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ABSTRACT

Critical Periods During Childhood and Adolescence: A Study of Adult Height Among Immigrant Siblings*

We identify the ages that constitute critical periods in children's development towards their adult health status. For this we use data on families migrating into Sweden from countries that are mostly poorer, with less healthy conditions. Long-run health is proxied by adult height. The relation between siblings' ages at migration and their heights after age 18 allows us to estimate the causal effect of conditions at a certain age on adult height. Moreover, we compare siblings born outside and within Sweden. We apply fixed-effect methods to a sample of about 9,000 brothers. We effectively exploit that for siblings the migration occurs simultaneously in calendar time but at different developmental stages (ages). We find important critical periods at ages 5/6 and 9. The effects are stronger in families migrating from poorer countries but weaker if the mother is well-educated.

JEL Classification: I10, I12, I18, F22, I20, I30, J10, N30

Keywords: early-life conditions, migration, parental education, adult health, height retardation, age, fetal programming, developmental origins

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1. Introduction

Recently, evidence has accumulated that conditions early in life influence health at higher ages. Children born under adverse economic and nutritional conditions or with a high disease exposure in the birth year have higher morbidity and mortality rates later in life.[1] Most of the evidence concerns conditions in utero or shortly after birth. Much less is known about conditions at other childhood ages. It is conceivable that the age interval from birth to adulthood contains so-called critical periods during which sub-optimal conditions have particularly adverse long-run implications for health later in life. One reason for the focus on conditions around birth is that the physical development is strongest in the first birth year, so that the physical state later in childhood is partly determined by conditions earlier in life. Accordingly, conditions later in childhood may be confounded by conditions around birth.

More in general, the empirical analysis of long-run effects of early-life conditions is hampered by two constraints. First, the use of observations of health or mortality at high ages entails that only cohorts born a long time ago can be studied. Secondly, early-life conditions need to be exogenous, or otherwise one needs to deal with their endogeneity. The first constraint can be dealt with by using adult height as a proxy for health outcomes later in life insofar as the latter are affected by conditions before adulthood (Steckel, 1995, 2008, Silventoinen et al., 2006). An adult individual's height has been denoted "probably the best single indicator of his or her dietary and infectious disease history during childhood" (Elo and Preston, 1992). Adult height has therefore been widely utilized as a marker of standards of living in the past, assessing secular trends and socioeconomic variations in childhood conditions (Silventoinen 2003; see also the literature discussion in Section 2).[2]

In this study, we explore the shift in living conditions for children migrating from different parts of the world to Sweden, a relatively wealthy nation in which people's stature and longevity are among the highest, and poverty rates among the lowest, in the world. Migration is a discrete event, potentially permanently shifting the standards of living. We analyze the association between age at migration and subsequent adult height among brothers in a family-fixed-effects framework. Family migration occurs for brothers usually at the same point in time but at different developmental stages, yielding the opportunity to consider

[1] See the literature overview in Section 2.
[2] On an individual basis, height has also been found to be associated with a range of cognitive and economic outcomes later in adulthood, such as cognitive ability, education, earnings and social position (Marmot, 1995, Mackenbach, 1992, Meyer and Selmer, 1999, Abbott et al., 1998, Silventoinen et al., 1999, Rashad, 2008, Case and Paxson, 2006, 2008).

critical periods during childhood for the development of adult stature. Moreover, we compare the adult height of brothers born outside and within Sweden, allowing us to also consider the role of early life conditions at the pre-natal stage. The fixed-effects approach effectively deals with the endogeneity of background characteristics. Brothers obviously differ genetically, but their genes are sampled from the same ancestral "gene pool", implying that any genetic height variation is randomly distributed between them. Besides genetic factors, the fixed-effects approach also neutralizes additive height effects of other unobserved heterogeneity between families, like heterogeneity in terms of location, family structure, traditions, values norms, habits, wealth and household practices, all potentially being connected to age at migration and nutrition, disease load, and, ultimately, height. For example, by comparing adult height of two brothers who immigrated at ages 11 and 13, one can isolate the effect of exposure to Swedish living conditions at ages 11-13 (compared to conditions in the country of origin) on adult height and thereby on adult health. It is conceivable that migration is induced by a particularly bad health of the youngest brother, in which case the conditions for a fixed-effects approach based on all brothers would be invalid. We can deal with this by excluding the youngest brothers and perform the estimation with data from families with at least three sons.

The analysis is relevant from various points of view. The most general relevance concerns the identification of critical age periods in human development. Knowledge of this has potentially important policy implications. If adverse conditions at a certain age before adulthood have particularly severe long-run effects on health (and thereby on economic outcomes like earnings) then the value of life is reduced for those affected, and this would increase the benefits of supportive policies for groups of individuals exposed to such conditions. Notice that the long-run effects of conditions during childhood on health in adulthood may be smaller than the instantaneous effects of current conditions, but the former exert their influence over a longer time span. Moreover, the presence of a time interval between childhood and the manifestation of the effect implies that there is a scope for identification and treatment of the individuals at risk. Specifically, young individuals exposed to adverse conditions at a critical age can be targeted for a screening of health markers and predictors, and those who have unfavorable test values are amenable to preventive intervention.

The analysis in this paper also has a more specific relevance concerning immigrant families. If they bring along children with ages just above a critical period, then such children will be at a higher risk of future health problems, and one may reallocate funding towards preventive health care for such children. Similarly, the analysis is relevant for adoption policies. Adopted children from poor countries with an adoption age above a critical period will also be at a higher risk of health problems, and therefore they may need special health care after adoption.

The data contain the full population of immigrants living in Sweden in the year 1999 who, in between 1984 and 1997, had been subjected to the mandatory enlistment test for military service. Specifically, we use merged registers from Statistics Sweden (including information on birth date, date of immigration, country of birth, and family structure, including birth order) and the Swedish National Service Administration (“Pliktverket” in Swedish). In principle, every male Swedish citizen enlists for the military when turning 18, and hence, we have a measure of their height/stature at a similar age.

We may rank the countries of origin by their wealth and their cultural distance to Sweden. We also observe the levels of education of the parents of individuals in our data. Most likely, the education levels capture economic well-being as well as health knowledge before migration. Interactions of the effect of age at migration with the region of birth and the parents’ levels of education allow us to shed some light on whether effects of adverse conditions during critical periods can be offset by wealth or by health knowledge. Also, the extent to which immigrants suffer from assimilation problems may depend on cultural distance and on age. By performing separate analyses by cultural distance we can, to some extent, separate such age-specific assimilation effects from the age effects due to critical periods. In all cases we control for birth-order effects.

The paper is organized as follows. In Section 2, we review the various bodies of literature that are connected to our study, notably the literature on long-run effects of early-life conditions and critical periods. Section 3 briefly describes the institutional context concerning military service and immigration in Sweden. In Section 4 we describe our data and the constructed variables, while Section 5 provides some descriptive patterns on age at immigration and height. Section 6 discusses the econometric methods we use and their underlying assumptions. We also provide a description in terms of treatment effects in a counterfactual framework. Section 7 presents our results. Section 8 concludes.

2. Related literature

2.1. Long-run effects of early-life conditions on health and mortality later in life

A number of bodies of work, from various disciplines, are relevant to our study. First, there is an expanding literature on the long-run effects of early-life conditions on late-life health outcomes. Secondly, there is a literature focusing on adult height as an outcome of events and conditions before adulthood. And third, there is a literature on the health of immigrants.

There are many surveys and meta-studies of the association between markers of early-life conditions (like birth weight) on the one hand, and health outcomes later in life on the other. For epidemiological and medical studies, see e.g. Poulter et al. (1999), Rasmussen (2001), and Huxley et al. (2007). Pollitt, Rose and Kaufman (2005) provide a survey and meta-study of the “life course” literature on causal pathways in which early-life socio-economic status (SES) is connected to morbidity and mortality later in life. Galobardes, Lynch and Davey Smith (2004) survey studies on early-life SES and cause-specific mortality in adulthood. See also Case, Fertig and Paxson (2005) and Case, Lubotsky and Paxson (2002), and references therein, for influential studies focusing on effects of economic household conditions early in life. Underlying explanations in this literature refer to nutrition, disease exposure, stress, and living conditions, as factors affecting the development of the child, and the extent to which these effects are exacerbated by schooling, career, family formation, and so on.

As noted in Section 1, almost all of this literature focuses exclusively on conditions at birth or shortly before birth as the starting point of a causal chain. Recently, interest has increased in long-run effects of conditions after birth. The survey in Eriksson (2007) focuses on medical early-life indicators measured after birth. Gluckman, Hanson and Pinal (2005) and Barker (2007) give overviews of the underlying medical mechanisms. We already pointed out that an association between conditions after birth and long-run outcomes can be confounded by conditions at birth. This poses a methodological challenge. In a study of the effects of conditions at ages 1-4 on over-all mortality later in life among those born in Denmark in 1873-1906, Van den Berg, Doblhammer and Christensen (2009) deal with this confounding issue by using the business cycle at ages 1-4 as exogenous idiosyncratic indicators of economic conditions at these ages. They find that the cycle at age 3 has a significant effect, in that those who reach the age of 3 during a recession have a significantly higher mortality rate later in life. This suggests that age 3 constitutes a critical period.

However, the business cycle displays autocorrelation over time, and since we can not rule out a priori at which ages it causes long-run effects, it is difficult to distinguish the effect of the cycle at age 3 from effects of the cycle at adjacent ages. Van den Berg and Gupta (2008), using data on individuals born in the Netherlands in 1815-1902, find that the average business cycle at ages 7-12 affects the individual mortality later in life for men (but not for women). However, this may be because the cycle at higher childhood ages may influence schooling decisions and subsequent occupational hazards, so that the net effect does not capture a direct effect of conditions at age 7-12 on health determinants. Notice that the use of adult height as an outcome precludes such indirect long-run effects.

