DISCUSSION PAPER SERIES

IZA DP No. 3734

Self-Productivity and Complementarities in Human Development: Evidence from the Mannheim Study of Children at Risk

Dorothea Blomeyer
Katja Coneus
Manfred Laucht
Friedhelm Pfeiffer

September 2008

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

Self-Productivity and Complementarities in Human Development: Evidence from the Mannheim Study of Children at Risk

Dorothea Blomeyer
ZI Mannheim

Katja Coneus
ZEW Mannheim

Manfred Laucht
ZI Mannheim and University of Potsdam

Friedhelm Pfeiffer
ZEW Mannheim, University of Mannheim and IZA

Discussion Paper No. 3734
September 2008

IZA

P.O. Box 7240
53072 Bonn
Germany

Phone: +49-228-3894-0
Fax: +49-228-3894-180
E-mail: iza@iza.org

IZA Discussion Paper No. 3734
September 2008

ABSTRACT

Self-Productivity and Complementarities in Human Development: Evidence from the Mannheim Study of Children at Risk*

This paper investigates the role of self-productivity and home resources in capability formation from infancy to adolescence. In addition, we study the complementarities between basic cognitive, motor and noncognitive abilities and social as well as academic achievement. 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 initial risk conditions cumulate and that differences in basic abilities increase during development. Self-productivity rises in the developmental process and complementarities are evident. Noncognitive abilities promote cognitive abilities and social achievement. There is remarkable stability in the distribution of the economic and socio-emotional home resources during the early life cycle. This is presumably a major reason for the evolution of inequality in human development.

JEL Classification: D87, I12, I21, J13

Keywords: initial conditions, intelligence, persistence, home resources, social competencies, school achievement

Corresponding author:

Friedhelm Pfeiffer
Centre for European Economic Research
P.O. Box 103443
D-68034 Mannheim
Germany
E-mail: pfeiffer@zew.de

* We gratefully acknowledge support from the Leibniz Association, Bonn, through the grant "Noncognitive Skills: Acquisition and Economic Consequences". Dorothea Blomeyer and Manfred Laucht thank the German Research Foundation and the Ministry of Science and Research for their support in conducting MARS. For their helpful comments, we thank Anja Achtziger, Lex Borghans, Liam Delaney, Wolfgang Franz, Bart Golsteyn, James Heckman, Andrea Mühlenweg, Pia Pinger, Karsten Reuß, participants at the Annual Meeting of the European Economic Association in Milano, and our colleagues at ZEW. For excellent research assistance we are grateful to Mariya Dimova and Moritz Meyer. Any remaining errors are our own.

1 Introduction

Economists and psychologists share a common interest in research on ability and health development (Heckman, 2000, 2007, 2008; Laucht, 2005; Schneider and Weinert, 1999; among others). Deep-seated skills are formed in a dynamic, interactive process starting in early childhood, and research that is based on only a subset of relevant factors may contain some bias. The relationship among initial risk conditions (from both organic and psychosocial perspectives), investments and ability development is analyzed to gain an understanding of the formation of competences in childhood.

Our contribution to this burgeoning multidisciplinary literature on individual development is twofold. First, we employ unique data from a developmental psychological approach to study economic models of ability formation for the first time. The data are taken from the Mannheim Study of Children at Risk (MARS[1]), an epidemiological cohort study that follows 384 children from birth to adulthood (Laucht et al., 1997, 2004). MARS provides detailed psychometric assessments and medical and psychological expert ratings on various child outcome measures. We utilize data from infancy to adolescence variables on initial risk conditions, on basic cognitive and motor abilities as well as on persistence, a noncognitive ability. Psychometric assessments of cognitive and motor abilities, *IQ* and *MQ*, were conducted at infancy (3 month), toddlerhood (2), preschool age (4.5), elementary school age (8) and secondary school age (11 years), representing significant stages of child development. Second, we analyze the relationship between economic and socio-emotional home resources and the formation of basic abilities, and between these and the children’s achievements in social and academic life. This should deepen the understanding of basic ability formation (Cunha and Heckman, 2007) in the early life cycle from both an economic and a psychological perspective.

