended to estimate the importance of $E \cdot G$ interactions, compared to the variance decomposition approaches using data on twins.[6]

4. Institutions, Data and Descriptive Statistics

[6] Relate also to the work by Turkheimer et al (.).

4.1 Institutional background: Adoptions in Sweden 1930-1975

There are several adoption studies for Sweden, looking at varying outcomes, which present the institutional background for domestic adoptions in Sweden (see, for instance, Lindahl et al, 2016, for a lengthy discussion of adoptions in Sweden during a similar period as in this period).[7] Here we just discuss this shortly with a focus on the following issues: Who gave up a child for adoption? Who did adopt? What were the legal rights of the adopted child? How was children matched to adoptive families? What was the experience of the child before adoption?[8]

The mothers who put their children up for adoption were typically young (30 % were teenagers), unmarried and had low income. Many biological fathers were "unknown". Although social workers tried to track down fathers, about 58 % of fathers are not recorded in our data. Mothers often contacted social authorities during pregnancy and typically made the formal decision of giving up the child when she had recovered from the delivery (she could not do so before). Unmarried fathers had no formal say in the adoption decision.

Adoptive parents should fulfill a number of requirements. They should be married, be at least 26 years of age and not have children of their own (although there are quite a lot of exceptions to this in the data). The adoptive father should have a stable income and adoptive mothers were expected to stay at home.

A basic principle of Swedish adoption laws have always been that an adoption should be "in the best interest of the child." This meant that adoptions and the choice of host family should be motivated by concern for the child. Adoptive children received same legal status as own children and formal connections to biological parents were broken. Those responsible for the adoption process were local social authorities. They handled the match between biological mothers who wanted to give up child for adoption and adoptive parents who wanted to adopt. Adoptive parents were not selected at random. In fact, the adoption agencies were instructed to match adoptive parents to biological parents' mental abilities (if possible) and physical appearances (if possible). However, the information available to the social worker were likely quite limited (Björklund, Lindahl and Plug, 2006). One concern, for our study, is the degree of non-random matching of adopted children to adoptive families and to what extent this has changed over time (we return to this issue below where we discuss evidence on selective placement and how it has evolved over time).

Newborn children that were given up for adoption rarely stayed with their biological parents. In fact, about 87 (94) percent of these were given up before they were 3(6) months old (Black, et al., forthcoming). Children were placed in different forms of care such as special nursery home, home for unwed mothers, temporary foster care or the home of the adoptive family. The child was placed in the adoptive family on trial basis. Placement was recommended before 6 months of age. The trial lasted 3-6 months and if the trial went well, parents could apply for formal adoption. The formal decision of adoption was then taken by the court. Björklund, Lindahl, Plug (2006), who uses an adoption sample of children born 1962-1966, are able to infer that about 80% of the sample of adopted children was adopted before they became 6 months old. It is not

[7] For a more lengthy discussion using original sources see Bohman (1970) and Nordlöf (2001).
[8] Maybe a bit about possible changes in rules etc over time.

possible to infer if this has been constant during the whole period that we study, although we don't think there are any reasons to expect why it would be markedly different.

4.2 Data and definition of key variables

The original data set consist of the population of Swedish-born children between 1932 and 1970.[9] The multigenerational registry is used to match the children to their biological and adoptive parents. The multigenerational registry covers individuals born 1932 or later, and their parents, although the coverage is quite poor for the first two, three birth cohorts. Parents and children are available in the register as long as they have survived January 1st 1961 and lived in Sweden at any time after that date.. We use the sample of adopted children and their biological and adoptive parents in our main analysis, and also compare it to results from using a reference sample of biological (non-adopted) children reared by their biological parents.

We use data on educational attainment from the censuses 1960, 1970 and 1990 for parents and from the censuses and administrative registers 1985-2009 for the children. All educational attainment data is reported in levels and we have converted them to years of education based on highest educational attainment observed for the individual at (around) age 40. The quality of the educational information for parents derived from the censuses has improved significantly over time. Hence, preference is given to later censuses.[10] Educational reforms have also increased the number of years of compulsory schooling, and an increased intake to high school and higher education has been observed as well. To make years of education comparable over time, we standardized it by year of birth and gender in the full population. We have also constructed a binary variable for having at least academic high school track (at least 12 years of education) to be used in some estimations.

