

PERINATAL CONDITIONS, HOME RESOURCES AND
COMPETENCIES IN THE EARLY LIFE COURSE

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This paper investigates the role of perinatal conditions and home resources for competence formation from infancy to adolescence. We study complementarities between cognitive, motor and noncognitive abilities and social as well as academic achievement and assess alternative educational policies in the early life course. Our data are taken from the Mannheim Study of Children at Risk, an epidemiological cohort study following the long-term outcome of early risk factors. Results indicate that organic and psychosocial perinatal conditions matter for competencies, as well as socio-emotional home resources in childhood and economic resources during the transition to higher secondary school track. Basic abilities acquired in childhood predict achievement at school age. There is a remarkable stability in the inequality of economic and socio-emotional home resources. This is presumably a major reason for the evolution of inequality in competencies from birth to adolescence.

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I. INTRODUCTION

In this paper, we investigate relationships among perinatal organic and psychosocial conditions, ongoing parental investments and competencies from birth until secondary school age. We try to contribute to the multidisciplinary literature on human development and inequality (Heckman, 2006, 2007) in the following way.

First, we employ unique data from a developmental psychological approach that provides detailed psychometric assessments and medical and psychological expert ratings on various child outcome measures. The data are taken from the Mannheim Study of Children at Risk (MARS¹), an epidemiological cohort study that follows children from birth to adulthood (Laucht et al., 2004). Psychometric assessments of cognitive and motor abilities, *IQ* and *MQ*, were conducted at infancy (3 month), toddlerhood (2), pre-school age (4.5), elementary school age (8) and secondary school age (11 years), representing significant stages of development. Second, we analyze the relationship between home resources and the formation of abilities, and between these and competence in social and academic life. We assess stage specific parameters of the technology of ability formation (Cunha and Heckman, 2007) and complementarities with social and school achievement. We take into account that parental activities may depend on children's abilities. Having a child with high cognitive (or noncognitive) abilities is likely to increase home resources to bolster development (and vice versa).

Our findings demonstrate that interpersonal differences in cognitive and noncognitive abilities are consistently associated with perinatal conditions and home resources, the relationship being age and ability specific. The findings are in line with the literature on the childhood skill multiplier summarized by Heckman (2007). Noncognitive abilities are significantly related to socio-emotional home resources throughout the early life course. Cognitive abilities are strongly related to socio-emotional home resources during pre-school age and only weakly during school age. However, the relationship between home resources and motor abilities is low. The interpersonal differences in motor abilities seem to be determined mainly by perinatal conditions. We find evidence for synergies in the development of abilities. Higher cognitive abilities are helpful in devel-

¹ MARS has been derived from the German title: **MA**nheimer **R**isikokinder **S**tudie.

oping higher noncognitive abilities and higher noncognitive abilities are helpful in developing higher cognitive abilities. Furthermore, it is demonstrated that abilities at preschool age predict social competencies and school grades at the age of 8. Children with higher cognitive and noncognitive abilities at preschool age have improved peer relationships, interests and better grades in math, reading and spelling at primary school age. Higher cognitive and noncognitive abilities at primary school age predict a higher-track secondary school attendance in Germany starting with the age of ten years or later.

Children are exposed to a matrix of perinatal organic and psychosocial risk conditions and each risk factor contributes to development as does the sum of all factors. During childhood the inequality of socio-emotional home resources is a major additional reason for the further evolution of inequality. Parental care, measured with socio-emotional home resources, significantly contributes to the formation of abilities. The availability of economic resources creates an additional differential factor for development and inequality during adolescence. *Ceteris paribus*, children with access to more economic resources more often attend a higher-track secondary school. We conclude that advantages from beneficial and disadvantages from adverse home environments cumulate during the developmental stages. According to further findings the quality of home resources does not differ much over time. For disadvantaged children, in early childhood, the development of cognitive abilities is hindered. This disadvantage continues, thus impairing noncognitive ability formation at school age. Disadvantaged children are again hindered during the transition to a higher-track secondary school, when low economic home resources constitute an additional barrier.

Our findings are related to literature on the stability of personality traits (Kadzin et al., 1997, Mischel et al., 1988, among others). We contribute to this literature through the use of expert rather than maternal rating of children's abilities. The stability of personality traits is associated with the stability of socio-emotional home environment during childhood. Our research is also related to the literature on the consequences of maltreatment in childhood for depressions and inflammations in adulthood (Caspi et al. (2008), among others), We conclude that there is an underinvestment in public investment during preschool age for children who grow up in an adverse home environment and examine alternative policies over the early course to help disadvantaged children.

The paper is organized as follows. Section 2 introduces the data. Section 3 examines the evolution of economic and socio-emotional home resources and competencies from birth to 11 years. Section 4 discusses our estimates of the developmental-specific technology of ability formation. Section 5 studies complementarities between abilities and social competencies and between abilities and school achievement. Compensating policies during the early life course are investigated in section 6. We conclude in section 7.

II. PERINATAL ORGANIC AND PSYCHOSOCIAL CONDITIONS

The MARS project aims at following infants who are at risk for later developmental disorders to examine the impact of initial adverse conditions on the probability of negative health and socio-economic outcomes (Laucht et al., 2004, 1997).² Risks stem from the individual, the environment and their interaction. To control for confounding effects related to home resources and the infant's medical status, only first-born children with singleton births to German-speaking parents of predominantly (> 99.0 percent) European descent, born between February 1986 and February 1988 were enrolled in the study. The first 110 children were included consecutively into the study, irrespective of risk-group status. These children form our approximate normative sample.

To separate the independent and combined effects of organic and psychosocial influences on child development, children were selected according to combinations of different risk factors. Infants were rated according to the degree of "organic" risk and the degree of "psychosocial" risk.³ Each risk factor was scaled as either no risk, moderate risk or high risk, a 3x3 design (Figure 1). Children were assigned to one cell of the two-factor matrix. All groups are about equal in size with a slight oversampling in the high-risk combinations. Sex is distributed evenly in all subgroups. Excluding children with

² Infants were recruited from two obstetric and six children's hospitals in the Rhine-Neckar region of Germany. Children with severe physical handicaps, obvious genetic defects or metabolic diseases were excluded. The initial participation rate was 64.5 percent, with a slightly lower rate in families from low socio-economic backgrounds.

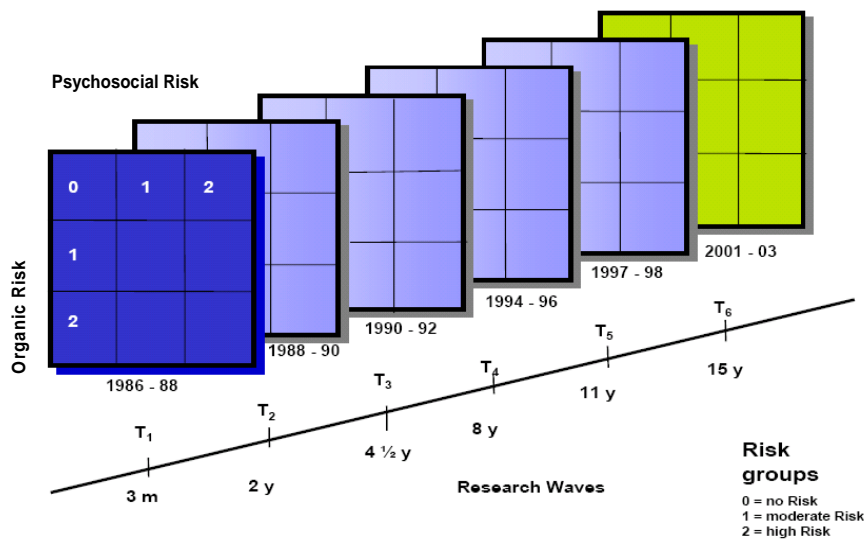
³ The relevance of APGAR and birth weight for adult outcomes has been demonstrated by Almond et al. (2005) and Black et al. (2007), among others. Other aspects of the initial risk matrix, such as neonatal complications, or maternal discord, have not been widely investigated in economic research.

missing values in some waves, 364 children (174 boys, 190 girls), or 95 percent of the 384 infants in the initial wave, remained.

Organic risk is determined by the degree of pre-, peri- or neonatal complications. The risk factors and their prevalence in the sample are shown in Table A1. Pre- and perinatal variables were extracted from maternal obstetrical and infant neonatal records and are used for organic risk classification. Organic risk is classified as follows:

1. The non-risk group consists of 118 infants who were born full-term, had normal birth weight and no medical complications (items 1–4).
2. The moderate-risk group contains 119 infants who had experienced premature births or premature labor, or EPH-gestosis of the mother but no severe complications (items 5–7 but not 8, 9 or 10).
3. The high-risk group comprises 125 infants who had very low birth weight or a clear case of asphyxia with special-care treatment or neonatal complications, such as seizures, respiratory therapy or sepsis (items 8–10).