2.2. Determinants of adult height

Now consider the literature concerning height as an outcome. We first mention some stylized facts on "normal" height development. Under reasonably good nutritional conditions and limited disease load, human height growth is rapid during infancy, slows down monotonically during childhood, and reaches a minimum until the adolescent growth spurt starts. This is illustrated by growth velocity rates (GVR, cm/year) for boys in Sweden in 1981, see Figure 1 (Werner and Bodin, 2006, Table IIa).[3] Over the first year of life GVR is 25.4. It decreases to about 5 at ages 10-12. Subsequently, it slightly increases to 7-7.5 at ages 12-15, thereafter slowly declining to zero past the age of 17. Overall, average birth height was 51 cm, while average final height (at age 19, in 1981) was 180.4 cm. Reviewing the literature, Silventoinen (2003) finds that about 20% of the variation in adult height, in post-war western civilizations, is due to environmental factors and the rest is attributable to heritable factors.

Across populations, environmental factors appear to account for most of the differences in average height (Steckel, 1995). The marked increase in body height in the developed world during the twentieth century occurred too rapidly to be attributable to genetic variation (Beard and Blaser, 2002). Moreover, despite ethnic diversities of average adult heights in the world, studies indicate that the genetic height *potential* is rather uniformly distributed, with children of different ethnical origin growing up under good circumstances on average becoming approximately equally tall (see Steckel, 1995).[4] It has been suggested

[3] The study population is a sample of all individuals born on the 15th of any of the months during 1981. It should be noted that including boys born abroad, with a birth weight lower than 2500 g, or with a chronic disease, has minuscule effects on the results: average height at birth and at age 19 are reduced from 51.0 to 50.7 and from 180.4 to 179.9 respectively.

[4] Komlos and Lauderdale (2007a, 2007b) analyze the stagnating US height growth, especially in comparison to the northern part of Europe, where average height currently surpasses that in the US. The US has higher per

that socio-economic variation in height depends on the social position of the family during childhood, the latter being a determinant of both early-life nutrition and social status of the offspring. Accordingly, children of wealthier families are less often subject to nutritional deficiencies, and higher educated parents, especially mothers, are more able (and inclined) to apply new information on child caring techniques. Upward social mobility is associated with height, while cognitive ability and IQ in childhood and adulthood have been positively linked to height in childhood, suggesting that socio-economic variation in height may also reflect inherent cognitive capabilities (Case and Paxson, 2008a, 2008b).

In Section 1 we already mentioned that adult height has been widely used in the literature as a marker of childhood conditions, and we cited studies showing that adult height is correlated to cognitive, economic, and health outcomes later in life. Height-growth velocity retardation is a bodily response to nutritional deficiencies during early life, childhood and adolescence. Natural experiments have been used to study the impact of extreme nutritional deficiencies at or before or after birth on cohort-average adult height. For example, Godoy et al. (2007) find that among native Amazonians, rainfall variability at ages 2-5 has a negative effect on adult height among women. Alderman, Hoddinott and Kinsey (2006) consider the effect of exposure to drought and war at ages 2 to 3 in Zimbabwe on height towards the end of adolescence. Like us, they also consider the difference between siblings' heights as the outcome of interest. They find significant effects of adverse conditions at ages 2 to 3.

Famines also provide natural experiments of nutritional deficiencies. Stanner et al. (1997) do not find any effect on adult height of having been exposed to intra-utero starvation during the Leningrad siege of 1941-44. Susser and Stein (1994), using data on cohorts born around the Dutch winter famine 1944-45, find that adult stature is susceptible to the postnatal but not the prenatal environment. Obviously, extreme conditions generate selection effects that tend to go in the opposite direction of the causal effect on height. Gørgens, Meng and Vaithianathan (2007) provide evidence for this based on data of families that experienced the Chinese famine around 1960.

In this respect it is also interesting that very low birth weight, assumed to capture adverse nutritional conditions in utero, is associated with short adult stature (Hack et al. 2003). This association between birth weight and adult height has also been found among

capita income, but disposable incomes and health care utilization are also more dispersed. Steckel (1995, 2008) suggests that inequality may affect average height negatively if height growth is a concave function of living standards and such utilization, i.e. if redistribution from the well off to the less fortunate implies that height is increased more for the latter than reduced for the former.

monozygotic twins, who share the same genes but may experience different in intrauterine environmental conditions (e.g. due to various positions in the womb), indicating that nutrition in utero affects adult height (Black et al., 2007). Given the selection effects that may occur in famine cohorts, and given the questionable exogeneity of birth weight, our study based on immigrant siblings' heights provides an informative complement to this literature.

A number of studies have found that the height effects of adverse conditions in early life can be mitigated by improvements in conditions up to adulthood. Notice that for our strategy to identify critical periods of development it is necessary that adult height is responsive to improvements in conditions at positive ages. Children from poor countries who are adopted by rich countries commonly show substantial catch-up growth. For example, Rutter et al. (1998) compare Romanian adoptees in the U.K. to native adoptees, and they find complete height catch-up at age 4 among the former if they entered the U.K. before the age of 6 months. Catch-up among those entering between 6 months and 2 years of age is also impressive but smaller. This suggests that the age interval between 6 months and 2 years constitutes a critical period. The meta-analysis by Van IJzendoorn, Bakermans-Kranenburg and Juffer (2007) concludes that height catch-up among children adopted within their first year is virtually complete in the sense that they become as tall as children in the destination country or environment, whereas catch-up of older children is incomplete. This suggests that adult height may not be a good marker for critical periods in the first months after birth. However, clearly, adoptee studies can not deal with the potentially endogenous selection of adoptees.

Height development catch-up may also occur if living conditions improve past the first few childhood years. Slave children in the US, who were among the shortest children ever measured in the world, possibly due to attenuated breastfeeding and limited food supply, displayed a strong increase in height growth past the age of 10 at which they entered the workforce, presumably because they started to receive better nutrition while working. Their ultimate adult height was only 1-2 cm shorter than contemporaneous Union Army troops (Steckel, 1987, 2008).

2.3. Health after immigration

In this subsection we cite some previous studies based on immigrants. Note that the adoptee studies mentioned in the previous subsection are also relevant here, to the extent that they consider cross-national adoptions.

Pak (2004) compares the height of adult escapees from North Korea to the height of adult South Koreans and shows that the divergence during the past 50 years moved in tune with the economic divergence of the two countries. Bates and Teitler (2008) provide a comprehensive literature overview of the health development of adult immigrants. They also list many studies showing that immigrant teenagers are more likely to develop health problems than natives. Obviously, all these studies are potentially affected by the same selection problems as adoptee studies.

Bates and Teitler (2008) also conjecture the existence of critical periods for cognitive and non-cognitive skill acquisition among adolescent immigrants. Identity formation and acquisition of a foreign language may be disproportionally more difficult for adolescents beyond a certain threshold age. Böhlmark (2008) provides some evidence for Sweden, by studying the effect of the number of years since immigration on the grades at graduation.[5] He infers from the estimation results that there is a critical period at age 10. This may transfer into adverse health-related behavior after this threshold, and to the extent that this behavior is ultimately revealed in adult height, such a causal pathway may show up in our estimates. This pathway is not driven by economic, nutritional, or health differences between Sweden and the country of origin, but by cultural barriers. By stratifying the analyses by country of origin, we can deal with this. Immigrants from Nordic countries do not face a major change in social and cultural context, and they do not face the same level of difficulty in learning Swedish as immigrants from outside of Europe. Many immigrants from Finland have learned at least some Swedish at school prior to migration. So we may assess whether jumps in the effect of age at migration on adult height vary with the social and cultural distance to Sweden.

[5] To our knowledge, Böhlmark (2008) is the only other study using a family-specific fixed effect in combination with migration data of children. His explanatory variable is the time from immigration to graduation.

3. Institutional context

3.1. Swedish society and health care

Sweden is a relatively wealthy country with 9.2 million inhabitants. Swedes are among the tallest in the world, especially the men in recent birth cohorts. Whereas the country fell in the OECD ranking of per capita GDP from 4 in 1970 to 12 in 2005, it has always had one of the 10 highest ranks in the UN Human Development Index (HDI) which incorporates life expectancy, adult literacy, educational attainment and GDP per capita into a composite measure. During the period 1960-75, the infant mortality rate per 1000 newborn decreased from 17 to 9, which implied that Sweden had the lowest infant mortality rate in the OECD. Since then, infant mortality rates have declined further, to 2.4 in 2005, which is a level similar to Iceland, Finland and Japan.

Sweden, together with Denmark, has also had the lowest estimated poverty rates and Gini coefficients since OECD started to make comparisons in the 1970s. Equality is also a prominent feature of the health care system which is based on universal compulsory national health insurance.[6] The aim of the health care system, as stated in the Swedish Health Care Act, is to provide "good health and health care on equal terms for the entire population". The ideal of equal access implies that health care fees are very low.[7] Similarly, there is a co-payment for drugs, but the annual expenditure for patients is capped. The financial constraints on parents' demand for children's health care are therefore small. Most children enroll in kindergarten before the age of 2 and, here as well as in school, they are served free lunches, typically based on potatoes, rice or pasta in combination with fish or meat.

3.2. Immigration

Post-war immigration to Sweden can be divided into two phases. The period 1945-1975 is dominated by labor migration of single men from other Nordic and from Southern European countries. Since then, refugee and tied-mover immigration have become more common, where the latter category consists of family-reunification immigration as well as immigration of family members who migrate simultaneously with the main immigrant. In 2000, 11.3% of

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[6] Health care is provided by 20 county councils. The county councils finance care, mainly via local proportional income taxes, and they also produce almost all health care.