We use data on cognitive and non-cognitive skills at age 18 from the military draft records, which is available for men born 1951-1970. Cognitive ability at age 18 is based on written tests for logical, spatial, verbal and technical abilities. We use the standardized sum of test scores. Non-cognitive ability at age 18 is based on assessment by certified psychologist through semi-structured interviews following a manual. It is a standardized composite measure of social-interactive ability, and has been shown to be highly predictive of future earnings (Lindqvist and Vestman, 2011).[11]

4.3 Sample restrictions and descriptive statistics

We require the adopted children to have been adopted by two parents (where neither is the biological parent), and that both the biological parents can be identified. The adoptees should have been born in Sweden. Between 1932 and 1970, there are 23,563 individuals born in Sweden, to which the multigenerational registry can match biological mothers, adoptive mothers and adoptive fathers. This means that the individuals and the

[9] Note that there are Swedish born adoptees also after 1970. However, these are few and comes from very non-typical families. Shortly, the supply of unwanted children decreased sharply during these years as abortions becomes legal and contraceptives widely available. The demand for children to adopt was however unchanged, which is why when the decrease in domestic adoptions is seen, a comparable increase in foreign adoptions is observed. As we are not able to identify the biological parents of foreign adoptees we only use domestic adoptees in this paper.

[10] In 1960, only a few levels were available and over 85) percent have the lowest level(?). If a parent has survived to 1970, educational data for 1970 is used over 1960, and so forth.

[11] See also Carlstedt, 2000.

parents need to have survived until January 1st 1961 and lived in Sweden at any time after that date. Further requiring the biological fathers to be identified the sample decreases to 12,227 children. Eliminating those families were none of the adoptive parents is a biological parent decreases the sample to 9,944. Data from the educational and birth registers must be available, but the coverage is almost 100%, so the sample is now 9,803 children.

In addition we require all individuals to have survived long enough to having been able to complete their education (26 years of age). The adoptive mother should be at least 24 years of age and the biological father at most 63 years of age at the time of birth of the adopted child. This decreases the sample to 9,043 children. Especially for later cohorts, we are able to infer how many children that are adopted by relatives (either by a grandparent, an uncle or an aunt). It turns out to be almost 200 individuals, decreasing the sample to 8,856 children.

In order to guarantee that the adoptive parents indeed capture the family environment of the adopted child we also require both adoptive parents to have survived until the child is 15 years of age and to have lived with both adoptive parents between ages 11 and 15. This further limits the sample to 7,981 children.

We also impose several restrictions to limit the possible selective placement of children to adoptive parents. Since we have detailed information on residential location bi-decennially from 1960 and birth parish for every year, we impose the following restrictions on the sample.[12] First, the biological parents should not live in the same parish as the adopted child when the child is between 11 and 15 years of age, and not be born in the same parish as any adoptive parent. Second, the adoptive parents should not live in the same parish as the adopted child were born in and also not live in this parish at the time as the child was born. This gives us the sample that we use in the estimations, which consists of 6,788 adopted children.

Descriptive statistics

TBA

4.4 Selective placement

Ideally, adopted children should be randomly allocated to adoptive families. However, there are reasons to be concerned about the existence of adoptions of relatives to the biological family as well as local matching of children to families, which might result in non-random allocation. As we discussed in the previous section, we therefore impose a number of restrictions to the sample with respect to grandparent and cousin adoptions, as well as to the residential location and birth of the parents and children. We note, however, that the association of years of education of adoptive and biological parents of adoptees, a measure of selective placement used in Björklund, Lindahl and Plug (2006), only decrease marginally when we impose these restrictions.

[12] The fact that we only have information on residential location from 1960 make some of the restrictions less binding for the first 10-15 birth cohorts. However, the fraction of the overall sample born during these years is anyway quite small.

As we discussed in section 4.1, the guidelines for the social workers to match children to families on observable traits suggest another reason for non-random assignment. Using the sample of non-related adoptions and with the locations restrictions imposed as well, we show the correlation coefficients for years of education of the adoptive and biological mothers and fathers over time in Figure 1. The education variables are standardized by year of birth and gender. As can be seen the correlations are relatively high, but in line with the results reported in Björklund, Lindahl and Plug (2006) for 1962-1966. The correlation coefficients are around 0.2 for much of the period, although lower for mothers during the first half of the period. Hence, there is still a high degree of selective placement of adopted children to adoptive families remaining. We interpret this result as non-random matching by adoption agencies being the main reason for selective placement.

The main issue for us is how and when we expect our results to be affected by selective placement. First, if we are interested in inferring how estimates of main or interaction effects have changed over time, we are not too worried about selective placement, as long as it has remained roughly constant over time. As we see in figure 1, it appears to be roughly constant from the mid-1950s to the end of the 1960s, at least for fathers, where a high fraction of our adoption sample was born.