Figure 1: MARS, the Mannheim Study of Children at Risk



Psychosocial risk is determined according to a risk index proposed by Rutter and Quinton (1977), which measures the presence of eleven unfavorable family characteristics. The "enriched" family adversity index includes adverse family factors during a period of one year prior to birth as reported in Table A2. Information for the psychosocial risk

rating was taken from a standardized parent interview conducted at the 3-month assessment. Psychosocial risk is classified as follows:

1. The no-risk group includes 120 infants who had none of the psychosocial risks.
2. The moderate-risk group contains 111 infants with one or two of these factors.
3. The 131 infants from the high-risk group came from a family dealing with 3 or more of these risk factors.

III. COMPETENCIES, HOME RESOURCES

Throughout the paper the expression competence on the one hand summarizes basic abilities of children, such as logical and verbal reasoning, motor abilities and persistence and on the other hand social as well as school related achievement, such as peer relationships, autonomy, interests and school grades. The section introduces to the measurement of competencies and home resources in the MARS data, together with descriptive statistics.

1. Cognitive, motor and noncognitive abilities

The terms *cognitive*, *motor*, and *noncognitive* abilities indicate three different, yet dependent and important basic dimensions of human capital and personality. Cognitive abilities include memory capacity, information processing speed, linguistic and logical skills, and general problem-solving abilities, *IQ*. Motor abilities are assessed as fine and gross motor skills and body coordination, *MQ*. For a detailed description of the measurement of cognitive and motor abilities in MARS (see the appendix *IQ, MQ*).

Our main dimension of noncognitive abilities measures the child's ability to pursue a particular activity and its continuation in the face of distractors and obstacles, defined as *persistence*, *P*. *P* is a deep-seated noncognitive ability related to effort regulation, perseverance, persistence and self-discipline. In MARS, the rating was made by trained raters⁴ on 5-point rating scales adapted from the New York Longitudinal Study NYLS (see Thomas and Chess, 1977). Until the age of 8, *P* is measured with the attention span

⁴ At the ages of 3 months and 2 years, the interrater reliability was measured in a study of 30 children. Satisfactory interrater agreement was obtained between two raters (3 months: mean $\kappa = 0.68$, range 0.51 - 0.84; 2 years: mean $\kappa = 0.82$, range 0.52 - 1.00). To avoid distortions resulting from parental judgment or one-time observations in an unfamiliar surrounding, a mean score was formed out of all 5 ratings.

within the same scale. Persistence was derived from a combination of a standardized parent interview and structured direct observations in four standardized settings on two different days in both familiar (home) and unfamiliar (laboratory) surroundings. *P* is available throughout the first five waves; it allows a monotonic interpretation and is related with economic outcomes.

Table 1 contains summary statistics of the abilities *IQ*, *MQ* and *P* in the nine risk groups of MARS. Note that the *IQ* and the *MQ* have been normalized in each developmental stage to mean 100 and SD 15 in the approximate normative sample of 110 children. For reasons of clarity we restrict the presentation to the age 3 months and 11 years. Below the first order temporal correlations will be discussed. In line with the literature on competence research (Egeland et al., 1993; Kazdin et al., 1997; Laucht et al., 2000, 2004, among others), our results indicate that unfavorable consequences of initial organic and psychosocial risks seem to persist until adolescence.

Organic and psychosocial risk factors exhibit equally negative effects but are specific to the areas they affect. Until the age of 11, the individual differences in children's abilities, assessed with the mean and the standard deviations, have increased. Initial inequality in the risk matrix exaggerates over time. While psychosocial risks primarily influence cognitive and socio-emotional functioning, the impact of early organic risks concentrates on motor and cognitive functioning. There is a monotonic decrease in the *IQ* and the *MQ* in (nearly) all risk dimensions, and differences in average *IQ*, *MQ* and *P* increase between the ages of 3 months and 11 years in the risk matrix. At the age of 3 months, the children without any risk have an average *IQ* of 103 compared to the children with high organic and high psychosocial risk, whose average *IQ* is 88. In addition, differences in the standard deviations increase with risk, from 13.2 in the no-risk to 19.8 in the highest-risk group (Table 1). The results for the *MQ* look rather similar.

Average *persistence* decreases monotonically along both risk dimensions. There is a 23 percent difference between the no-risk and the highest-risk group of children at the age of 4.5 years (3.8 vs. 3.1, Table 1), and the heterogeneity of the noncognitive ability increases along the risk dimensions. At the age of 11 years, children without any risk have an average *IQ* of 108 (SD 15.3), compared to the children with the highest organic and psychosocial risk with an average score of 87 (SD 27.3) (Table 1). The results for the

MQ at the age of 11 are very similar to the results for the *IQ*. The average gap in cognitive abilities at the age of 11 between the no-risk and the maximum-risk group has increased to 21.⁵

Table 1: Children's abilities at 3 months and 11 years evaluated in the risk matrix (means and SD)

		Psychosocial Risk					
		no-risk		moderate		high	
<i>IQ (Intelligence Quotient)</i>							
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	103*	108*	102*	107*	96*	100*
		13.5	15.3	16.7	16.3	15.9	18.9
	moderate	101*	105*	99*	98*	97*	97
		16.0	10.4	16.5	13.3	16.3	19.2
	high	95	101*	93	92	88	87
		13.2	20.0	17.4	24.0	19.8	27.3
<i>MQ (Motor Quotient)</i>							
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	103*	104*	102*	106*	103*	104*
		12.1	13.0	12.5	17.2	13.9	12.8
	moderate	101*	97*	98*	103*	99*	98*
		13.6	12.3	15.7	14.1	13.6	18.1
	high	93	98*	92	97*	89	86
		12.1	16.9	13.5	23.6	13.8	26.5
<i>P (Persistence score) (measured at 4.5 years instead of 3 months)</i>							
		4.5 years	11 years	4.5 years	11 years	4.5 years	11 years
Organic Risk	no-risk	3.82*	4.27*	3.50*	4.13*	3.17	3.84
		0.68	0.54	0.73	0.59	0.83	0.79
	moderate	3.54*	4.02*	3.38	3.87	3.20	3.63
		0.63	0.53	0.75	0.59	0.80	0.73
	high	3.61*	3.99*	3.14	3.71	3.07	3.55
		0.64	0.56	0.70	0.64	0.77	0.91

MARS, 364 observations; *IQ* and *MQ* are normalized to mean 100 and SD 15 in the normative group; persistence scores vary between 1.0, 1.1, ... (low) and 5.0 (high) * indicates the significance of differences relative to the highest-risk group at the 5 percent level.

⁵ The difference is greater when compared to the *IQ* of Romanian adoptees at maximum risk and the group of English adoptees without comparable risk (which amounts to 17, see Beckett et al., 2006).

Our findings reveal that initial risk conditions matter for inequality of cognitive, motor and noncognitive abilities and that the cumulative effect of organic and psychosocial risks corresponds to the sum of the single risk effects. Differences in average cognitive, motor and noncognitive abilities accelerate, and heterogeneity increases along the risk dimensions. In the data we found significant sex differences in the *IQ* only in the years 2 and 4.5 (the *IQ* of girls is 6% higher), and in *P* after the age of two years (girls score higher, between 0.42 at 4.5 years and 0.22 at 11 years). There is a significant correlation of 0.28 between the *IQ* and the height at the age of 3 months, confirming findings by Case and Paxson (2008) that height is a proxy for cognitive abilities in early childhood.

3. Economic and socio-emotional home resources

There are two types of home resource variables by which the children were assessed in their early life cycle, summarized into socio-emotional categories, *H*, and economic categories, measured by the monthly net equivalence income per household member, *Y* (Table 2). In MARS, the socio-emotional home resources were rated with the Home Observation for Measurement of the Environment (HOME, Bradley, 1989). The HOME in MARS uses the original subscales of the HOME and modifications for the German living conditions.

The HOME at the age of 3 months consists of six subscales: (1) emotional and verbal responsibility of the mother, (2) acceptance of the child, (3) organization of the environment, (4) provision of appropriate play materials, (5) maternal involvement with the child and (6) variability. At the age of 2 years the modified version comprises the six subscales plus the caretaking activities. At the age of 4.5 years the modified version consists of the original subscales plus the caretaking activities items and items related to the included parent interview. At the age of 8 and 11 years MARS adopted HOME, which consists of 6 subscales and 81 items. All items were evaluated by trained home visitors (interviewers) in contact with the primary caregiver.