[7] Fees for primary health care as well as specialist consulting were about 50-100 SEK in 1990, rising to 100-250 (depending on council) in 1997 (exchange rate: about 6-8 SEK/USD 1990-97). From 1998, children's (up to 18 years of age) primary health has been free of charge. Maternal care during pregnancy is free of charge in most counties.

the Swedish population was foreign born, of which one third had migrated from the Nordic countries, one third from other European countries, and one third from non-European countries. During the period 1980-2001, the Swedish admission board granted residence permits to about 730,000 people, of whom 8,000 were labor migrants, 275,000 were refugee migrants, and 354,000 were tied movers, while the remaining were guest students, adoptees and EU/EES–movers. In this study we focus on children in immigrant households, and these are tied movers. See Böhlmark (2008) and references therein for a description of the Swedish educational system and special arrangements for immigrant children.

The recorded date of immigration into Sweden is the date at which a residence permit is granted. This is not always the same as the date of migration from the source country. A family who immigrate as tied movers to a refugee and who immigrate simultaneously with the refugee might spend time in an asylum camp before receiving a residence permit. Rooth (1999) reports that among such cases, the average duration of intervening spells is typically less than half a year. Immigration due to family reunification does not involve an intervening spell.

Individuals with a residence permit may apply for Swedish citizenship. Advantages of naturalization are that it gives the individual a passport with which he/she can travel abroad, that it leads to the certainty associated with the right to live and work a rich and stable country, and that it gives the right to participate in elections. In our observation window, the time from the date of immigration until Swedish citizenship was about two years for families from Nordic countries and about 4 to 5 years for immigrants from other parts of the world. Some decide not to naturalize; this is particularly common if they migrate from other EU countries (see Section 4 for figures extracted from our data registers).

3.3. Military service

In principle, every male Swedish citizen enlists for the military when turning 18. Enlistment is mandatory. Individuals who become Swedish citizen after the age of 17 but before the age of 25 usually have to enlist as well. The Enlistment Office performs a series of tests, including a measurement of the individual’s height.

A refusal to enlist results in fines, and eventually in imprisonment. Individuals are exempted from enlistment if they are imprisoned, if they have ever been convicted for heavy crimes (which mostly concerns violence-related and abuse-related crimes), or if they are in care institutions and are deemed to be unable to function in a war situation. During our study period, the annual cohort size of men turning 18 was about 50,000. Per cohort, around 1,250 (i.e., 0.25%) were exempted from enlistment. No information is available about the distribution of immigrants in the latter group.

4. Data

The empirical analysis is based on a data set constructed by integrating registers from Statistics Sweden (including RTB[8] and The Multi Generation Register[9]) and the Swedish National Service Administration, which contain every individual living in Sweden in the year 1999 who enlisted for the military between 1984 and 1997. For each of these individuals we observe their height at the date of enlistment, i.e. close to age 18. In our sample, 73 percent enlists at age 17 to 19, while 12 percent enlists at an age older than 21.[10] Given the enlistment rules, our data only contain individuals born between 1956 and 1979. Data originating from the military service enlistment registry have been used in a number of studies, usually to establish associations with outcomes later in life, and usually focusing on native Swedish individuals. See e.g. Magnusson, Rasmussen and Gyllensten (2006) who find a strong positive relation between height and educational achievement after age 18.

Immigrants are identified from the registers as having been born abroad and having foreign-born parents. Siblings are identified by having the same mother. In our analyses, we focus on two overlapping samples. The first (smallest) one consists of those who immigrated to Sweden, who enlisted, and who have at least one brother who also enlisted. Moreover, we restrict the sample to brothers born in the same country.[11] We do not observe the height of those not becoming Swedish citizens, since those do not enlist.[12] We also restrict our sample to those who immigrated to Sweden before the age of 18.[13] Although those who become

[8] The Register of the Total Population (RTB) includes information on birth date, date of immigration, sex, country of birth and parents' country of birth.

[9] The Multi Generation Register (Flergenerationsregistret) includes information on which individuals that are siblings on the mothers side and identifies them through a family id.

[10] Since we find a positive correlation between age at immigration and age of enlistment, and since our measure of height may depend on at what age it is measured, we will control for age of enlistment in our regressions. We also perform sensitivity checks on whether the estimates change when we put various restrictions on the age of enlistment on our sample. Note that male growth usually has ended by age 18.

11 For brothers born outside Sweden, being born in different countries is uncommon (we lose only 87 observations).

[12] However, typically, all siblings within a family have the same nationality.

[13] This restriction implies that we exclude 306 individuals above the age of 17 at immigration and who have at least one brother that is included in the data set being used.

Swedish citizen after age 17 and before age 25 have to enlist up to the age of 25, the registers are sometimes inaccurate when it comes to assigning a person to a family for those immigrating at age 18 or older, i.e., as adults.

The RTB register contains 51,578 male individuals who were born abroad, immigrated before age 18, and belong to the birth cohorts 1956-1979. Of these, we observe the height for 37 percent, or 18,827 individuals, namely for those who became Swedish citizens and enlisted in 1984-1997 and who lived in Sweden in 1999. The share is relatively low for Nordic (34%), Western (22%) and Southern European immigrants (28%), but higher for Eastern European (47%) and non-European immigrants (Middle East 43%, Asia 52%, Latin America 43%, and Africa 26%). This reflects naturalization decisions by their parents. In the end, our sample of foreign-born siblings consists of 5,576 individuals, distributed across 2,524 families.

The data allow us to examine which family members naturalize. Among pairs of brothers having immigrated to Sweden before the age of 18 who are 25-40 years old in 2003 and who live in Sweden in 2003, both brothers were Swedish citizens in 76% of the cases, whereas none of them was in 11% and one of them in 16% of the cases. This reflects the fact that some brothers who arrive at higher ages, such as 17, will pass the enlistment age before becoming Swedish citizens. Among brother pairs of Swedish citizenship, in which both migrated before the age of 13, both had also later enlisted in 70% of the cases, where none of them had enlisted in about 10% of the cases.

Our second sample adds families with both Swedish-born and foreign-born members. This increases the sample since some families may consist of, for instance, two brothers where one is born in Sweden and one is born outside Sweden. Some of these families would not have been included in our first subsample, since they may have only had one person born in abroad in the data. As a result, this sample consists of 8,691 brothers in 3,893 families.

The two key variables in the empirical analyses – height and age at immigration – are objectively measured. Age at immigration is measured as the difference between the date of immigration, which is the first day of being granted a residence permit in Sweden, and the individual's birth date, with the difference transformed into yearly intervals. Recall from Section 3 that even among children who immigrate at the same time as their refugee parents, the time between entry into Sweden and the registration as immigrant is often less than half a year. There is no intervening spell for non-refugee households.

The four most common countries of origin are Finland, Iran, Iraq, and Bosnia. In our empirical analyses, we aggregate the country of origin into 5 groups: Nordic, European, Middle East, Asian, and Latin American. The Nordic group consists for 89% of individuals from Finland. The European group mainly consists of individuals from Eastern and Southern Europe, predominantly from Bosnia. Means of the variables in the empirical analysis are shown in Table 1 and 2.

5. Descriptives

In Table 3 and 4, mean height according to age at migration is shown for out two subsamples. The first column of Table 3 shows a pattern of declining height by age at immigration for the full sample. While the average height seems to be rather similar for those being born in Sweden and those who arrived at ages 0 to 1, height starts to decline at ages 2 and onwards. There also appears to be certain ages at which average height declines substantially. People arriving at age 13 are on average about 1.2 centimeters (cm) shorter than people arriving at age 12, for instance. These patterns also seem to mask some important differences across groups based on their region of origin. In the remaining columns of Table 3, height by age at immigration is shown for 6 of the larger region of origin groups. The pattern of declining height by age at immigration is less clear in the population of Nordic immigrants and immigrants from the rest of Europe. This is not surprising, since, the difference in living standards compared to Sweden is less pronounced in these country groups. In the other country groups, i.e. Middle East, Asia, and Latin America, where the differences in living standards compared to Sweden are greater, the pattern of declining height by age at immigration is more pronounced. Similar patters are obtained in the sample of siblings born outside Sweden, as shown in Table 4. These descriptive statistics seem to suggest a pattern where height is related to age at immigration and even more so the poorer the home country of the immigrant is.

Before going into the empirical analysis, it may be useful to briefly discuss the distribution of the age at migration variable. In our data, relatively few, about 2 percent, arrive before the age of 1. This may reflect that parents find it stressful to immigrate at the moment around birth of a baby, and hence, few choose to do so. In addition, relatively few, only 2.6 percent, immigrated at age 17, while the most common ages to immigrate at are 3 to

6, at which ages about 30% of the sample immigrated. Another clear pattern is that immigration occurs at a younger age for individuals born in the Nordic or the other European countries. In these birth regions a higher proportion of individuals arrive before school-starting age compared to individuals born in countries outside Europe. This may reflect a greater deal of choice in the former groups, where people may find it easier to plan their move according to the age and situation of their children. For individuals migrating from poorer countries or from war zones, the age of immigration may be more random, being less determined by the age of the children. In sum, these patterns suggest that it is important to account for country of origin when conducting our empirical analyses.

6. Empirical model

In order to analyze the association between age at immigration and height, we estimate versions of the following equation:

$$y_{if} = \alpha + \theta A_{if} + \delta X_{if} + \mu_f + \varepsilon_{if},$$

where y_{jf} denotes the adult height in cm of individual i in family f, A_{if} denotes a vector of variables capturing the age at immigration of individual i, X_{jf} denotes a vector of control variables, μ_f denotes family-specific unobserved determinants, and ε_{if} is an individual-specific, i.i.d. error term. We will also estimate specifications where age at immigration enters linearly or as a piecewise linear function, in which cases age at immigration is a continuous measure.