Second, as we include years of education of both the adoptive and the biological parents in the estimations, we only need conditional random assignment. Hence, what we are worried about is matching on unobservable characteristics, and how this will affect our results. This can be seen as a problem of measurement error in the adoptive and biological parent's years of education variables, where the measurement errors are positively correlated.[13] For the additive separable model (without an interaction term), imposing uncorrelated measurement errors, this is modelled in Björklund, Lindahl and Plug (2006), which conclude that the bias is probably quite small. If we include an interaction term, and simulate the bias due to measurement error, we get that the estimates for years of education of an adoptive parent, years of education of a biological parent and the interaction between these two variables, leads to all estimates being biased towards zero and the bias in the interaction term being about twice as large (in percentage terms) as the bias of the main effects.[14]

5. Results

5.1 Estimations of the intergenerational transmission in the population

Table 1 reports estimates of the intergenerational transmission of skills using the population of biological children. We use samples of sons and daughters born between 1932-1970 for education and sons born 1951-1970 for cognitive and non-cognitive skills. All variables are standardized within the population to have mean zero and a standard

[13] One can also think of a more realistic model were the measurement error of the biological (adoptive) parent's education is positive correlated with the true value of the adoptive (biological) parent's education.

[14] That classical measurement error in several right-hand side variables bias estimates for all variables towards zero is well known. Since we impose a positive correlation between the measurement errors, it is not very surprising that this results still holds. Also, that the bias of the interaction terms becomes larger makes a lot of sense, sine the measurement error is amplified from taking the product of two variables, where both are measured with error.

deviation equal to one. In the first panel, we report the results from a model where mother's and father' education are entered separately, and in the second panel, we use a model where we use the average of mother's and father's education. All regressions include an intercept and controls for year-of-birth fixed effects for the children and a quadratic function of both parent's year of birth. Standard errors are clustered on the biological mother.

Figure 1 shows trends in the intergenerational transmission of education using all children born 1945-1970. We show results for mothers and fathers separately and for both parents. We also compare the trend of the association for all parents with biological children to the trend using only the sample of adopted children and adoptive parents. The trends are always based on moving averages of estimates for 5-year periods. The first point is for 1945-1949, the second point for 1946-1950, and so forth up to 1966-1970. As the number of adopted children born before 1945 is small (less than 300 children for the whole period), we limit the period to 1945-1970.

We see that the importance of mother's education has increased over time, whereas the reverse is true for father's education. Overall, the intergenerational transmission of education has decreased somewhat up to the second half of the 1950s and increased slightly after that. The magnitude of the change is not very large though: it goes from about 0.42 in the early years to about 0.38, and then reverses to 0.40 at the end of the period. A similar pattern is observed for adoptive families. The U-shape pattern seems more pronounced for adoptives, but it should be kept in mind that the confidence bands are also quite large for this sample. The similar pattern at least suggests that results using the adoption sample, when we decompose the intergenerational association into pre- and post-birth factors, are likely to be representative of the full population.

5.2 Estimations of the importance of pre-and post-birth factors for the intergenerational transmission of skills

Table 2 reports estimates for the intergenerational transmission of skills using the sample of adopted children. We use samples of adopted sons and daughter born between 1932-1970 for education and sons born 1951-1970 for cognitive and non-cognitive skills. All variables are standardized against a population having mean zero and standard deviation one. The estimated models and the structure of the table is similar to table 1, with the difference that we now report the results from a model where adoptive and biological mother's and father' education are entered separately, and in the second panel, from a model where we use the average of adoptive mother's and father's education and the average of biological mother's and father's education.

The estimated effects of parents' education in the pooled sample of children show a positive association with child's education for all parental types, but the association is strongest for biological mother's education and weakest for adoptive mother's education. These results are qualitatively similar as in Björklund, Lindahl and Plug (2006), even though their estimate for adoptive mother's education was smaller in magnitude and statistical insignificant. Estimating separate models for sons and daughters (column 4 and 5), reveals a stronger association with the biological parents for daughters than for sons, and a stronger association with the adoptive parents for sons than for daughters.

Turning to models where we associate cognitive and non-cognitive skills for adopted sons with the education of their adopted and biological parents we find a similar pattern as for education of sons. The associations with cognitive skills are stronger than for non-cognitive skills, and for non-cognitive skills the association with adoptive mother's education is statistically insignificant.

Looking across columns, a general pattern is that estimates for biological mother's education are larger than the estimates for biological father's education. This is consistent with prenatal (and very early postnatal) environmental effects being captured to a higher degree from biological mothers than from biological fathers. This is especially true for adopted children as the involvement of biological fathers during the pregnancy and shortly thereafter typically is very limited. Hence, an estimate for biological father's education better capture the genetic endowment, compared to the estimate for biological mother's education, which capture both genetic endowment and the prenatal environment. A similar result was found in Björklund, Lindahl and Plug (2006), but the difference was so small (and statistically insignificant for years of education) that they concluded that prenatal environmental effects were relatively small. In the present paper the difference in the associations between biological mother's and biological father's education is large enough (between 10-50%) that we think there is evidence in favor of a large role for prenatal environment. This is also in line with several studies which often have found very large negative effects on children's outcomes from having experienced negative environmental shocks to the mother during pregnancy.[15] We will therefore, when we look at how the environment and genetic endowment interacts, mostly use the biological father's education as a proxy for the genetic endowment of the adopted child.