We use the sum of all items, the total HOME score, *H*. Todd and Wolpin (2006) also use the total HOME score, while Cunha and Heckman (2008) use subscales, such as theatre visits, musical instruments and books.

Table 2: *H* and *Y* in children aged 3 months and 11 years evaluated in the risk matrix (means and SD)

		Psychosocial Risk					
		no-risk		moderate		high	
		<i>H: HOME score</i>					
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	106*	108*	102*	105*	93	92
		12.9	6.5	12.9	10.2	17.0	19.8
	moderate	105*	107*	100	99	95	92
		14.2	6.9	12.9	12.6	14.1	21.7
	high	106*	106*	100*	98	94	94
		10.5	9.1	12.7	10.8	18.6	16.6
		<i>Y: monthly net equivalence income per head</i>					
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	1,275*	1,699*	1,122*	1,632	775	1,256
		775	681	542	832	465	643
	moderate	1,293*	1,644*	903	1,325	948	1,325
		649	627	239	555	774	641
	high	1,180*	1,806*	927	1,425	863	1,355
		403	629	295	495	344	636

MARS, 364 observations; for the initial risk matrix, compare Table A1 and A2 and the text. *Y* in DEM; *H* is normalized to mean = 100 and SD = 15 in the normative group for comparison reasons; * indicates significance of mean differences relative to the high-risk group at the 5 percent level.

Both measures of a child's home resources decline steadily along the psychosocial risk dimension (Table 2). For the group of children with high psychosocial risk, *Y* is on average 60 percent of the value in the no-risk group. The differences in the average *H* in the risk matrix show a similar pattern, although the gap between the cells is lower. *H* for the group of children with high psychosocial risk is 87 percent compared to the no-risk group. The partial elasticity of *H* with respect to *Y* is on average 0.08 ($t_1=0.06$, $t_2=0.09$, $t_3=0.11$, $t_4=0.08$, $t_5=0.07$). If economic resources were doubled, *H* would be 6 to 11 percent higher. One interesting finding in our data is this relationship between *H* and *Y* and their variation for the children in the risk matrix. Although the relationship is clearly positive in the sense that more economic resources are associated with a better HOME score, the absolute magnitude seems to be rather low.

3. Social competencies

Social competencies of children were assessed from the ages of 4.5 to 11 by the Scales for Levels of Functioning and from 8 to 11 years, using the Perceived Competence Scales (Harter and Pike, 1984; German version by Asendorpf and van Aken, 1993). Based on expert ratings, these scales aim to measure independence in everyday life, *autonomy*, hobbies, *interests*, and integration in groups and social life, *peers*, Table 3. In addition to the expert-rated Levels of Functioning scale, peers, a self-rating indicating perceived peer acceptance, is included for comparison reasons. *Peer acceptance* is a subscale of the Harter scale which consists of 6 items, each ranging from 1 to 4. The items correspond to children's self-perceptions regarding their peer relationships. For example, children were asked how many friends they have, whether they play together in general and whether they play on a children's playground.

Table 3: Social achievement at the age of 8 years evaluated for children in the risk matrix (means)

		Psychosocial Risk		
		no-risk	moderate	high
		<i>interests / autonomy</i>		
Organic Risk	no-risk	5.09* / 4.64*	4.87* / 4.84*	4.37 / 4.78*
	moderate	4.98* / 4.83*	4.42* / 4.52	4.09 / 4.35
	high	4.92* / 4.59	4.31 / 4.26	3.95 / 4.07
		<i>peer relations (expert- / self-rated)</i>		
Organic Risk	no-risk	4.82* / 18.23	4.62* / 18.20	4.57* / 18.36
	moderate	4.48* / 18.50	4.45* / 18.06	4.39 / 17.84
	high	4.81* / 19.11	4.41 / 18.27	3.98 / 18.49

MARS, 364 observations; social competence scores range from 1.0 (low), 1.1, ... to 5.0 (high), self-concept scores range from 10 (low) to 24 (high); * indicates significant mean differences relative to the high risk group at the 5 percent level.

Table 3 contains the means of the competencies variables evaluated at the age of 8 years for the cells of the risk matrix. Risk effects seem to cumulate, and the three social adjustment scores from expert ratings decrease along both dimensions of the risk matrix. The gaps in average social competencies at the age of 8 years are significant. The difference between the no-risk and the highest-risk groups amounts to roughly 25 percent. However, two exceptions are worth mentioning. First, if there is no psychosocial risk, organic risks seem to lose significance for *autonomy*, *interest* and *peers*. For pursuing various interests and popularity with peers, the initial psychosocial risk load seems to be, on average, more harmful than organic risks. Second, based on the self-rating, there seems to be little variation in the cells of the risk matrix. From the child's viewpoint, the differences in social life seem to be less significant compared to the expert ratings.

4. School achievement

On average 45 percent of the children in MARS attend a *Gymnasium*, which is the highest-track/grammar school in Germany.⁶ For attending the *Gymnasium*, the initial risk matrix matters significantly (Table 4). In the highest-risk group, only 15 percent of the children attend the *Gymnasium*, compared to 74 percent in the no-risk group. Average school attendance decreases (nearly) monotonically along the two dimensions of our risk design with two exceptions observed for children born without any psychosocial risk and without any organic risk. In the former case, there seems to be no difference between the moderate and the high organic risk groups and, in the latter case, between the no-risk and the moderate psychosocial risk groups.

School choice takes place, as a rule, after the age of 10 in Germany. Grades are relevant for tracking. School achievement at the age of 8 years, measured with grades in *math*

⁶ Thirty percent attended a *Realschule*, 16 percent a *Hauptschule* (lowest secondary school track) and 8 percent more specific school types (*Förderschule*, *Walldorfschule*). A *Förderschule* is a school type for children with learning disabilities or who are disabled. According to official statistics on the 2000/01 school year in Baden-Württemberg, 30 percent of the students in class 9 attended *Gymnasium*, 35 percent *Realschule* and 35 percent *Grund- und Hauptschule* (without *Förderschule*) (in 2006/07, the numbers including the *Förderschule* are 28 percent, 31 percent, 29 percent, and in addition 11 percent *Förderschule*, and 1.3 percent *Walldorfschule*). We conclude that in our data more children attend higher second-

and *German*, confirm the importance of the initial risk conditions with the exceptions described above. Grades in the highest-risk group are about one grade lower than grades in the no-risk group. A high psychosocial risk has the largest negative average effect. Not surprisingly, there is not much variation between the average grades in these three subjects in each cell of the risk matrix. This finding suggests that the initial risk matrix has implication for all school subjects.

Table 4: School achievement (grades) at age 8 and higher-track secondary school attendance at age 11

		Psychosocial Risk		
		no-risk	moderate	high
<i>Grades in reading, spelling and math ^{a)} at age 8</i>				
Organic Risk	no-risk	2.0*/ 2.1*/ 2.1*	2.2*/ 2.2*/ 2.1*	2.3/ 2.6 / 2.4*
	moderate	2.2*/ 2.2*/ 2.2*	2.4 / 2.4*/ 2.4	2.8 / 2.9 / 2.7
	high	2.1*/ 2.2*/ 2.3*	2.4 / 2.4 / 2.6	2.8 / 3.0 / 2.9
<i>Higher-track secondary school attendance Gymnasium / Realschule / Others ^{b)} at age 11(in percent)</i>				
Organic Risk	no-risk	74* / 24* / 02*	77* / 09* / 14*	43 / 21* / 36
	moderate	45 / 40* / 15*	38 / 38* / 34*	33 / 23 / 44
	high	54* / 23* / 23*	27 / 38 / 45	15 / 28 / 67

MARS, 322 to 357 observations, depending on the available information; ^{a)} in the German educational system grades range from 1.0 (excellent) to 6.0 (insufficient), ^{b)}Haupt-, Förder- and Walldorfschule, *indicates significant mean differences relative to the high-risk group at the 5 percent level.

5. First Order Temporal Correlations

We utilize the longitudinal dimension of MARS and calculate the first-order temporal correlations for our cognitive, motor and noncognitive abilities and for social achieve-

ment in higher-track secondary school compared to the average in Baden-Württemberg for class 9. One reason is that children from immigrant families with poor German language skills have not been included.

ment, Table 5. The interpersonal rate of consolidation of competencies varies during development. While it is lower for some abilities, for example self-regulation, it may be higher for others, for example motor abilities. A high value of the first-order temporal correlations is a hint that measured competencies at two different developmental stages are in fact similar. Interpersonal differences have been stable between the two periods. Taking measurement errors and further factors of influence into account (discussed in section 4 below) a correlation coefficient between 0.30 and 0.49 indicates moderate consolidation, a value between 0.5 and 0.69 indicates consolidation and values above 0.70 hints at high consolidation of interpersonal differences over time.