The above equation can be derived from a counterfactual framework in which an individual has different potential adult heights, depending on the age at immigration. In this interpretation, the age at immigration is a treatment value. Now recall that we are ultimately interested in the causal effect on adult height (and health) of intervening in the life of an individual by assigning good or bad living conditions in one particular age year. This corresponds to the difference in potential outcomes for two consecutive ages at immigration. We study this by exploiting cross-individual variation in outcomes, but such inference needs to take into account that the actual treatment assignment process is not randomized, in the sense that there are unobserved confounders that may influence the outcomes and the age at migration. By assuming that these factors are family-specific, we can remove them by fixed effects methods.

It is useful to discuss the latter in some more detail. The migration decision is taken at the family level, and the family members migrate at the same point in time. The family fixed effect μ_j will absorb all characteristics that are identical across members of the same family, such as country of migration, year of migration, origin, family structure, traditions, values norms, habits, wealth, household practices, neighborhoods, and family-level preferences. The estimates of θ are therefore not affected by factors at the family-level that are correlated with age at migration. (In OLS analyses across children from different families, such unobserved determinants of migration at the family level may confound the estimated effects of age at migration.) The fixed-effects approach also conveniently deals with selectivity of the observation window and the population from which we sample. For example, one may argue that our population is a selective sub-population of the population of all immigrants, because it only contains naturalized immigrants. To the extent that the association between naturalization and height is captured by the family fixed effect, our results can be generalized to the full population of immigrants.

As noted in the introduction, the migration decision may also be induced by a particularly bad health of one of the children, in which case the conditions for a fixed-effects approach based on all brothers would be invalid. We deal with this by excluding the youngest (or other subsets of) brothers and perform analyses with data from families with at least three sons.

Our baseline results are based on the sample of siblings born outside Sweden. The age at immigration dummies in A_{if} here range from age 1 to age 17, with age zero being the omitted reference category. With the sample that includes Swedish-born siblings, the omitted category is replaced by being born in Sweden, and we can identify the effect of immigration at age zero.

Since height is measured at about the same age for everyone, and since height does not change to any important extent after the age of 18, the age at test should be virtually orthogonal to our height variable. To be sure, however, we include a control variable measuring the exact age at which the measurement was taken.[14] In addition, since the siblings in our sample immigrate at the same point in time, any immigrant-cohort effects will be picked up by the family fixed effect.

[14] In addition, we will conduct sensitivity analyses, putting different restrictions on what ages to include.

A complication not solved with family fixed effects is that birth order may be correlated with height. If the economic conditions of the family are improving over time, later-born children will always be brought up under more favorable circumstances than their earlier born siblings. Since age at immigration is correlated with parity, this may then induce a negative correlation between age at immigration and height that simply reflects parity effects. This is not solved by the family fixed effects approach and we lack information on the economic circumstances of the family at each birth.

A substantial literature, however, suggest that parents favor earlier-born children in a variety of dimensions. Horton (1988) found that later-born children in the Philippines received less nourishment than first-born, as assessed through children's height and weight. Such patterns may reflect that additional children put an additional burden on the budget constraint of the family and dilute resources.[15] In addition, and in line with this, a number of studies in both developed countries and developing countries have found that later-born children are less likely to be vaccinated (Barreto and Rodrigues, 1992; Kaplan et al., 1992). First-borns often have higher educational achievements than their later born siblings (Black et al., 2005; Conley and Glauber, 2006; Kantarevic and Mechoulan, 2006). In sum, being first-born, or among the first in the birth order, is usually found to be of advantage in a variety of dimensions. If this also applies to height, any negative effect of age at immigration on height would be underestimated. To address this concern we will, however, include an indicator of being first born in our regressions. It should also be noted that it is not obvious that economic conditions surrounding the births of our respondents has been improving over time. This is because the reason to migrate in the first place may be that economic conditions are not improving over time or are even getting worse. In this case, later-borns will not have been born under better conditions and the there will at least be no upward bias in the coefficient of age at migration on height.

It is well known that the role of measurement errors in the explanatory variables is more severe in sibling-fixed-effects models (Griliches, 1979). When using age at immigration as a continuous variable, any classical measurement errors in the variable will lead to a downward bias in the estimates. It should be remembered though that this measure is constructed using the date of immigration and the birth date of the child. In the former case, any measurement error will be the same for members of the same family and will therefore be

[15] Some studies suggests favorable outcomes for first and last-born children, possibly reflecting that first and last-born children are the only one that have some period of exclusive attention in which resources are not shared.

netted out when using family fixed effects. Any downward bias would therefore result from the measurement error in the birth date variable, which is hard to assess. The role of measurement errors is less clear when measuring age at migration with dummy variables, since the measurement errors would no longer be classical.

Finally, it is important to point out that there is barely any secular trend towards increasing height during our study period. Figure 2 shows the cohort-specific average adult height of Swedish males born between 1956 and 1979, i.e. during our period of study. It should be noted that the estimates for cohorts born before 1964 are imprecise due to their small sample size.[16] From 1965 until 1971, there appears to be a weakly increasing trend in height. From 1971 onwards, average height seems to stabilize. Over the entire period 1965-1979, average height increases by less than 1 cm.

7. Results

7.1. Baseline results for sample of siblings born outside of Sweden

The results based on the sample of siblings born outside Sweden are presented in Subsections 7.1-7.4. In Subsection 7.5, we turn to the results for the sample including Swedish-born siblings.

Table 5 shows the results from the OLS and family Fixed Effects (FE) regressions of adult height on age at immigration, where all regions of origin are pooled together. In columns 1 and 2, age at immigration is indicated by dummy variables, the omitted reference category being age at immigration equal to zero. The columns 3 and 4 display the estimates if the effect of age at immigration is assumed to be linear.

The OLS results in column 1 show that immigration at ages 9 and above is significantly and negatively related to adult height. This specification includes country-of-birth fixed effects. The decrease in adult height seems particularly pronounced at ages 6, 9-11, 13, and 15-16. The analysis allowing for family fixed effects (which is more reliable, as it deals with a range of potential endogeneity issues) gives somewhat different results. Again, there are significant coefficients for the indicators of immigrating at or beyond age 9. For these ages at immigration, individuals become on average between 1.6 and 4.6 cm shorter

[16] The data concern men enlisting during the years 1984 to 1997, so the samples from older cohorts are potentially selective and smaller groups of men who enlisted at ages above 18.

than individuals immigrating at age 0. Such differences are too large to be attributable to secular changes within the countries of origin.

According to the FE results, adult height is relatively strongly dependent on whether one immigrates just before the ages 5, 6 and 9, or whether one immigrates after these ages. This means that the most visible critical periods in children's development are at ages 5/6 and 9. It is important to point out that this cannot be attributed to institutional features of the Swedish school system. In this system, individuals used to enter primary school at age 7. Inflow into complexity-defined trajectories only takes place after age 14. This suggests that the critical periods are not due to the importance of the corresponding school years in Sweden. This in turn lends credence to the view that we are capturing direct health effects on adult height (and, ultimately, adult health) instead of an indirect effect of health through educational attainment on adult height.

Notice also from Figure 1 that the critical periods do not correspond to ages at which the average bodily growth is highest. This means that the critical periods findings are not simply driven by a mechanical proportional decrease of height growth.

In Figure 3 we visualize the FE coefficients of the age at immigration. Notice that there is a saw-toothed pattern of the coefficients at ages beyond age 9. This pattern (which is also visible in the OLS coefficients) is hard to explain, and, indeed, it turns out to be an artifact of aggregation over different regions of origin. In the next subsections we show that this pattern is absent for results by country of origin, and that the pattern is less regular if we use the larger sample including siblings born in Sweden.

More in general, it is hard to assign a level of statistical significance to the critical periods we find. A priori their location is not known, and the number of coefficients is too large to obtain significance of adjacent pairs of coefficients from each other. At the same time, the finding of a critical period at age 9 is justified by the fact that this is the lowest age for which the coefficient is significantly negative.

All of this makes it interesting to consider the robustness of our findings across regions of origin (see Subsection 7.2 below). We may also look for significance in more parsimonious specifications, notably specifications that are piecewise constant or piecewise linear in the age at immigration, where the intervals in which the effect is continuous in age at immigration are larger than one year. In general, in the case of piecewise constant specifications with a discontinuity at one of the critical periods we found, the size of the jump is significantly negative. In the case of a piecewise linear specification it sometimes is significant and it sometimes is not.

To illustrate these issues, we first consider a fully linear specification. Columns 3 and 4 of Table 5 provide the corresponding estimates. The OLS results suggest that each additional year of exposure to the old home country is associated with a decrease in adult height by 0.15 cm. Again, introducing family fixed effects substantially increases the magnitude of the association; a one year increase in the age at immigration is now associated with a 0.25 cm decrease in height. To allow for a discontinuity at age 9, we perform the FE regression, allowing for different slopes and intercepts before and after age 9. The values before and after age 9 are not significantly different. In fact, from Figure 3 it is immediately clear that a piecewise linear specification is too flexible to detect a discontinuity.

As noted, the coefficients are typically larger in absolute value for the FE analyses than for the corresponding OLS analyses. In fact, the difference is close to zero for small ages and more pronounced for higher ages of immigration. This suggests that the self-selection in migration is such that families with small children in bad health tend to migrate more often. In Subsection 7.4 we examine possible selection mechanisms in more detail.