In the second panel, we use the average of the adoptive and biological parent's education, and consistently find larger associations with biological parent's education than with adoptive parent's education. The magnitude of the estimates show that a standard deviation (S.D.) higher education for all parents is associated with about 0.4 S.D. units higher education for the child, with about 40% coming from the adoptive parents and 60% form the biological parents. The overall associations are similar for cognitive skills, but lower for non-cognitive skills.

Next, we investigate trends in pre-birth and post birth factors for explaining the intergenerational transmission of education. Figure 2 show trends for the association of children's education and the education of the biological and adoptive mothers and fathers, whereas Figure 3 show trends for the association of children's education with the education of the biological and adoptive parents (defined as averages of mothers and fathers, as in Table 1). In both figures, we compare these trends by parental types to the sum of the estimates for all parents (the upper line in both figures). The trends are, as in Figure 1, based on moving averages of estimates for 5 year periods.

As was shown in Figure 1, for all parents of adoptees, there seems to be a downward trend until around 1960, when it reverses and increase again. Looking separately for parental types, it seems like the overall pattern is driven by biological and adoptive fathers' education. However, the pattern is quite erratic as the confidence bands are wide. To increase precision we in figure 2, show trends where we have separate the parents into biological an adoptive parents. It is then clear that the overall U-shaped pattern almost entirely is explained by the adoptive parents. This suggests that the role of the post-birth environment for the intergenerational transmission of education has changed over time, whereas the role for pre-birth environment has been roughly

[15] List a survey and the most important studies.

constant. Below we will investigate if changing role of post-birth environment partly is due to “nature-nurture” interactions or if the work independently of genetic endowment.

5.3 Estimations of the importance of interaction effects between pre-and post-birth factors for the intergenerational transmission of skills

Table 3 reports estimates for the intergenerational transmission of skills using the sample of adopted children from models including both main and interaction effects. We start with estimating a general model which include four interaction effects, birth mother’s education interacted with adoptive mother’s and adoptive father’s education and birth father’s education interacted with adoptive mother’s and adoptive father’s education. We report F-tests of three combination of interaction effects: all interactions equal to zero, birth father’s interactions equal to zero and birth mother’s interactions equal to zero.

The estimated effects of the interaction effects for education in the pooled sample of children show negative interaction effects, which are driven by those for the biological fathers. The interaction effects for birth mothers are never statistically significantly different from zero. Turning to the other columns, results are confirmed for education and cognitive skills of sons, but not for education for daughters or non-cognitive skills for sons. The difference between results for biological mothers and fathers suggest at least two things: First, genetic and post-birth environmental factors are substitutes in the production of skills. Second, prenatal and post birth environmental factors are complements, and the complementarity is strong enough so as to making the sum of genetic and prenatal environmental factors neither substitutes or complements with post-birth environment. Looking only at biological mothers, we would wrongly infer that the simplest linear additive separable model is an accurate representation of the child’s skill production function.

Because we are worried about that the biological mother’s education also captures prenatal environment, we also show estimates from models without this variable. Results from estimating of such models, shown in Tables 4 and 5, pretty much confirm the results shown in Table 3.

Figure 5 show trends in estimates from the model underlying Table 5. We see that the main effects from adoptive parents’ and the biological father’s education all show a downward, whereas the interaction effects has increased over time.