Table 5: First-order temporal correlations

	3 months 2 years	2 years 4.5 years	4.5 years 8 year	8 years 11 years
<i>Basic abilities</i>				
<i>IQ</i>	0.34	0.72	0.74	0.81
<i>MQ</i>	0.35	0.63	0.53	0.60
<i>P</i>	0.03	0.42	0.59	0.64
<i>Social achievement</i>				
<i>Peers</i>	n.a.	n.a.	0.31	0.65
<i>Interests</i>	n.a.	n.a.	0.58	0.64
<i>Autonomy</i>	n.a.	n.a.	0.33	0.56

MARS, 364 observations; all correlation coefficients are significant at the 5 percent level.

The analysis suggests that interpersonal differences in cognitive and motor abilities in our sample consolidate between the second and the fourth/fifth year. The correlations vary between 0.63 and 0.72, suggesting a relatively high degree of stability of interpersonal differences in the *IQ*. The first-order temporal correlations for persistence are lower. They indicate only moderate stability until the age of 4.5 years and an increase in stability afterwards. There is moderate stability of social competences between the ages 4.5 and 8 years and consolidation afterwards. Social competences such as good peer relationships and interests that demonstrate child's social integration seem to consolidate in the age between 8 and 11 years.

With respect to the economic and socio-emotional home resources, Y and H , a high stability from birth until the age of 11 years is evident. The first order temporal correlations always exceed the value of 0.7. This demonstrates that children experience a relatively high degree of stability of their home environment, be they adverse or beneficial.

IV. ABILITY FORMATION IN THE EARLY LIFE COURSE

1. Econometric approaches

Factors that are responsible for the production of abilities, Θ_t , in period t , have been summarized in the technology of ability formation (Cunha and Heckman, 2007), see equation (1). Θ represents the vector of cognitive, motor, and noncognitive abilities. E represents perinatal conditions, Θ_{t-1} the vector of abilities from the period before, and I_t age specific investments intended to enhance abilities.

$$\Theta_t = f_t \left(I_t, \Theta_{t-1}, E \right) \quad (1)$$

Our epidemiological cohort data allow a detailed look at organic and psychosocial birth conditions. Moreover, the data contain comprehensive psychometric assessments as well as medical and psychological expert ratings of abilities and stage specific home resources during development. We assume that equation (1) can be represented in a Cobb-Douglas form. Taking the natural logarithm (lower case letters indicate the natural logarithm of the variables) yields equation (2):

$$\theta_{t,i}^j = \alpha_{0,t}^{j,R} + \alpha_t^{h,j} \cdot h_{t,i} + \alpha_t^j \cdot \theta_{t-1,i}^j + \alpha_t^{k,j} \cdot \theta_{t-1,i}^k + \alpha_t^{l,j} \cdot \theta_{t-1,i}^l + \varepsilon_{t,i}^j \quad (2)$$

where j, k, l are indices for the basic abilities IQ, MQ and P , and $i = 1, \dots, N$ ($=364$) is an index for the children. There are five different periods, indicated with t : infancy, toddlerhood, preschool age, elementary age and secondary school age. The variable R contains all nine cells of the two-dimensional risk matrix in MARS. The error term, ε , represents some unobserved factors that influence abilities.

In the econometric analysis we focus on the role of the HOME score, H , in period t and the stock of abilities from period $t-1$ for the production of abilities. All parameters can be interpreted as partial elasticity. The Cobb-Douglas form (equation (2)) implies that

actual abilities can be produced continuously by socio-emotional home resources and the stock of abilities available from the past period. While perinatal conditions may have lasting effects on the level of abilities, change remains possible in each period.

The relationship between parental investments and children's abilities may be reciprocal. Having a child with high abilities is likely to increase H to bolster development. Having a child with low abilities may be a source of stress for the parents, which may even lead to a reduction of H . If parental investment depend on abilities in such a way an OLS estimates of equation (2) may be biased downward, since children with higher abilities also have higher home resources. To address the endogeneity of H we compare OLS with Two Stage Least Square results (2SLS). In the first stage we estimate H as a function of the ability under consideration, for instance the IQ , and use the economic home resources, Y , as an additional variable. This is equivalent of using Y as an instrument for H .

Monthly net equivalence income per head, Y , is partially related to H , one necessary condition for an instrumental variable. We find a significant (partial) correlation in each period (reported in section 3 above). On average a 10% increase in Y is associated with a 1% increase in H . A second condition for Y being a valid instrument is that it should only affect abilities through its relation with H . As the exogeneity of an instrument is not testable for the one-instrument case, we assume that the socio-emotional home resources, parental care, cause ability development. While parental care itself may depend on the availability of economic home resources the latter do not have a direct impact on ability formation. This does not rule out that there exist a direct pathway from Y to other competencies, for instance social achievement and school grades. Furthermore, the choice for higher secondary education in adolescence directly depends on the availability of economic resources (compare section 5 below).

In the data, the influence of Y on children's abilities is never significant when we include H in equation (2). During the period of ability formation in childhood Y has no measurable direct partial relationship with abilities in our data, if past abilities and socio-emotional home resources are included in the estimation equations. The relationship is dominated by the variation of socio-emotional home resources and past abilities, and not by the inequality of per capita income in the family. Thus under the assumption

that financial resources has no direct impact on abilities, 2SLS identifies the causal relationship between H and abilities.

A different, though related, source of bias may stem from other correlations between the HOME score and the error term. Levels of abilities from the distant past could be related with current socio-emotional home resources. For instance, parents may have changed the home environment as a reaction of some unobserved aspects of child's emotional regulation or cognitive abilities in early childhood. Since the quality of parental care is correlated over time a correlation between the error term and actual H may still exist. In that case OLS estimates of the H coefficient may be biased upwards. To reduce this type of bias we include all available lags of abilities into equation (2) (see Wooldridge, 2005).

2. *Econometric results*

Table 6 documents the estimates of the different econometric approaches for the IQ and P equation: OLS without and with additional lags and 2SLS without and with lags. For reasons of clarity we exclude the results for the MQ equation. Although the relationship with socio-emotional home resources is always positive, it lacks statistical significance at the 5% level (results for the approaches without lags are available in Blomeyer et al., 2008). We conclude that motor abilities strongly depend on perinatal organic and psychosocial conditions (compare Table 1 above), while we could not find a significant association with socio-emotional home resources after birth. Thus, there appears to be a high degree of stability in interpersonal differences in the MQ during the early life course.

A significance level of 5 percent has been chosen throughout the study and standard errors have been estimated with robust techniques. Each equation contains the set of dummies from the initial risk matrix, R . Starting with age four/five this set of dummies was not jointly significant at the 5 percent level for cognitive and noncognitive abilities and a second estimate has been performed without R .

The OLS estimates indicate that H is significantly related to cognitive and noncognitive ability development at all developmental stages (Table 6). The role of socio-emotional home resources and the level of abilities from the past period for ability formation

changes in a way specific to age. Basic cognitive and noncognitive abilities are strongly related to the socio-emotional home resources. P is always significantly associated with H , with the estimated partial elasticity varying between 0.28 and 0.50. The highest elasticity, 0.50, is estimated at the age of 4.5 years. The IQ is positively related to H until the age of 4.5 years, with an estimated partial elasticity varying between 0.55 at three months and 0.38 at the age of 4.5 years. At school age, the elasticity falls to 0.19. Although this is still a remarkable positive relationship, it is no longer significant at the 5% level.

Not surprisingly, the estimated elasticity of the past abilities steadily increases during the early life course. It is low until toddlerhood and increases thereafter. With the increasing values of abilities the child reaches higher levels of independence from home resources. During development the socio-emotional home environment loses their strong relationship with abilities in preschool age. The more abilities children acquired during childhood the higher the stock of cognitive abilities at school age will be, when the relationship to socio-emotional home resources decreases and becomes weaker.

The 2SLS estimates for the IQ and P equation are, in the case they are significant, higher (Table 6) (with one exception: at preschool age the coefficient for the P equation is lower for the 2SLS estimate). For example, in the third period (age 4.5 years), the coefficient in the IQ equation is 0.53, compared to OLS, 0.38. In infancy and toddlerhood, the difference is higher. If parents provide a higher H for their first-born children with a higher IQ , then the OLS underestimates the partial elasticity as a result of simultaneity bias. For the equation on noncognitive abilities, P , 2SLS are, with one exception, higher than OLS coefficients.