7.2. Results by region of origin

Having established that there is a significant association between age at immigration and height in the family fixed-effects specifications, we next turn to analyses by region of origin. One may expect the association to be larger for individuals having migrated from poorer regions than from richer regions, since the difference in living standards between the home country and Sweden will be greater. On the other hand, people able to migrate from poor countries may more often come from the upper end of the income distribution compared to people coming from less poor countries, suggesting a less clear role of the poorness of the country in mediating the relationship between age at immigration and height.

Table 6 shows the family fixed-effects results for five different region of origin groups; Nordic countries, other European countries, Non-European countries, and then separately for Asia, Middle East, and Latin America. In these specifications, we use the continuous measure of age at immigration instead of the dummies, since the sample sizes are much smaller and there would be too few observations at each age at immigration.

The results show that the associations between age at immigration and height are substantially stronger for those coming from poorer countries. In the case of Asia, one additional year of age at immigration is associated with a 0.38 cm decrease in height.[17] For the Middle East group, the point estimate is -0.28 and allowing for different slopes and intercepts before and after age 8 did not change the results to any important extent.[18] The greatest association is obtained for those having migrated from Latin America, where one additional year of age at immigration is associated with almost 0.5 cm adult height reduction. Here, our spline regression suggested that the estimated slope was significantly steeper for the subsample arriving at Sweden up until the age of 7 (-0.69, versus -0.21 for those arriving after 8 years of age).

For the Nordic and European regions, the point estimates are negative but small and insignificant.[19] In Subsection 7.5, where we include siblings born in Sweden, some results for these regions are significant.

7.3. Interaction effects

Next, we explore potential interaction effects between age at immigration and parents' education, parents' age at immigration and year of immigration. Since educated parents may cope better with adverse economic conditions and since the change in the economic conditions may be less for families where the parents have a higher education, we expect the association between age at immigration and height to be less in magnitude for these families. Moreover, mothers' age at immigration may mediate the relationship between age at immigration and height. Parents arriving at younger ages in Sweden may more easily adapt to a new culture and take greater advantage of the improved living conditions. For year of immigration, we do not have an a priori expectation about the sign of the interaction effect and it could very well differ by region of origin. For some countries, such as Finland, the difference in economic conditions compared to Sweden has been narrowing over time and the effect of age at immigration could therefore be expected to decrease over time.

The results of the interactions, shown in Table 7 for continuous age at immigration and including family fixed effects, suggest that the association between age at immigration and height in the sample of foreign-born brothers is smaller in magnitude for those having

[17] Since Table 2 suggests that there are large declines in height between certain ages in the Asian group, we also estimated the model, allowing for different slopes and different intercepts before and after certain age. We didn't find any evidence of differential slopes or intercepts, however, and the slopes before and after age 13, for instance, were -0.37 and -0.30, respectively and the difference was not significant.

[18] Before age 9, the slope was -0.31, while being -0.24 after the age of 9. The difference was not statistically significant (p=0.49).

[19] In these country groups, we found no significant differences in the slopes at different potential break-points, such as at age 8. These results are available on request.

parents with higher education.[20] The effects are significant for both the mother's and the father's education but the magnitude of the coefficient is greater for mother's education. This is in line with previous results, suggesting that the mother's education is more important for the health of the child than the education of the father (see e.g. Strauss and Thomas 1995). The analyses by region of birth, however, suggest that the protecting effect of mother's education is found in the non-European group, whereas the protective effect of the father's education is found in the European group.

The mother's age at immigration only affects the association between age at immigration and height in the Nordic group. Here, the effect is to increase the negative impact of age at immigration, suggesting that older mothers have more difficulties in cushioning the adverse effects of their children arriving at later ages in Sweden. For year of immigration the interaction term is again only significant in the Nordic group, where the point estimate suggests that the negative association between age at immigration and height has become smaller in magnitude over time. This is what we would expect, since the gap in economic conditions between Finland and Sweden has declined over time.

7.4. Sensitivity checks

While Swedish men are supposed to enlist for the military test the year they become 18 years old, a substantial fraction of our sample enlist at older ages. In order to check the sensitivity of our result when including these late-enlisters, we re-run the family fixed effects regressions, this time with different age-at-enlistment restrictions. We ran the analyses, using our continuous measure of age at immigration, for the age groups 17-18, 17-19, 17-20, 17-21, 17-22, 17-23, and 17-24. The results are shown in Table 8. The association between age at immigration and height is in all cases significant and negative, with the point estimate being slightly smaller in magnitude for those enlisting at younger ages, 17-18. Similar results are obtained when indicating age at immigration with dummy variables (results available on request). The results do thus not seem to be very sensitive to including the sample of late-enlisters.

We also re-run our analyses deleting observations with very low or very tall heights. People with a very low height may for instance suffer from specific diseases. In a similar vein, very tall people may be so tall because of certain genetic characteristics. In these cases,

[20] The sample size is now reduced to 3,308 observations, due to missing observations on parental education. It should be noted, though, that the significant association between age at immigration and height persists in this reduced sample. The point estimate is now -0.32 and is significant at the 1% level.

extreme heights may be unrelated to early life conditions and deleting these outliers could, if anything, therefore be expected to strengthen the association between age at immigration and height. We exclude the upper-1 and lower-1 percentiles of the height distribution, meaning individuals below 163 cm and above 186 cm. This results in a decrease in the number of observations to 4,901. This does not affect the results to any important extent. The estimated coefficient of the continuous measure of age at immigration changes from -0.25 to -0.23.

To investigate whether immigration is driven by adverse health of the youngest or oldest brother in the family, we replicate the analyses excluding the youngest and/or oldest brother at the moment of migration. This entails that we discard data from families with only one or two brothers at the moment of migration. It turns out that the results (available upon request) are remarkably similar to those presented in this paper. If anything, excluding the youngest brother at the moment of migration results in a slightly smaller (in absolute value) estimate of the decline of adult height as a function of age at immigration. This is in agreement with the hypothesis that an exceptionally weak youngest child in the family may trigger a migration. However, the results on critical periods are the same as in our baseline analyses.

7.5. Results for full sample including siblings born in Sweden

The sample that includes Swedish-born siblings enables an examination of how conditions around the date of birth affect adult outcomes. We estimate model specifications that include one additional dummy indicator for whether the child had age zero when immigrating to Sweden. The reference category now concerns being born in Sweden after migration of the family, with at least one brother being alive at the date of migration. The specifications nest those estimated above, but we use larger samples. The first two columns of Table 9 display the new results.

Starting with first column of Table 9, the OLS results show again a strong negative association between age at immigration and height. Those arriving at age 2 and later are on average significantly shorter as adults than those born in Sweden. The later the arrival, the larger is the effect. An individual arriving at age 10 is for instance 2 cm shorter on average. In the FE analyses (second column of Table 9), starting from age 2 and onwards, the results are still significant, and the associations are even larger in magnitude. For a person arriving at age 10 the average difference is now almost 3 cm. These findings echo those for the baseline analyses in Subsection 7.1. More importantly, the critical periods are exactly like they were in the baseline analyses. If only, the magnitude of the jumps at ages 5/6 and 9 (see Figure 4) is even larger than in Table 5 and Figure 4.

One concern with these results is that mothers immigrating to Sweden may re-marry with Swedish men and have additional children with them. This would mean that for some siblings, the father is not the same, introducing a new source of heterogeneity which the fixed effects estimator would not deal with. Although, the number of such cases is rather small, about 6% of the sample, we re-ran the analyses, excluding cases where the father was born in Sweden. The results, shown in the third column of Table 9, suggest that our results are not affected to any important extent by this restriction, however.

Another concern comparing siblings born outside and within Sweden is that their early life experiences differ in many respects. A person born in Sweden, with a mother who has been here 10 years, will face a very different upbringing compared to a sibling born by the same mother outside Sweden. In order to check the sensitivity of the results for such different early life experiences, we restricted our sample to those cases where the mother had been in Sweden no more than one year before giving birth and re-ran our analyses. As shown in the fourth column of Table 9, this restriction hardly affects the results.

Finally, we re-run our analyses on the full sample of siblings separately by country group. As shown in Table 10, the results vary quite substantially by country group. For the Nordic group, people immigrating at ages 9 and 11 are significantly shorter on average. At other ages at immigration, there are no significant differences though. In the European group, point estimates are rather large and negative from age 1 and onwards, but only significant at ages 6, 8, 9, 11, and 15. The point estimates are in general somewhat larger than the ones obtained in the Nordic group, which is expected, since the difference in economic conditions between Sweden and the latter countries is smaller.

These estimates pale in comparison with those obtained for the non-European group. Here, the effects are significant, negative, and large from age 1 and onwards. A person arriving at age 13, for instance, is on average 7 cm shorter compared to a brother born in Sweden. Even a person arriving at age 1 is on average already more than 2 cm shorter than a brother born in Sweden. The magnitude of the associations seem to increase substantially between ages 4 and 5 and between ages 12 and 13. In the non-European group, the greatest effects are obtained for persons born in Asia and Latin America, where individuals immigrating to Sweden at age 1 are already between 3.6 and 4.6 cm shorter on average than those born in Sweden.

In sum, the results of this subsection show the importance of early life conditions by comparing siblings born outside and within Sweden. As expected, the effects were greatest for those coming from poorer countries, whereas weaker effects were obtained when comparing siblings from Nordic and European countries.

8. Conclusions

This paper introduces a new approach to identify critical periods in childhood and adolescence for health later in life. By exploiting the differences in ages at immigration across brothers in the same family, and by comparing brothers born outside and within Sweden, we are able to assess the causal effect of conditions at given pre-adult ages on later life health.

Not surprisingly, adult height (and thus health later in life) decreases with exposure to adverse conditions during childhood and adolescence. We find that there is a downward trend in this effect: the higher the age at which conditions improve, the lower the adult height. Moreover, in addition to this trend, there are some ages at which adverse conditions have a particularly strong effect on adult height. These are the critical periods at ages 5/6 and 9.