6. Sensitivity analysis

TBA

7. Conclusions

TBA

References *(Incomplete list)*

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FIGURE 1

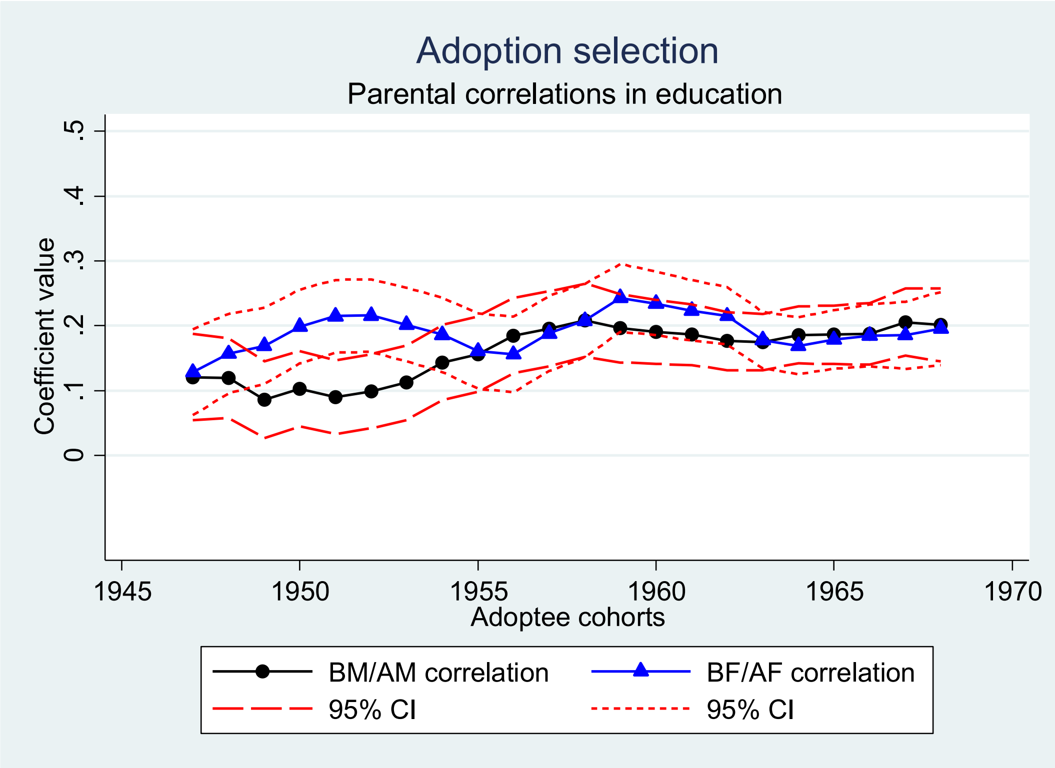


FIGURE 2

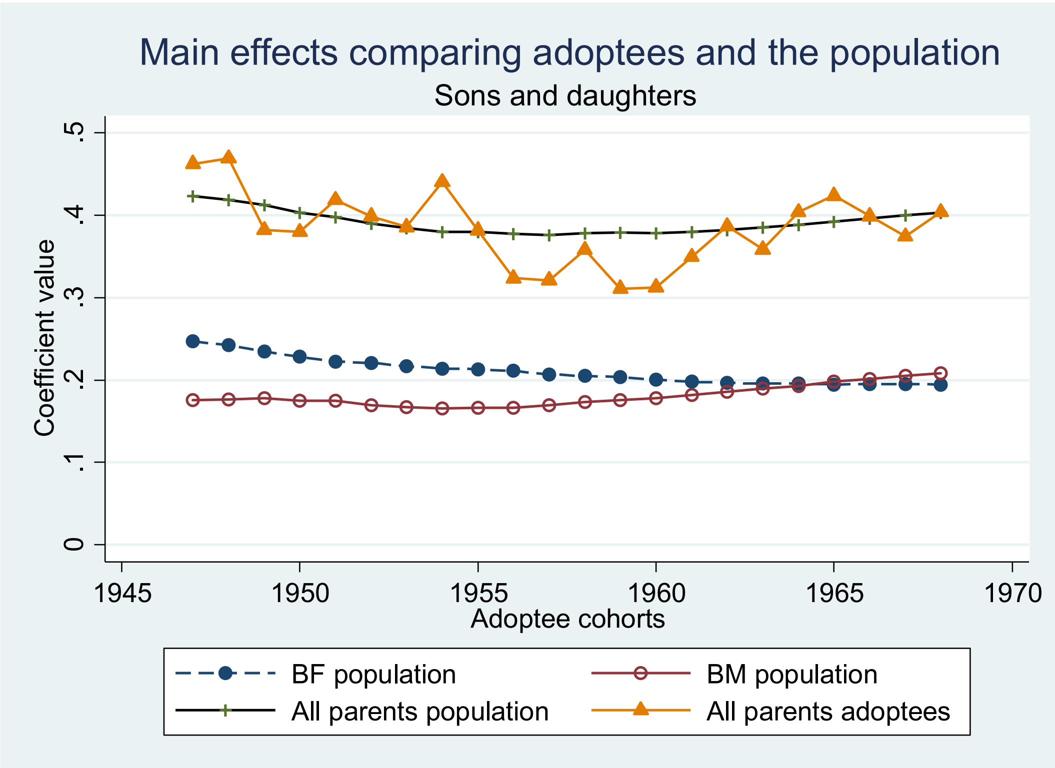


FIGURE 3

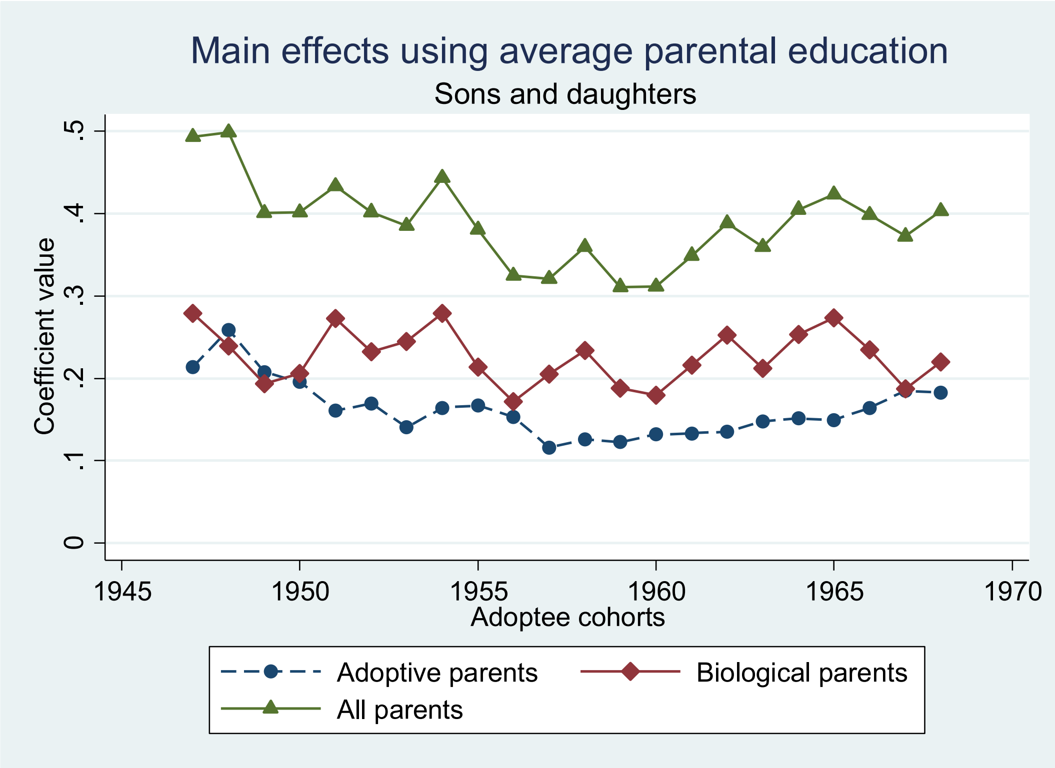


FIGURE 4

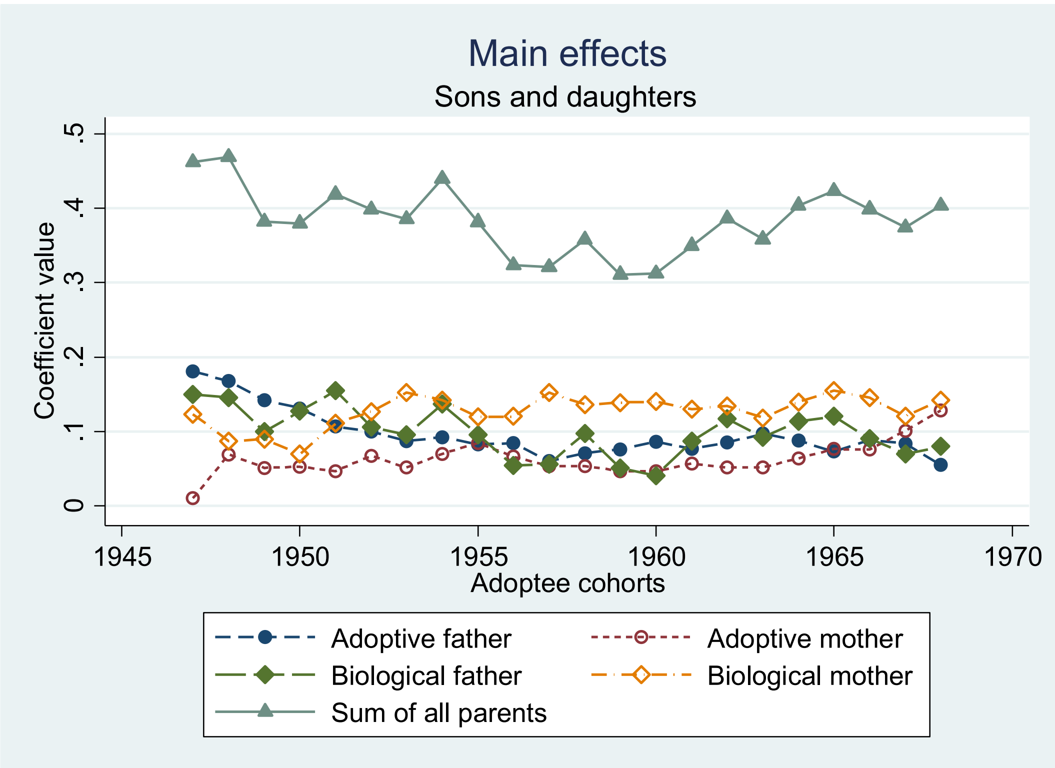
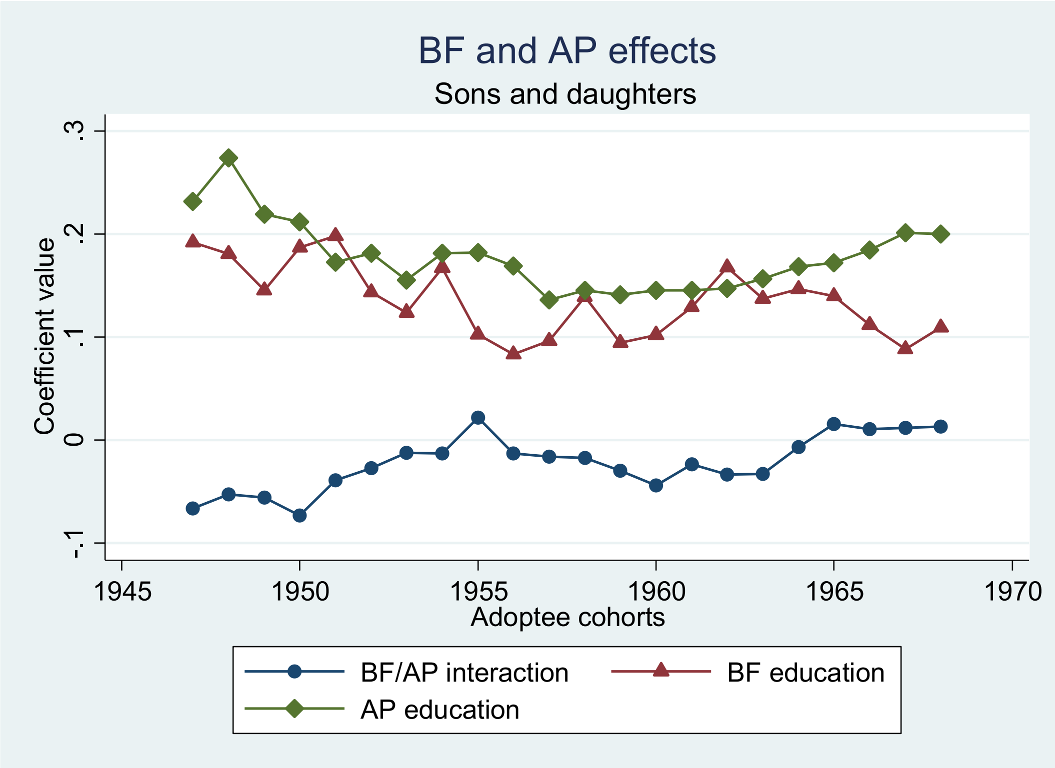


FIGURE 5


BF and AP effects
Sons and daughters
Coefficient value
-.1
0
.1
.2
.3
1945
1950
1955
1960
1965
1970
Adoptee cohorts
BF/AP interaction
BF education
AP education

Population estimates

TBA

Table 2
Main effects