Under the assumption that economic resources have no direct impact on ability 2SLS identifies the causal relationship. If the assumption holds, the socio-emotional home resources are even more important for child development than the OLS results suggest. Although this is in line with evidence on the eminent role of early childhood summarized by Amor (2003) and Heckman (2007), among others, there is a caveat in our analyses. 2SLS estimates produce higher standard errors (for the year 4.5 and the IQ equation (2) the point estimate is 0.53 with standard error 0.18 compared to OLS: 0.38, 0.7). Therefore the difference to OLS is not well-determined from a statistical point of view.

Table 6: Econometric findings for ability formation, equation (2)
(standard errors in brackets)

	IQ_t				P_t			
	OLS	OLS + lags	2SLS	2SLS + lags	OLS	OLS + lags	2SLS	2SLS + lags
$t = 3$ months^{a)}								
$H(t-1)$	0.54*		2.37*		0.30*		0.66	
	(0.14)		(0.98)		(0.14)		(0.73)	
Adj. R ² /F-test	0.10		2.54		0.02		1.15	
$t = 2$ years^{a)}								
$H(t-1)$	0.37*		1.57*		0.36***		1.33**	
	(0.08)		(0.45)		(0.11)		(0.58)	
$IQ(t-1)$	0.23*		0.09		0.11		0.001	
	(0.06)		(0.10)		(0.08)		(0.11)	
$P(t-1)$	0.13*		0.16*		-0.07		0.18*	
	(0.06)		(0.09)		(0.07)		(0.11)	
Adj. R ² /F-test	0.30		6.94		0.12		3.49	
$t = 4.5$ years								
$H(t-1)$	0.38*	0.37*	0.50*	0.51***	0.54*	0.53*	0.04	-0.02
	(0.09)	(0.09)	(0.18)	(0.20)	(0.22)	(0.22)	(0.40)	(0.43)
$IQ(t-1)$	0.53*	0.53*	0.50*	0.50*	0.55*	0.53*	0.67*	0.65*
	(0.06)	(0.06)	(0.07)	(0.07)	(0.12)	(0.12)	(0.14)	(0.14)
$P(t-1)$	0.02	0.02	0.008	0.01	0.16*	0.18*	0.19*	0.21*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)	(0.06)	(0.07)	(0.07)
Adj. R ² /F-test	0.58	0.58	71.12	45.28	0.34	0.34	29.85	19.38
$t = 8$ years								
$H(t-1)$	0.19	0.18	0.31	0.24	0.43*	0.38*	0.64	0.53
	(0.16)	(0.15)	(0.35)	(0.37)	(0.18)	(0.18)	(0.45)	(0.50)
$IQ(t-1)$	0.84*	0.77*	0.82*	0.76*	0.27*	0.21*	0.24*	0.19
	(0.08)	(0.10)	(0.10)	(0.10)	(0.10)	(0.12)	(0.13)	(0.14)
$P(t-1)$	0.09*	0.08*	0.08*	0.07	0.29*	0.28*	0.28*	0.27*
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
Adj. R ² /F-test	0.64	0.64	37.61	17.87	0.36	0.35	27.92	13.10
$t = 11$ years								
$H(t-1)$	0.17	0.16	-0.59	-0.90	0.39*	0.38*	0.89	1.38*
	(0.15)	(0.15)	(0.51)	(0.59)	(0.18)	(0.19)	(0.61)	(0.70)
$IQ(t-1)$	0.88*	0.75*	1.02*	0.89*	0.22*	0.32*	0.12	0.19
	(0.07)	(0.07)	(0.12)	(0.11)	(0.07)	(0.09)	(0.13)	(0.13)
$P(t-1)$	0.11*	0.11*	0.15*	0.14*	0.29*	0.25*	0.26*	0.22*
	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.07)
Adj. R ² /F-test	0.76	0.78	49.14	19.28	0.36	0.39	25.68	9.19

MARS, 364 observations, all variables in natural logarithm; estimates include a constant; ^{a)} the equations for 3 months and 2 years contain nine dummies for the cells in the perinatal risk matrix; + lags: in this column all available lags of IQ MQ and P are included in addition to the one period lag, although the coefficients are not reported here; * indicates significance at the 5 percent level, based on heteroscedasticity-robust standard errors; Adj. R²/F-test: for OLS the Adj. R² for 2SLS F-test are reported.

OLS results with lower standard errors may be closer to the “true” parameters of the technology of ability formation. Nevertheless, 2SLS estimates demonstrate that socio-emotional home resources might be more important for cognitive ability than OLS results suggest. Therefore, we regard the 2SLS results as an upper bound and the OLS results as a lower bound of the “true” value of the elasticity. We will compare policy conclusions based upon the upper and the lower bounds in section VI below. Including all available lags (compare Wooldridge (2005) in order to reduce a bias from correlations between socio-emotional home resources and abilities from the past does neither change the coefficient of H nor those for the lagged abilities (one period lag) much (Table 6, column 3, column 5). We conclude that potential correlations between past abilities (with a lag longer than one period) and H neither bias the OLS nor the 2SLQ estimates.

If a sex indicator is included in equation (2), the respective coefficients are significant in Model 1 in two from the five periods. The estimated sex differences vary around 0.02 and 0.04, if significant. Since all other coefficients remain unaffected, we conclude that sex differences play only some minor role in the production of cognitive and noncognitive abilities in our data. If we include height (and/or weight) in addition the explanatory power of Model 1 is not higher and the additional coefficients are never significant. These results (available upon request by the authors) suggest that height is a proxy for cognitive abilities in early childhood (Case and Paxson (2008)). It seems to lose its explanatory power once past values of abilities are available for research on the development of abilities.

3. Further results

A set of quantile regressions was performed to look at differences for each quantile of the ability distribution, starting at the age of 2 years. The set of results for the IQ are reported in Table A3. The quantile estimates suggest that the partial elasticity of H with respect to the IQ is slightly lower at the tails of the IQ distribution (or slightly higher in the midst). For children with rather low and rather high cognitive abilities H seems to be less important compared to children with medium abilities. At the age of 11 years and for the 50th and 60th percentile of the IQ distribution the partial elasticity of H with respect to the IQ turns out to become significant (see Table A4). We conclude that the

production of abilities depends on the level of abilities. Although the number of observations in our data is too low to quantify the differences more precisely, the results suggest the relationship is strongest in the midst of the distribution and less strong at the tails. Socio-emotional home resources have a lower association with the IQ in the group of children with low and high IQ measures.

Finally, Table A4 documents separate regression results for the verbal and the nonverbal part of the IQ to investigate whether there is evidence for sensitive investment periods specific to either group of basic cognitive abilities. The partial elasticity of H with respect to the verbal IQ is higher in comparison to the nonverbal IQ at all developmental stages (Table A4). We conclude that socio-emotional home resources have a higher relationship with language development than with perception, understanding and logical reasoning. The window of ability formation with the help of improved socio-emotional home resources seems to be shorter with respect to the basic nonverbal aspects of cognitive abilities, like logical reasoning and longer with respect to the verbal and language aspects of cognitive abilities.

VI. ABILITIES AS PREDICTORS OF COMPETENCIES AT SCHOOL AGE

In this section, we proceed with the analysis of competence formation during the transition from preschool to primary and from primary to secondary school. We try to shed more light on complementarities between basic cognitive and noncognitive abilities and social and school achievement during the early life course to assess further important aspects of the childhood ability multiplier (Heckman (2007)). Furthermore we study whether higher secondary school track does still improve basic cognitive and noncognitive abilities.

1. Abilities in preschool age as predictors of competencies at primary school age

Do cognitive and noncognitive abilities at preschool age predict social competencies at primary school age? We present findings from regression models to explain four (measures of) social competencies at primary school age. On the right hand side of the regression equation home resources, H and Y , and the level of IQ , MQ and P measured at preschool age are included. The results from OLS estimates, documented in Table 7, demonstrate substantial complementarities between abilities acquired during childhood and

social competencies a child achieves at elementary school age and some differences between the four competencies.