Our approach does not detect effects of conditions close to the date of birth. The adult heights of boys born just before migration and their brothers born just after migration are very similar on average. Apparently, adult height does not reflect causal long-run health effects of conditions close to the date of birth. This is in accordance to adoptee studies claiming complete height catch-up if adoption takes place within 6 months after birth, even though those studies are sensitive to selection bias.

High parental education and migration from relatively wealthy regions are associated with smaller effects of age at immigration on adult height. These interactions show that the effects of adverse conditions during critical periods can be offset to some extent by wealth or by health knowledge.

The results suggest that it is particularly important to take care of living conditions of children at ages 5/6 and 9. Failure to do so may result in higher long-run health care costs than failure to focus on conditions at other childhood ages. An important topic for future research is to shed more light on the underlying mechanisms. Specifically, are critical periods important because of the quality or the quantity of the nutritional intake, or does disease exposure or stress play a role? By linking the present data to observed health outcomes after age 18 one may be able to address these issues.

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Figure 1. Height growth among Swedish males.

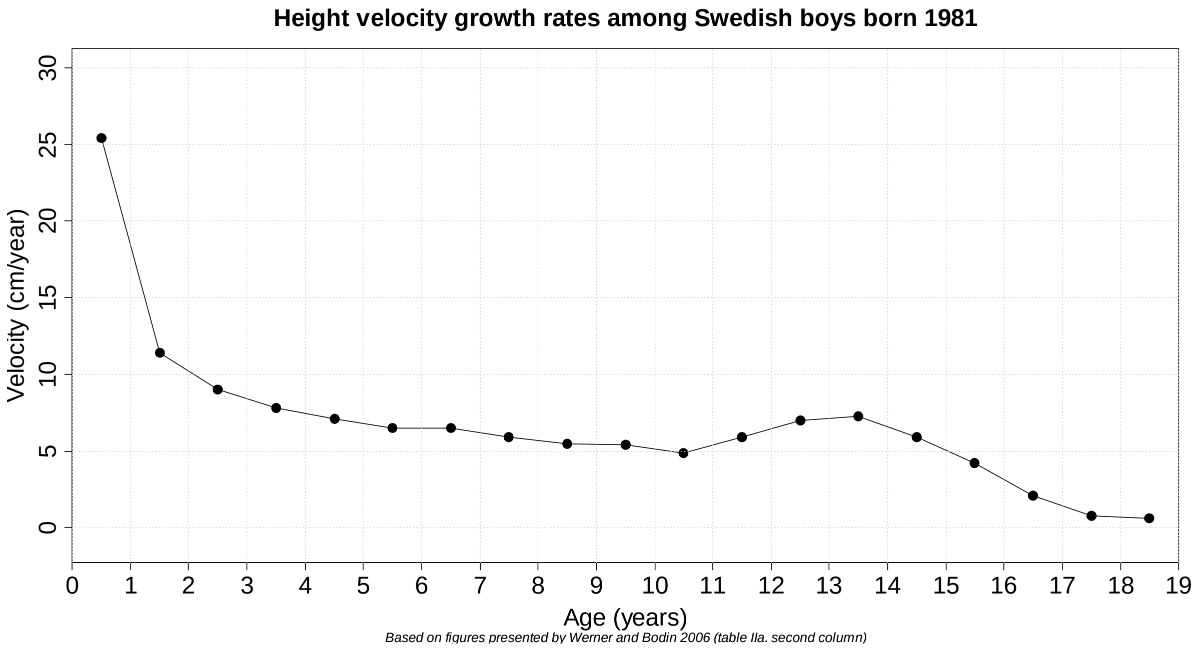

Figure 2. Height of Swedish males born 1956-1979.

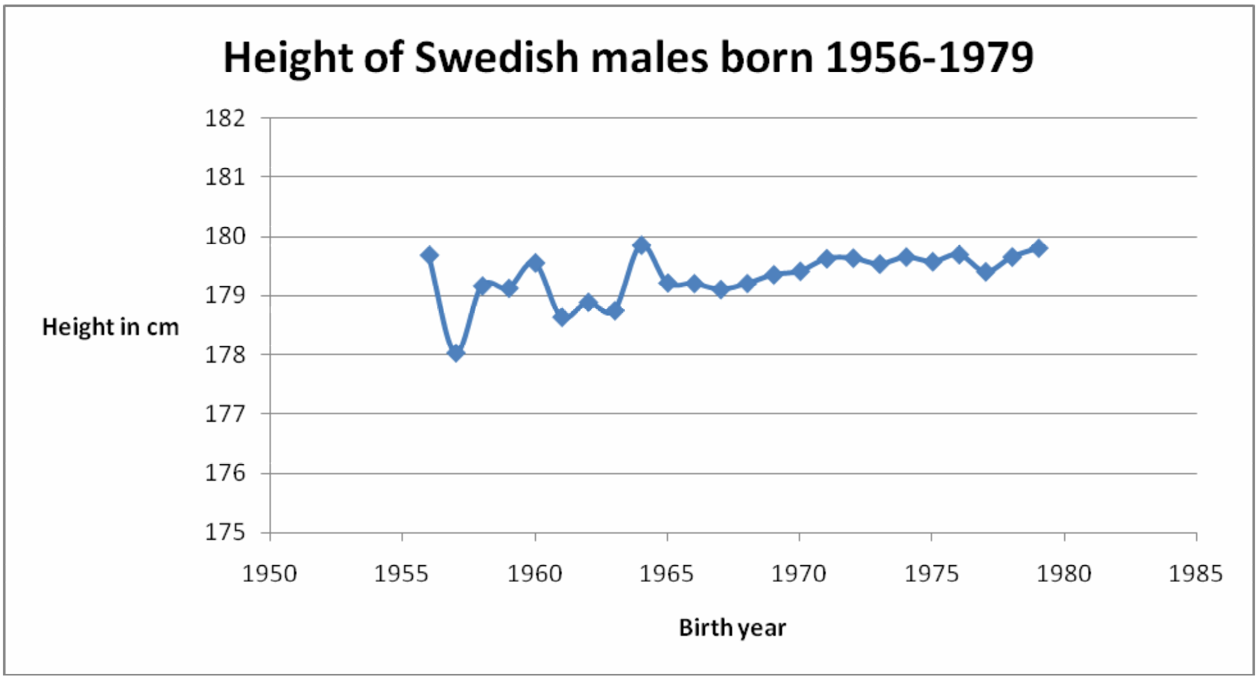

Table 1. Descriptive statistics on full siblings sample.

Variable	Pooled sample	Sweden	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
Height in cm	175.56	177.72	177.62	177.15	172.44	173.54	169.56	172.32
	(6.88)	(6.48)	(6.33)	(6.67)	(6.34)	(6.11)	(6.21)	(6.15)
Age at Immigration	4.68	-3.12	3.75	6.05	8.89	9.27	8.88	7.71
	(5.85)	(2.75)	(3.14)	(4.54)	(4.42)	(4.43)	(4.33)	(4.29)
First born sibling	.31	.014	.45	.54	.29	.29	.27	.34
	(.46)	(.12)	(.50)	(.50)	(.46)	(.45)	(.45)	(.47)
Age at military test	19.26	18.60	19.32	19.61	19.44	19.70	19.03	19.11
	(1.77)	(1.02)	(1.68)	(2.10)	(1.93)	(2.03)	(1.61)	(1.84)
Sweden	.20							
	(.40)							
Nordic	.28							
	(.45)							
Europe	.13							
	(.34)							
Non-Europe	.39							
	(.49)							
Middle East	.23							
	(.42)							
Asia	.09							
	(.28)							
Latin America	.074							
	(.26)							
Observations	8691	1746	2404	1150	3391	2006	741	644

Note: Standard deviations in parentheses

Table 2. Descriptive statistics on sample of siblings born outside Sweden.

Variable	Pooled sample	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
Height in cm	174.43	177.46	176.69	172.40	173.52	169.44	172.32
	(6.79)	(6.26)	(6.70)	(6.33)	(6.10)	(6.13)	(6.15)
Age at Immigration	7.62	4.54	7.53	9.15	9.56	9.09	7.96
	(4.55)	(3.28)	(4.49)	(4.33)	(4.31)	(4.25)	(4.27)
First born sibling	.31	.31	.40	.28	.27	.26	.32
	(.46)	(.46)	(.49)	(.45)	(.45)	(.44)	(.47)
Age at military test	19.45	19.42	19.45	19.47	19.73	19.06	19.15
	(1.89)	(1.75)	(1.95)	(1.95)	(2.04)	(1.63)	(1.87)
Nordic	.28						
	(.45)						
Europe	.14						
	(.35)						
Non-Europe	.58						
	(.49)						
Middle East	.34						
	(.47)						
Asia	.13						
	(.33)						
Latin America	.11						
	(.31)						
Observations	5576	1576	778	3222	1906	709	607

Note: Standard deviations in parentheses.

Table 3. Height in centimeters by age at immigration and by country group for the full sample.