	Pooled	Sons			Daughters
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Standardized education	Cognitive skill	Non-cognitive skill	Standardized education	Standardized education
All parents separately					
AF education	0.104***	0.119***	0.112***	0.108***	0.0952***
	(0.0106)	(0.0198)	(0.0216)	(0.0150)	(0.0153)
AM education	0.0573***	0.0692***	0.0302	0.0689***	0.0492***
	(0.0110)	(0.0196)	(0.0211)	(0.0157)	(0.0155)
BF education	0.0976***	0.137***	0.0560**	0.0770***	0.123***
	(0.0149)	(0.0256)	(0.0269)	(0.0205)	(0.0217)
BM education	0.127***	0.169***	0.115***	0.113***	0.135***
	(0.0154)	(0.0296)	(0.0307)	(0.0224)	(0.0210)
R^2	0.092	0.102	0.053	0.099	0.102
Average parental education					
AP education	0.163***	0.189***	0.142***	0.179***	0.146***
	(0.0110)	(0.0192)	(0.0211)	(0.0158)	(0.0151)
BP education	0.225***	0.307***	0.172***	0.188***	0.261***
	(0.0194)	(0.0360)	(0.0362)	(0.0276)	(0.0267)
R^2	0.091	0.101	0.051	0.098	0.101
Observations	6,788	2,493	2,452	3,538	3,250

Covariates include year of birth fixed effects for the adoptees as well as linear and quadratic controls for parents' year of birth.
Education is standardized with respect to year of birth and gender.
Standard errors are clustered on the biological mother.