Table 7: The partial elasticity of abilities and home resources for social competencies at the age of $t=8$ years (standard errors in brackets)

	<i>interests</i>		<i>autonomy</i>		<i>peer relations:</i>			
					<i>expert-rated</i>		<i>self-rated</i>	
$H(t)$	1.44*	(0.18)	0.07	(0.26)	0.76*	(0.20)	0.27	(0.23)
$Y(t)$	-0.00	(0.02)	-0.04	(0.03)	-0.00	(0.03)	0.03	(0.03)
$IQ(t-1)$	0.54*	(0.10)	0.07	(0.14)	0.12	(0.12)	0.13	(0.11)
$MQ(t-1)$	0.21*	(0.07)	0.65*	(0.10)	0.29*	(0.08)	0.05	(0.09)
$P(t-1)$	0.13*	(0.04)	-0.06	(0.07)	0.21*	(0.06)	0.05	(0.06)
Adj. R ²	0.60		0.23		0.29		0.04	
No. of Obs.	364		364		363		352	

MARS, OLS regressions, including a constant, with heteroscedastically robust standard errors; all variables in natural logarithm; * indicates significance at the 5 percent level.

Cognitive and noncognitive abilities at preschool age predict achievement and social competences at primary school age. Contemporary H enhances both popularity among peers, *peer relations*, and the variety of actively followed interests, *interests*, according to the expert ratings in our data. According to our interpretation the findings demonstrate complementarities in competence formation. Higher basic cognitive and noncognitive abilities acquired in childhood help children to perform better grades at school age and in friendship. Children from adverse home environments appear to suffer twice, due to poor investments in their abilities from conception until preschool age and due to insufficient support again during primary school age.

There are significant associations between the indicator of social competence, *peers*, and H , the past MQ and P . *Interests* are additionally associated with the IQ from the past period. *Autonomy*, measuring maturity in everyday life, is solely linked with the past MQ . Surprisingly, however, there is no significant coefficient in the *self-rated peer relations* equation at all. None of our observables are related to the child's self-rating with respect to social relationships and friendships (last column, Table 7). Findings from self-ratings differ from those of expert ratings. This discrepancy could be caused

by a self-protection mechanism employed by children at risk to cope with a situation of continuing lack of emotional support. To overcome their misery they rate their peer relationship as appropriate. Another possible explanation is that children with lower levels of basic abilities are satisfied with less variety in their relationship with friends and in their interests.

2. Abilities in primary school age as predictors of achievement at secondary school age

In this section we proceed studying the transition from primary to secondary school. Do cognitive and noncognitive abilities at primary school age predict school achievement at secondary school age? What is the role of home resources in this period? Findings from linear regression predicting school grades are summarized in Table 8 and from probit models predicting secondary school attendance are summarized in Table 9. Grades in primary school at the age of 8 years, before ability tracking (grading) takes place, are predicted for the topics German *reading*, *spelling* and *math*.

All grade equations include the current H , the current Y and the cognitive, motor and noncognitive abilities measured before entry in school has taken place, at the age of 4.5 years. In an additional model, the IQ is divided into two aspects, the verbal and the non-verbal abilities, $V-IQ$ and $NV-IQ$, respectively. Note that a negative coefficient in Table 8 means a better grade. The estimates can be interpreted in terms of partial elasticity since the (natural) logarithm has been used for all variables. The IQ and P at preschool age are significantly related to better grades in *reading* and *spelling* as well as in *math*, with similar coefficients, while the MQ is not (Table 8). *Persistence* is an important predictor for later achievement in school, which is in line with Heckman (2000).

Interestingly, neither H nor Y is related at all to the grades received at age 8. Considering the different aspects of IQ , only the $NV-IQ$ remains a significant predictor of better grades. Accordingly, higher cognitive ability of logical reasoning and noncognitive abilities tend to be more important for predicting school achievement at the primary school level than verbal cognitive abilities, for example language competencies. This is of utmost interest for policies to foster human capital since the window of improving logical reasoning through improved socio-emotional resources available for the child ends early in childhood.

Table 8: The partial elasticity of home resources in t and abilities in $t-1$ for school grades ^{a)} at primary school age, $t=8$ years (standard errors in brackets)

	<i>reading</i>		<i>spelling</i>		<i>math</i>	
	<i>IQ</i>	<i>V-/NV-IQ</i>	<i>IQ</i>	<i>V-/NV-IQ</i>	<i>IQ</i>	<i>V-/NV-IQ</i>
<i>H (t)</i>	-0.10 (0.43)	-0.05 (0.41)	-0.64 (0.43)	-0.62 (0.39)	-0.49 (0.42)	-0.57 (0.40)
<i>Y (t)</i>	-0.02 (0.02)	-0.02 (0.06)	-0.06 (0.05)	-0.07 (0.05)	-0.04 (0.06)	-0.04 (0.06)
<i>IQ (t-1)</i>	-0.84* (0.19)		-0.60* (0.19)		-0.66* (0.19)	
<i>NV-IQ (t-1)</i>		-0.96* (0.23)		-1.18* (0.21)		-1.16* (0.23)
<i>V-IQ (t-1)</i>		-0.26 (0.23)		0.16 (0.21)		0.21 (20)
<i>MQ (t-1)</i>	-0.17 (0.13)	0.009 (0.13)	-0.21 (0.12)	0.001 (0.12)	-0.10 (0.12)	0.04 (12)
<i>P (t-1)</i>	-0.32* (0.10)	-0.23 (0.10)	-0.29* (0.10)	-0.19* (0.10)	-0.25* (0.10)	-0.22* (0.10)
Adj. R ²	0.1919	0.2368	0.2005	0.2670	0.1709	0.225
No. of Obs.	327	327	322	322	327	327

MARS, ^{a)} in the German educational system grades range from 1.0 (excellent) to 6.0 (insufficient); OLS regressions for *reading*, *spelling* and *math* including a constant, heteroscedastically robust standard errors, all variables in natural logarithm; * indicates significance at the 5 percent level.

All probit estimates for attending the Gymnasium include the stage-specific home resources H and Y , and the cognitive, motor and noncognitive abilities. These are measured at primary school age (8 years), two years before tracking takes place. In a further specification, the total IQ is split into verbal and non-verbal cognitive abilities. In addition, all available lags of the three abilities are included in the probit equation to reduce a potential bias from endogeneity (Wooldridge, 2005) (Table 9).

The IQ , the MQ and the P at the primary school age are significantly related to the probability of attending the Gymnasium. The magnitude of P is lower compared to the IQ and higher compared to the MQ . Home resources increase the probability of attending the Gymnasium. H is as important as the IQ , and at this stage of transition from primary to secondary school attendance the economic resources, Y , come into play. If

the verbal and the non-verbal IQ are considered separately, the $NV-IQ$ tends to be slightly more important than the $V-IQ$. Using all lags of ability (Table 9) further reduces some of the coefficients in the probit equation. The reduction does not change our conclusions.

Table 10: Average marginal effects for attending the *Gymnasium*
(standard errors in brackets)

	IQ		$IQ; + \text{lags}^a$	
$H(t)$	0.82*	(0.37)	0.60*	(0.38)
$Y(t)$	0.15*	(0.05)	0.18*	(0.05)
$IQ(t-1)$	1.03*	(0.15)	0.84*	(0.19)
$MQ(t-1)$	0.37*	(0.15)	0.33*	(0.16)
$P(t-1)$	0.49*	(0.12)	0.38*	(0.11)
Pseudo R^2	0.29		0.32	
Observations	357		357	

MARS, ^{a)} this specification contains all available additional lags in abilities, albeit not reported here; these lags are jointly significant (LR-tests: 86.18*, 71.35*); * indicates significance at 5 percent level.

We numerically examine the importance of the stock of abilities and socio-emotional home resources (all values are taken from the estimation with all lags included) for higher-track secondary school attendance. If the IQ at age 8 were 110 instead of 100 (that is, 10 percent higher), the average marginal probability of attending the Gymnasium increased by 8.4 percent. If P at age 8 were 3.3 instead of 3, the average marginal probability increased by 3.8 percent. If H at age 11 were 110 instead of 100 the average marginal probability increased by 6 percent and if Y at age 11 increased by 10 percent the marginal increase in the probability would be 1.8 percent.

3. Higher-track secondary school and basic abilities

Does attending *Gymnasium* influence the cognitive, motor and noncognitive abilities measured at the age of 11? To address this question we estimate equation (2) again, including an additional indicator variable *Gymnasium*. We estimate the extended version of equation (2) with OLS and 2SLS methods in order to take a potential selectivity bias into account. Children with higher abilities are also those children who have a higher

probability of entering *Gymnasium*. In the 2SLS, Y is used as an instrumental variable for *Gymnasium*. The results (not reported here, available upon request) indicate that *Gymnasium* is not associated with cognitive and motor abilities at secondary school age. Only the coefficient in the *persistence* equation is significantly different from 0 when OLS is used, with a value 0.06 (and a standard error of 0.02). All else equal, students attending the *Gymnasium* score 6 percent higher in *persistence* compared to the other students. Although in the 2SLS estimate the point estimate is higher 0.13, the standard error is also high, 0.12. So the coefficient is statistically no longer different from 0.