Age at immigration	All	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
Born in Sweden	177.71	177.64	178.73	176.33	176.29	177.24	175.73
0	177.78	177.87	179.44	174.63	174.88	177.00	173.23
1	177.46	178.07	178.15	174.00	174.93	172.82	172.79
2	176.72	177.77	177.23	173.43	173.73	171.34	174.63
3	176.34	177.63	177.12	173.65	174.29	172.74	173.02
4	175.93	177.32	176.36	173.83	174.81	171.14	173.48
5	175.40	177.24	177.82	172.77	173.41	170.43	174.13
6	174.92	177.36	176.22	172.63	173.23	170.90	172.89
7	174.48	177.78	177.43	172.30	173.14	170.53	172.00
8	174.33	178.63	176.57	172.40	174.02	169.36	171.75
9	173.90	176.50	177.65	172.43	174.26	168.74	171.90
10	173.68	176.75	176.84	172.15	173.80	168.82	170.70
11	173.31	174.54	176.02	172.71	174.37	168.76	170.51
12	173.55	179.26	176.86	172.39	173.28	169.91	171.35
13	172.30	176.76	176.00	171.26	172.73	168.02	170.50
14	173.55	179.40	178.09	172.49	173.51	168.56	173.27
15	171.88	180.75	176.45	171.07	172.51	166.32	170.79
16	171.36	168.75	174.71	170.84	171.85	167.59	170.85
17	171.63	181.20	177.17	170.26	171.56	165.76	172.00
Total	175.56	177.63	177.57	172.70	173.75	169.93	172.54
n	8691	3482	1569	3640	2173	778	689

Table 4. Height in centimeters by age at immigration and by country group for the sample of Siblings born outside Sweden.

Age at immigration	All	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
0	176.86	177.10	179.53	174.45	175.33	175.75	173.23
1	176.31	177.33	176.58	173.39	174.15	171.73	172.82
2	176.30	178.15	175.48	173.56	173.71	171.46	174.97
3	176.12	177.74	177.08	173.51	174.46	172.51	172.36
4	175.63	177.01	175.46	174.18	175.24	171.06	174.21
5	175.27	177.17	178.50	172.70	173.27	170.30	174.20
6	174.78	177.28	176.43	172.59	173.26	170.69	172.85
7	174.25	178.01	175.88	172.39	173.24	170.53	172.27
8	174.24	178.51	176.37	172.50	174.11	169.39	171.86
9	173.83	176.53	177.74	172.42	174.24	168.77	171.90
10	173.65	177.05	176.92	172.17	173.80	168.85	170.70
11	173.31	174.78	176.02	172.68	174.32	168.69	170.51
12	173.58	179.26	176.91	172.44	173.34	169.91	171.35
13	172.33	176.75	176.47	171.25	172.72	168.02	170.50
14	173.61	179.40	178.09	172.55	173.49	168.87	173.27
15	171.80	180.75	176.42	171.07	172.51	166.32	170.79
16	171.38	168.75	174.96	170.84	171.85	167.59	170.85
17	171.56	181.50	177.17	170.26	171.56	165.76	172.00
Total	174.43	177.46	176.69	172.40	173.52	169.44	172.32
n	5576	1576	778	3222	1906	709	607

Table 5. Regression on age at migration and length in cm. Sample of siblings born outside Sweden.

	Dummies for age at immigration		Continuous age at immigration	
	(1)	(2)	(3)	(4)
One	-0.548	-0.0333		
	(0.64)	(0.62)		
Two	-0.265	0.333		
	(0.62)	(0.60)		
Three	-0.211	-0.0798		
	(0.62)	(0.60)		
Four	-0.559	0.117		
	(0.62)	(0.62)		
Five	-0.669	-0.363		
	(0.62)	(0.62)		
Six	-1.016	-0.958		
	(0.63)	(0.64)		
Seven	-1.015	-0.731		
	(0.64)	(0.65)		
Eight	-1.000	-0.964		
	(0.64)	(0.66)		
Nine	-1.266*	-2.233***		
	(0.65)	(0.68)		
Ten	-1.562**	-1.561**		
	(0.65)	(0.69)		
Eleven	-1.718***	-2.476***		
	(0.66)	(0.70)		
Twelve	-1.344**	-1.763**		
	(0.68)	(0.74)		
Thirteen	-2.359***	-2.993***		
	(0.68)	(0.76)		
Fourteen	-1.266*	-2.376***		
	(0.71)	(0.80)		
Fifteen	-2.745***	-3.629***		
	(0.75)	(0.86)		
Sixteen	-3.164***	-3.230***		
	(0.79)	(0.92)		
Seventeen	-2.887***	-4.566***		
	(0.85)	(0.98)		

Age at immigration			-0.153***	-0.251***
			(0.025)	(0.039)
Constant	177.2***	175.1***	177.8***	176.6***
	(1.16)	(1.44)	(0.95)	(1.14)
Observations	5576	5576	5576	5576
Family fixed effects	No	Yes	No	Yes

Notes: Age at immigration measured by dummy variables in (1) and (2) and as a continuous variable in (3) and (4). Country fixed effects are included in specifications (1) and (3). *** p<0.01, ** p<0.05, * p<0.1

Table 6. Regression on age at migration and length in cm. FE estimation on sample of siblings born outside Sweden. Age at immigration as continuous variable.

	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
Age at immigration	-0.0376	-0.0192	-0.327***	-0.282***	-0.378***	-0.470***
	(0.086)	(0.13)	(0.047)	(0.057)	(0.10)	(0.13)
Age at test	0.0643	-0.103	-0.0269	-0.0942	0.00378	0.363*
	(0.14)	(0.18)	(0.083)	(0.10)	(0.20)	(0.21)
First born	-0.206	0.295	0.696***	0.157	0.353	2.680***
	(0.34)	(0.46)	(0.24)	(0.31)	(0.54)	(0.58)
Constant	176.4***	178.7***	175.7***	178.0***	172.7***	168.3***
	(2.53)	(3.15)	(1.41)	(1.71)	(3.45)	(3.60)
Observations	1576	778	3222	1906	709	607

*** p<0.01, ** p<0.05, * p<0.1

Table 7. Age at migration by country group and length in cm for sample of siblings born outside Sweden. Age at immigration as continuous variable and interaction effects. FE regressions.

	Pooled	Nordic	Europe	Non-Europe	Middle East	Asia	Latin America
Age at immigration	-1.014***	0.414	-0.751	-1.484***	-0.724	-0.804	-2.717***
	(0.24)	(0.61)	(0.53)	(0.36)	(0.47)	(1.04)	(1.02)
Age at test	0.152**	0.493***	-0.137	0.125	0.103	0.0440	0.257
	(0.067)	(0.15)	(0.15)	(0.087)	(0.11)	(0.22)	(0.22)
First born	0.440**	-0.629	1.266***	0.525**	0.0863	0.332	2.437***
	(0.19)	(0.40)	(0.45)	(0.25)	(0.31)	(0.56)	(0.61)
Age at immigration*	0.0278*	-0.0246	0.0866**	0.0204	0.00266	0.00354	0.0532
father's education	(0.015)	(0.045)	(0.038)	(0.019)	(0.024)	(0.061)	(0.041)
Age at immigration*	0.0515***	-0.000706	-0.0431	0.0873***	0.0252	0.0314	0.117**
mother's education	(0.019)	(0.041)	(0.042)	(0.027)	(0.044)	(0.077)	(0.047)
Age at immigration*	0.000632	-0.0250*	-0.000710	0.00501	0.00116	0.00959	0.0195
Mother's imm. age	(0.0049)	(0.015)	(0.018)	(0.0057)	(0.0066)	(0.015)	(0.019)
Age at immigration*	-0.00538	0.0343*	0.00298	-0.00425	0.00362	-0.0142	-0.00568
year of immigration	(0.0061)	(0.019)	(0.016)	(0.0091)	(0.010)	(0.028)	(0.026)
Constant	-0.00513	-0.0245	-0.000505	-0.000603	-0.00621	0.0205	-0.000263
	(0.054)	(0.11)	(0.12)	(0.072)	(0.090)	(0.16)	(0.18)
Observations	3308	745	541	2022	1228	424	370

*** p<0.01, ** p<0.05, * p<0.1

Table 8. Age at migration and length in cm with different age restrictions. FE regressions.

	(Ages 17-18)	(Ages 17-19)	(Ages 17-20)	(Ages 17-21)	(Ages 17-22)	(Ages 17-23)	(Ages 17-24)
Age at immigration	-0.211***	-0.252***	-0.268***	-0.251***	-0.261***	-0.268***	-0.251***
	(0.061)	(0.051)	(0.046)	(0.044)	(0.042)	(0.040)	(0.040)
Age at test	0.590	0.380*	0.179	0.0981	0.0400	0.0513	-0.00782
	(0.37)	(0.21)	(0.15)	(0.11)	(0.091)	(0.081)	(0.074)
First born	0.558**	0.598***	0.724***	0.595***	0.553***	0.534***	0.500***
	(0.27)	(0.23)	(0.21)	(0.20)	(0.19)	(0.18)	(0.18)
Constant	164.9***	169.1***	172.9***	174.3***	175.5***	175.4***	176.4***
	(6.79)	(3.87)	(2.69)	(2.02)	(1.61)	(1.41)	(1.29)
Observations	2540	3501	4074	4580	4981	5232	5402

*** p<0.01, ** p<0.05, * p<0.1

Table 9. Regression on age at migration and length in cm. Including siblings born in Sweden.