Table 3
Main effects and all interaction effects

	Pooled	Sons			Daughters
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Standardized education	Cognitive skill	Non-cognitive skill	Standardized education	Standardized education
AF education	0.105***	0.120***	0.111***	0.105***	0.0980***
	(0.0108)	(0.0209)	(0.0227)	(0.0156)	(0.0154)
AM education	0.0548***	0.0536**	0.0333	0.0708***	0.0453***
	(0.0115)	(0.0210)	(0.0223)	(0.0163)	(0.0162)
BF education	0.118***	0.175***	0.0712**	0.100***	0.141***
	(0.0164)	(0.0276)	(0.0294)	(0.0219)	(0.0247)
BM education	0.125***	0.198***	0.108***	0.122***	0.122***
	(0.0170)	(0.0306)	(0.0348)	(0.0239)	(0.0240)
BF/AF interaction	-0.0295**	-0.0236	-0.0391	-0.0442**	-0.0194
	(0.0123)	(0.0228)	(0.0250)	(0.0185)	(0.0169)
BF/AM interaction	0.00618	-0.0249	0.0211	0.0187	-0.00115
	(0.0140)	(0.0258)	(0.0274)	(0.0206)	(0.0195)
BM/AF interaction	0.0193	-0.00386	0.0174	0.000169	0.0338*
	(0.0130)	(0.0288)	(0.0278)	(0.0191)	(0.0183)
BM/AM interaction	-0.0206	-0.0485	-0.00768	-0.0151	-0.0229
	(0.0133)	(0.0296)	(0.0299)	(0.0185)	(0.0183)
$P > F_{(1,2,3,4)}$	0.055*	0.014**	0.6149	0.0877*	0.3111
$P > F_{(1,2)}$	0.03**	0.051*	0.2825	0.0416**	0.3872
$P > F_{(3,4)}$	0.226	0.117	0.8193	0.5931	0.1732
Observations	6,788	2,493	2,452	3,538	3,250
R-squared	0.093	0.108	0.054	0.102	0.103

Covariates include year of birth fixed effects for the adoptees as well as linear and quadratic controls for parents' year of birth. Education is standardized with respect to year of birth and gender. Standard errors are clustered on the biological mother.
P-values in brackets […] are F-tests of interaction coefficients from regressions that include squared main effects.

Table 4
BF, AF and AM effects

	Pooled	Sons			Daughters
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Standardized education	Cognitive skill	Non-cognitive skill	Standardized education	Standardized education
BF education	0.138***	0.201***	0.0868***	0.116***	0.165***
	(0.0163)	(0.0273)	(0.0290)	(0.0215)	(0.0247)
AF education	0.111***	0.135***	0.117***	0.113***	0.104***
	(0.0107)	(0.0198)	(0.0220)	(0.0152)	(0.0154)
AM education	0.0639***	0.0704***	0.0379*	0.0788***	0.0538***
	(0.0113)	(0.0201)	(0.0216)	(0.0161)	(0.0160)
BF/AF interaction	-0.0226*	-0.0226	-0.0345	-0.0434**	-0.00726
	(0.0119)	(0.0212)	(0.0251)	(0.0181)	(0.0160)
BF/AM interaction	0.00389	-0.0316	0.0241	0.0193	-0.00668
	(0.0135)	(0.0260)	(0.0272)	(0.0203)	(0.0186)
$P > F_{(1,2)}$	0.104**	0.02**	0.388	0.042**	0.728
Observations	6,788	2,493	2,452	3,538	3,250
R-squared	0.082	0.092	0.049	0.093	0.090

Covariates include year of birth fixed effects for the adoptees as well as linear and quadratic controls for parents' year of birth.
Education is standardized with respect to year of birth and gender.
Standard errors are clustered on the biological mother.

Table 5
BF and AP effects

	Pooled	Sons			Daughters
	(1)	(2)	(3)	(4)	(5)
VARIABLES	Standardized education	Cognitive skill	Non-cognitive skill	Standardized education	Standardized education
BF education	0.136***	0.202***	0.0845***	0.112***	0.166***
	(0.0163)	(0.0275)	(0.0290)	(0.0213)	(0.0248)
AP education	0.177***	0.206***	0.154***	0.193***	0.160***
	(0.0109)	(0.0193)	(0.0209)	(0.0155)	(0.0154)
BF/AP interaction	-0.0198*	-0.0529***	-0.0107	-0.0275*	-0.0129
	(0.0118)	(0.0196)	(0.0222)	(0.0159)	(0.0176)
Observations	6,788	2,493	2,452	3,538	3,250
R-squared	0.081	0.091	0.046	0.092	0.088

Covariates include year of birth fixed effects for the adoptees as well as linear and quadratic controls for parents' year of birth.
Education is standardized with respect to year of birth and gender.
Standard errors are clustered on the biological mother.