The result suggests that OLS estimates are biased. Those who attend *Gymnasium* also have higher cognitive abilities (higher *IQ*). They choose *Gymnasium* because they have higher abilities. Attending *Gymnasium* after the age of ten years seems to have no longer any measurable impact on improving the basic cognitive, motor and noncognitive abilities in our data. These abilities are produced with adequate socio-emotional home resources during the early life course. They predict school achievement, help to perform in grades, and predict higher track school attendance. Although the results do not imply that *Gymnasium* has no relationship to competencies trained at the *Gymnasium* (like languages, math or natural sciences), they suggest that effective policies designed to improve secondary school achievement should, whenever this is intended, start at preschool age (see also Heckman (2007)). In the following section trade offs in policies to foster competence formations during the early life course are analyzed.

VI. POLICIES TO IMPROVE COMPETENCIES AND SCHOOL ACHIEVEMENT

What can be learned from our investigation for education policies? Assume that the government has two objectives: it intends to improve competencies at secondary school age and increase the share of children entering the *Gymnasium*. Since ability formation is a cumulative process the government may face a trade off in the early course that we would like to illustrate numerically.⁷ Either the government helps the children early in their life to overcome constraints through poor socio-emotional home resources or the government helps the children later at school age to overcome credit constraints.

⁷ For a theoretical analysis of optimal human capital investment over the life cycle, compare Cunha and Heckman (2007), and for an application over the whole life-cycle see also Pfeiffer and Reuß (2008), among others.

It is assumed that the government is willing to raise Y for all households by 10% (that is an increase of 103 DEM per child on average in nominal terms 1986/1987, 1st wave, 151 DEM in nominal terms 1997/1998, 5th wave). A 10% increase in Y has no direct implication for the formation of cognitive, motor and noncognitive abilities during childhood. However, on average it is related with a 1% increase in H in our data. To help children in ability formation it is necessary to improve their access to socio-emotional home resources (or qualified parental care). Although low economic and poor socio-emotional home resources are correlated, mainly the socio-emotional home resources are relevant for development (see section 5). To improve H by 1%, a 10% increase in Y suffices. Either families receive a direct 10% income support or H is increased by other means (for example direct emotional support for the children). Such a program may cost around 10% of Y .

We take all direct and indirect multiplier and accelerator effects from the age-dependent 1% increase in H into account and further compare the results from OLS and 2SLQ estimates. We regard the OLS estimates as a lower bound, and the 2SLQ estimates as an upper bound of the policy effect. The impacts of age-dependent policies are summarized in Table A5. On the one hand, looking at the columns, Table A5 documents the percent point increases of a 1 % increase in H at five developmental stages during the early life course, for example at 3 months or 2 years, a s o.. On the other hand, looking at the rows, Table A5 documents the resulting effects at a specific developmental stage, for example at the age of 8 or 11 years, a s o..

Firstly, a reflection on lower and upper bound effects leads to a set of similar and a set of different policy implications. Both bounds indicate that the first four to five years in life are optimal for bolstering basic cognitive abilities, while the window for improving noncognitive abilities widens until adolescence. While both bounds clearly indicate that childhood is of utmost importance for competencies at secondary school age, the results for the upper bound suggest that infancy and toddlerhood is even more relevant than preschool age. The lower bound results indicate that policies at infancy, toddlerhood and preschool age have effects of similar magnitude. In what follows we further discuss implications from the lower bound findings. We regard the upper bound results, although they are in line with Heckman (2007) and psychological research for future re-

search based on better data to assess the precision of the bounds. Note that standard errors of the 2SLS estimates are relatively high (see section 5).

If policy successfully raises H by 1% at the age of three months (2 years, 4.5 years), until the age of 11 years the IQ would have been increased by 1.11% (1.06%, 1.10%), the MQ by 0.56% (0.31%, 0.19%) and P by 0.60% (0.96%, 0.94%). The probability of entering *Gymnasium* would be higher by an amount of 1.3% (1.3%, 1.1%). If H would have been increased by 1% each of the 3 developmental stages in childhood, the resulting effects on abilities can be added (for example the IQ would have been increased by $1.11+1.06+1.10\% = 3.27\%$). Such a policy would increase the probability of entering *Gymnasium* by 3.7% in our sample.

We compare these policies for improving the socio-emotional home resources available in childhood with an increase in economic home resources during the transition to secondary school age. A 10% increase of Y implemented when the child is 11 years old would increase the probability of attending the *Gymnasium* by 1.8% (see section 6). Such a policy would, through an improvement of socio-emotional home resources at secondary school age, also be helpful in further increasing noncognitive abilities, while it has no measurable impacts on cognitive and motor abilities. Both policy approaches (additional support in early childhood versus support at secondary school age) are successful in raising the probability of entering *Gymnasium*. However, they differ in their success to improve competencies.

The policy of supporting students at secondary school age mainly reduces credit market constraints and, to some degree improves noncognitive abilities. The policy of supporting students at preschool age or before helps to overcome a lack of socio-emotional home resources. Therefore this policy is more effective in improving basic abilities. As a result of complementarities in development higher social and school competencies will emerge. Indeed, a combination of both types of policies should be preferable for children left behind. For helping these children, support should be extended continuously during all developmental stages. It should be designed to overcome constraints in the availability of socio-emotional home resources in early childhood and credit market constraints in adolescence.

VII. CONCLUSIONS

This paper contributes to uncovering the relationship between initial risk conditions and home resources for competence formation in childhood as well as complementarities between children's early and later achievement. Using data taken from MARS, an epidemiological cohort study from birth to adulthood, our findings demonstrate that socio-emotional home resources are significantly related to ability formation across child development. The strength of the relationship differs between abilities and over time, which is in line with Heckman (2007).

Advantages from favorable socio-emotional home resources and disadvantages from poor socio-emotional home resources cumulate across development. Starting with risk and growing up in an unfavorable environment impedes the development of cognitive and motor abilities. The disadvantage continues during the early life cycle until school age, a stage particularly important for noncognitive ability formation (Heckman, 2000). Disadvantaged children are impeded once again when the transition to higher-track secondary school attendance takes place. At this stage, low economic home resources create an additional barrier.

We conclude that investment into better socio-emotional home resources during childhood bolsters cognitive and noncognitive abilities and improves social and school competencies. Economic support at school age increases the probability to enter *Gymnasium* in addition because it reduces credit market constraints. Future research on competence formation based on economic models should focus even more on more specific characteristics of the early parent-child-interaction, such as infant smiling and maternal responsiveness, and child development. Improved data are needed to fully understand the role of the parent-child-interaction during pregnancy and the first two years in life.

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Table A1: Definition of organic risk

	Criteria		N
1	normal birth weight	2.500–4.200 g	118
2	normal gestational age	38–42 weeks	118
3	no signs of asphyxia	pH ^a ≥ 7.2 lactic acid ^b ≤ 3.5 mmol/l CTG ^c score ≥ 8	118
4	no surgical delivery	except elective	118
5	EPH-gestosis	edema ^d proteinuria ^e hypertonia ^f	53
6	premature birth	≤ 37 weeks	151
7	signs of risk of premature birth	premature labor tocolytic treatment cerclage ^g	43
8	very low birth weight	≤ 1.500 g	46
9	clear case of asphyxia	pH ^a ≤ 7.1 lactic acid ^b ≥ 8.00 mmol/l CTG ^c score ≤ 4 treated neonatally for ≥ 7 days	38
10	neonatal complications	seizures respiratory therapy sepsis	83

^aThe pH-value measures an acid or basic effect of a hydrous solution. For individuals a low pH-value indicates less oxygen in the blood. ^bLactic acid, also known as milk acid, is a chemical compound that plays a role in biochemical processes. ^cA CTG (cardiotocograph) measures the child's heartbeat during pregnancy and labor. ^dAn edema, also known as hydropsy, is the increase of interstitial fluid in any organ during swelling. ^eProteinuria is an indicator of possible severe damage to metabolism or of kidney disease. ^fHypertonia is an indicator of a possible disease of the blood vessel system. ^gCerclage is an operative sealing of the cervix to prevent premature birth.