	(1)	(2)	(3)	(4)
Zero	-0.0865	-0.557	-0.327	-0.540
	(0.39)	(0.37)	(0.40)	(0.50)
One	-0.236	-0.358	-0.0957	-0.569*
	(0.29)	(0.26)	(0.27)	(0.34)
Two	-0.711**	-0.666**	-0.588**	-0.620*
	(0.29)	(0.27)	(0.28)	(0.33)
Three	-0.793***	-0.949***	-0.794***	-1.107***
	(0.30)	(0.29)	(0.30)	(0.34)
Four	-1.068***	-1.080***	-0.828**	-0.909**
	(0.31)	(0.31)	(0.32)	(0.36)
Five	-1.144***	-1.499***	-1.275***	-1.599***
	(0.33)	(0.34)	(0.34)	(0.38)
Six	-1.382***	-2.200***	-2.074***	-2.186***
	(0.34)	(0.36)	(0.37)	(0.40)
Seven	-1.302***	-1.975***	-1.815***	-1.964***
	(0.36)	(0.39)	(0.40)	(0.42)
Eight	-1.501***	-2.207***	-1.936***	-2.223***
	(0.37)	(0.40)	(0.42)	(0.44)
Nine	-1.698***	-3.421***	-3.306***	-3.420***
	(0.38)	(0.43)	(0.43)	(0.46)
Ten	-2.017***	-2.809***	-2.770***	-2.797***
	(0.39)	(0.45)	(0.46)	(0.48)
Eleven	-2.270***	-3.867***	-3.764***	-3.818***
	(0.41)	(0.47)	(0.48)	(0.50)
Twelve	-1.904***	-3.172***	-3.077***	-3.060***
	(0.43)	(0.51)	(0.51)	(0.54)
Thirteen	-2.960***	-4.398***	-4.317***	-4.352***
	(0.43)	(0.52)	(0.53)	(0.55)
Fourteen	-1.934***	-3.848***	-3.773***	-3.777***
	(0.48)	(0.58)	(0.58)	(0.60)
Fifteen	-3.354***	-5.108***	-5.058***	-4.993***
	(0.53)	(0.63)	(0.64)	(0.67)
Sixteen	-3.806***	-4.807***	-4.705***	-4.677***
	(0.58)	(0.71)	(0.72)	(0.75)
Seventeen	-3.611***	-6.087***	-6.129***	-5.966***
	(0.65)	(0.77)	(0.78)	(0.81)
Constant	177.4***	176.2***	175.8***	176.3***
	(0.87)	(1.11)	(1.12)	(1.25)
Observations	8691	8691	8137	6820

Notes: In (1) and (2) no restrictions on the nationality of the father is made. In (3), cases with Swedish-born fathers are excluded. In (4), Swedish-born siblings are only included if the mother had been in Sweden at most one year after migration. *** p<0.01, ** p<0.05, * p<0.1

Table 10. Regression on age at migration and length in cm. Including siblings born in Sweden.

	Nordic	Europe	Non-Europe	Middle-East	Asia	Latin America
Zero	-0.285	0.0674	-1.569	-0.170	-2.416	-3.493
	(0.43)	(0.92)	(1.07)	(1.41)	(2.62)	(2.22)
One	0.467	-0.654	-2.298***	-1.417*	-3.612**	-4.573***
	(0.32)	(0.62)	(0.65)	(0.79)	(1.75)	(1.50)
Two	0.307	-0.663	-2.808***	-2.587***	-3.198**	-3.757***
	(0.36)	(0.63)	(0.59)	(0.74)	(1.50)	(1.37)
Three	0.0472	-1.042	-2.720***	-2.010***	-3.862***	-4.800***
	(0.40)	(0.74)	(0.55)	(0.65)	(1.48)	(1.35)
Four	-0.293	-1.085	-2.471***	-1.759***	-3.800**	-4.319***
	(0.46)	(0.77)	(0.55)	(0.66)	(1.58)	(1.33)
Five	0.474	-1.332	-3.959***	-3.158***	-6.300***	-4.926***
	(0.52)	(0.85)	(0.54)	(0.66)	(1.41)	(1.42)
Six	-0.413	-2.217**	-4.381***	-4.136***	-5.315***	-5.563***
	(0.59)	(0.91)	(0.57)	(0.68)	(1.50)	(1.42)
Seven	0.236	-1.763	-4.295***	-3.642***	-5.200***	-6.777***
	(0.68)	(1.10)	(0.56)	(0.67)	(1.51)	(1.48)
Eight	0.812	-2.145**	-4.616***	-3.082***	-6.936***	-7.289***
	(0.80)	(1.06)	(0.57)	(0.69)	(1.52)	(1.47)
Nine	-1.850**	-2.160*	-5.684***	-4.996***	-6.915***	-7.647***
	(0.84)	(1.24)	(0.59)	(0.70)	(1.53)	(1.61)
Ten	-0.951	-1.832	-5.077***	-3.899***	-7.139***	-7.876***
	(0.94)	(1.23)	(0.61)	(0.73)	(1.56)	(1.67)
Eleven	-2.313*	-3.892***	-5.930***	-4.944***	-7.650***	-8.562***
	(1.28)	(1.41)	(0.62)	(0.72)	(1.63)	(1.76)
Twelve	0.246	-1.487	-5.646***	-4.683***	-6.784***	-8.802***
	(1.58)	(1.40)	(0.66)	(0.76)	(1.70)	(2.04)
Thirteen	0.474	-1.632	-7.187***	-6.136***	-8.798***	-9.402***
	(1.48)	(1.49)	(0.68)	(0.81)	(1.67)	(2.09)
Fourteen	-1.280	-1.706	-6.355***	-4.737***	-11.23***	-7.737***
	(1.99)	(1.71)	(0.74)	(0.87)	(1.85)	(2.22)
Fifteen	-2.496	-3.455*	-7.603***	-6.224***	-9.382***	-10.92***
	(3.14)	(1.82)	(0.82)	(0.96)	(2.01)	(2.57)
Sixteen	-2.627	-3.070	-7.323***	-5.751***	-8.979***	-11.32***
	(3.20)	(1.98)	(0.92)	(1.09)	(2.25)	(2.66)
Seventeen	-0.731	-1.893	-9.053***	-7.401***	-10.66***	-13.26***
	(2.98)	(2.23)	(1.00)	(1.18)	(2.38)	(3.07)
Constant	176.8***	181.1***	176.0***	179.0***	172.9***	169.6***
	(1.87)	(2.46)	(1.74)	(2.04)	(4.83)	(4.71)
Observations	3482	1569	3640	2173	778	689

*** p<0.01, ** p<0.05, * p<0.1

Figure 3. Adult height difference (in cm) with brothers aged zero at immigration to Sweden (FE panel data estimates Table 5 column 2)

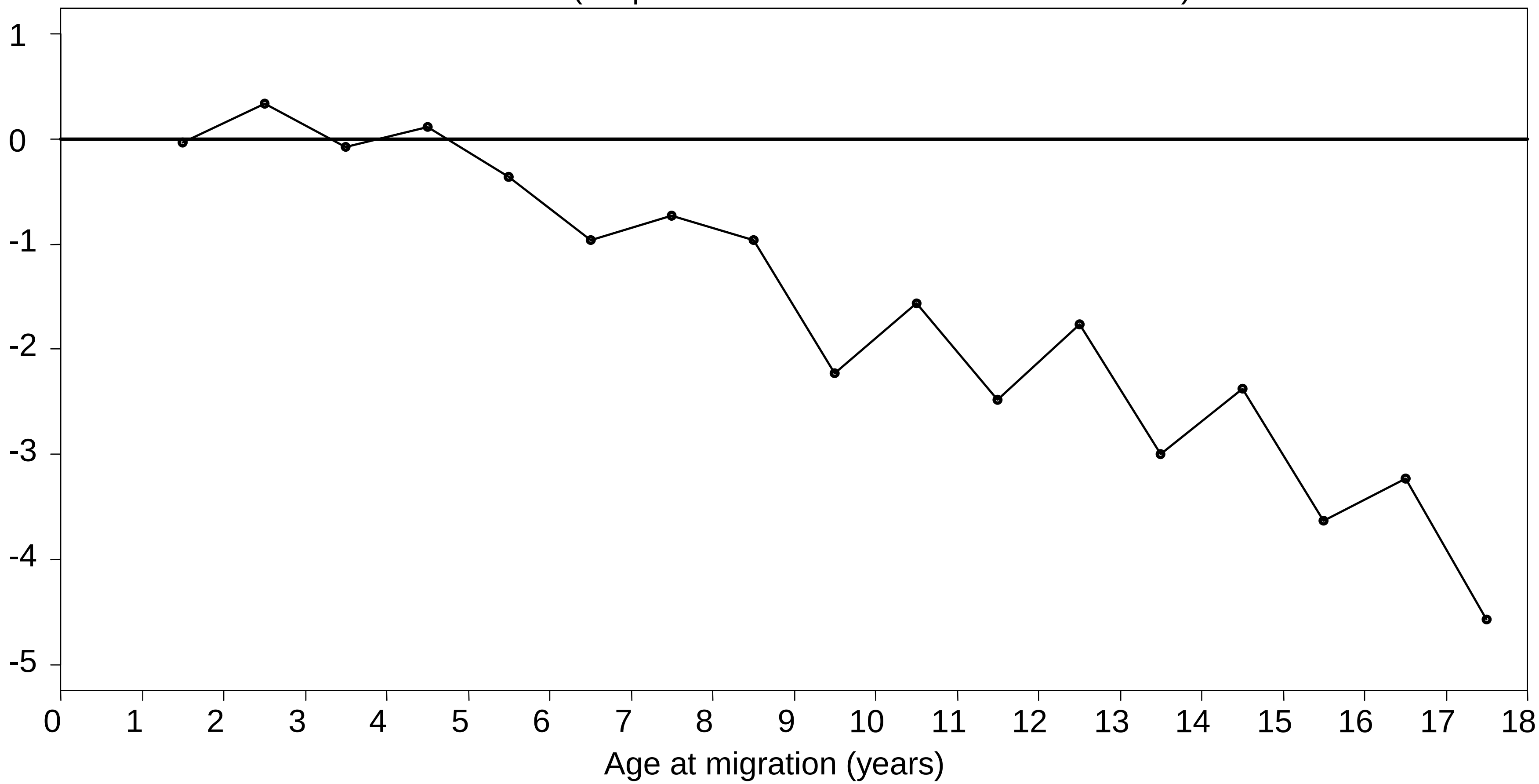

Figure 4. Adult height difference (in cm) with brothers born after immigration to Sweden (FE panel data estimates Table 9 column 3)