Table A2: Definition of psychosocial risk

	Items of the Risk Index	Explanation	N
1	Low educational level of a parent	Parent without completed school education or without skilled job training	74
2	Overcrowding	More than 1.0 person per room or size of housing $\leq 50 \text{ m}^2$	34
3	Parental psychiatric disorder	Moderate to severe axis I or II disorder according to DSM-III-R ^a criteria (interviewer rating, kappa = .98)	76
4	History of parental broken home or delinquency	Institutional care of a parent / more than two changes of parental figures until the age of 18 or history of parental delinquency	74
5	Marital discord	Low quality of partnership in two out of three areas (harmony, communication, emotional warmth) (interviewer rating, kappa = 1.00)	43
6	Early parenthood	Age of a parent ≤ 18 years at child birth or relationship between parents lasting less than 6 months at time of conception	93
7	One-parent family	At child birth	38
8	Unwanted pregnancy	An abortion was seriously considered	57
9	Poor social integration and support of parents	Lack of friends and lack of help in child care (interviewer rating, kappa = .71)	14
10	Severe chronic difficulties	Affecting a parent lasting more than one year, such as unemployment, chronic disease (interviewer rating, kappa = .93)	104
11	Lack of coping skills	Inadequate coping with stressful events of the past year e.g. denial of obvious problems, withdrawal, resignation, overdramatization (interviewer rating, kappa = .67)	146

^aThe DSM-III-R is the Diagnostical and statistical manual of mental disorder, third edition, revised form.

Table A3: Quantile regressions for the IQ (standard errors in brackets) ^{a)}

Quantile	10	20	30	40	50	60	70	80	90
<i>t = 2 years</i>									
$H(t)$	0.49*	0.50*	0.49*	0.55*	0.52*	0.57*	0.54*	0.46*	0.23*
	(0.16)	(0.10)	(0.14)	(0.09)	(0.12)	(0.08)	(0.10)	(0.07)	(0.02)
$IQ(t-1)$	0.36*	0.32*	0.31*	0.30*	0.25*	0.19*	0.19*	0.04	0.03
	(0.14)	(0.08)	(0.11)	(0.07)	(0.09)	(0.06)	(0.07)	(0.06)	(0.02)
<i>t = 4.5 years</i>									
$H(t)$	0.34*	0.39*	0.53*	0.47*	0.48*	0.40*	0.27*	0.27*	0.33*
	(0.16)	(0.11)	(0.08)	(0.07)	0.08()	(0.08)	(0.06)	(0.05)	(0.09)
$IQ(t-1)$	0.70*	0.60*	0.47*	0.48*	0.47*	0.43*	0.38*	0.38*	0.23*
	(0.10)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.03)	(0.07)
<i>t = 8 years</i>									
$H(t)$	0.08	0.31	0.29	0.19	0.18	0.19	0.20*	0.05	0.01
	(0.16)	(0.16)	(0.16)	(0.11)	(0.13)	(0.13)	(0.10)	(0.11)	(0.18)
$IQ(t-1)$	1.2*	1.0*	0.99*	0.72*	0.76*	0.74*	0.73*	0.71*	0.57*
	(0.09)	(0.09)	(0.09)	(0.06)	(0.07)	(0.07)	(0.05)	(0.06)	(0.08)
<i>t = 11 years</i>									
$H(t)$	0.04	0.14	0.10	0.22	0.26*	0.20*	0.04	0.08	0.17
	(0.29)	(0.11)	(0.10)	(0.12)	(0.11)	(0.10)	(0.07)	(0.09)	(0.11)
$IQ(t-1)$	1.03*	0.97*	0.93*	0.87*	0.81*	0.74*	0.72*	0.67*	0.53*
	(0.11)	(0.06)	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)	(0.05)	(0.06)

MARS, 364 observations; all regressions include a constant; all variables in natural logarithm;

a) All regression models also contain $MQ(t-1)$, $P(t-1)$, as right hand side variables; the resulting coefficients are not reported here, because they do not differ (much) from the OLS estimates (see Table 5);

* indicates significance at 5 percent level.

Table A4: The partial elasticity of H on the nonverbal ($NV-IQ$) and the verbal ($V-IQ$) dimensions of intelligence ^{a)} (standard errors in brackets)

ability	2 years	4.5 years	8 years	11 years
$NV-IQ$	0.22 (0.16)	0.29* (0.08)	-0.06 (0.12)	0.21 (0.10)
$V-IQ$	0.42* (0.07)	0.44* (0.07)	0.30* (0.11)	0.24* (0.10)
IQ ^{b)}	0.38* (0.07)	0.38* (0.07)	0.19 (0.13)	0.17 (0.10)

MARS, 364 observations, all OLS regressions include a constant, all variables in natural logarithm; * indicates significance at 5 percent level.

^{a)} All regression models also contain $MQ (t-1)$, $P (t-1)$; the resulting coefficients are not reported here, because results do not differ (much) from OLS (see Table 5).

^{b)} Taken from Table 5 to facilitate comparison.

Table A5: The estimated childhood ability multiplier: direct and indirect ability effects of a successful one percent increase in H , in percent

		One percent gain in H at stage leads to an			
increase at stage (%)		3 months	2 years	4.5 years	8 years
3 months	IQ (OLS)	0.55			
	IQ (2SLS)	2.37			
	MQ (OLS)	0.15			
	P (OLS)	0.28			
2 years	IQ (OLS)	0.72	0.38		
	IQ (2SLS)	2.66	1.58		
	MQ (OLS)	0.29	0.00		
	P (OLS)	0.34	0.37		
4.5 years	IQ (OLS)	0.83	0.59	0.38	
	IQ (2SLS)	2.83	2.44	0.50	
	MQ (OLS)	0.44	0.14	0.04	
	P (OLS)	0.46	0.67	0.50	
8 years	IQ (OLS)	0.96	0.82	0.74	0.19
	IQ (2SLS)	3.02	3.50	0.88	0.31
	MQ (OLS)	0.50	0.19	0.06	0.12
	P (OLS)	0.55	0.84	0.76	0.43
11 years	IQ (OLS)	1.11	1.06	1.10	0.42
	IQ (2SLS)	3.26	4.79	1.28	0.71
	MQ (OLS)	0.56	0.31	0.19	0.26
	P (OLS)	0.60	0.96	0.94	0.65

Calculations of all direct and indirect multiplier and accelerator effects based on OLS estimates of equation (2) (without additional lags, see Table 6) and, for the IQ in addition based on 2SLS estimates of equation (2) (without additional lags, see Table 6).

APPENDIX: IQ AND MQ

3 months: Cognitive abilities, *IQ*, were measured using the Mental Developmental Index (MDI) of the Bayley Scales of Infant Development (Bayley, 1969). The fine and gross motor abilities, *MQ* (called the motor quotient), were assessed by the Psychomotor Developmental Index (PDI) of the Bayley Scales.

2 years: The *IQ* was derived from the Mental Developmental Index (MDI) of the Bayley Scales of Infant Development. A differentiation is made between verbal abilities, *V-IQ*, and nonverbal cognitive abilities, *NV-IQ*. The verbal ability score is derived from the items of the Bayley Scales indicating language development, in combination with the expressive and the receptive language scales of the Münchener Funktionale Entwicklungsdiagnostik (MFED) (Köhler and Egelkraut, 1984). The nonverbal cognitive abilities are derived from the nonverbal items of the Bayley Scales, indicating basic, general abilities, such as perception, understanding and reasoning. The *MQ* was assessed by the Psychomotor Developmental Index (PDI) of the Bayley Scales.

4.5 years: The composite score of the *IQ* contained the Columbia Mental Maturity Scale (CMMS) (Burgmeister et al., 1972) and the subtest "sentence completion" of the Illinois Test of Psycholinguistic Abilities (ITPA), (Kirk et al., 1968; for the German version, see Angermaier, 1974). From these, a differentiation is made between *V-IQ*, language dependent abilities and *NV-IQ*, indicating nonverbal abilities. The *MQ* was derived from the Test of Motor Abilities (MOT) 4-6 (Zimmer and Volkamer, 1984).

8 years: The composite score of the *IQ* was assessed by the Culture Fair Test (CFT) 1 (Weiss and Osterland, 1977), measuring nonverbal skills, such as the ability to perceive and integrate complex relationships in new situations, and the subtest "sentence completion" of the ITPA, mentioned above, indicating verbal reasoning (*V-IQ*). The *MQ* was assessed with the body coordination test for children (KTK) (Kiphard and Shilling, 1974).

11 years: The *IQ* was measured with the CFT 20 (Cattell, 1960; for the German version see Weiss, 1987) and a vocabulary test of the CFT 20, allowing again distinguishing verbal, *V-IQ*, and nonverbal abilities, *NV-IQ*. The *MQ* at age 11 years was assessed by means of a short version of the body coordination test for children (KTK).