Our findings demonstrate that interpersonal differences in cognitive and noncognitive capabilities are consistently associated with socio-emotional home resources, the relationship being stage-specific. Individual differences in basic abilities amplify between the ages of 3 months and 11 years. Adverse consequences of initial organic and psychosocial risks cumulate and persist until adolescence. Noncognitive abilities are related to home resources until the age of 11 years, and to cognitive abilities until the age of 4.5

years. For motor abilities, self-productivity seems to be high throughout the development process. Persistence fosters cognitive abilities and school achievement. Basic abilities at preschool age significantly predict social competencies and school grades at the age of 8. Better basic abilities at primary school age and home resources significantly predict a higher-track secondary school attendance.

There is a great deal of stability in the economic and socio-emotional home resources over time. This is presumably a major reason for the increase of inequality in development. Our findings are related to literature on the stability of personality traits in development (Mischel et al., 1988; Kadzin et al., 1997, among others). We contribute to this literature through the use of expert rather than maternal assessments of children's abilities. The stability of personality traits in development also seems to be in part the result of the stability of home resources. Disadvantages from adverse home environments cumulate during the developmental stages. In early childhood, the development of basic cognitive and motor abilities is hindered. This disadvantage continues, thus impairing noncognitive ability formation at school age (see also Heckman, 2000). These children are again hindered during the transition to a higher-track secondary school, when low economic home resources constitute an additional barrier.

The paper is organized as follows. Section 2 introduces the MARS project, section 3 the evolution of basic abilities and the economic and socio-emotional home resources from birth to 11 years. Section 4 examines the first-order temporal correlation of ability development and social achievements. Section 5 presents our estimates of the developmental-specific technology of ability formation. Section 6 studies complementarities between basic abilities and social competencies; section 7 between basic abilities and school achievement. Conclusions are drawn in section 8.

2 MARS: Research design and initial risk matrix

MARS 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 (Esser et al., 1990; Laucht et al., 1997).[2] Risks stem from

[1] MARS has been derived from the German title: **MA**nnheimer **R**isikokinder **S**tudie.
[2] The study was approved by the ethics committee of the University of Heidelberg, and written, informed consent was obtained from all participating families. Infants were recruited from two obstetric and six

the individual, the environment and their resulting 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. Each risk factor was scaled as either no risk, moderate risk or high risk. Children were assigned to one of the nine groups resulting from the two-factor, 3x3 design (Figure 1). As a result of this design, all groups are about equal in size with a slight oversampling in the high-risk combinations. Sex is distributed evenly in all subgroups.

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.[3] 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).

Psychosocial risk is determined according to a risk index proposed by Rutter and Quinton (1977), which measures the presence of eleven unfavorable family characteristics.

---

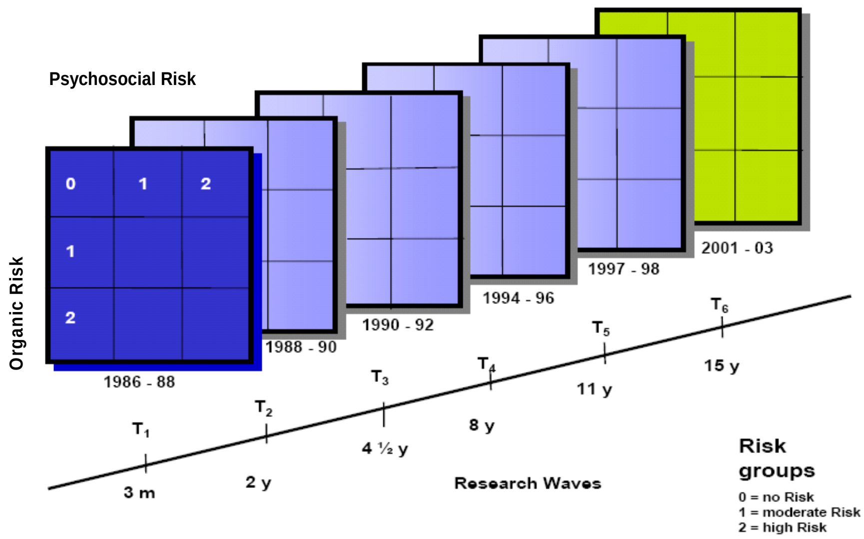
children's hospitals in the Rhine-Neckar region of Germany. Children with severe physical handicaps, obvious genetic defects or metabolic diseases were excluded. The initial participation rate was 64.5 percent, with a slightly lower rate in families from low socio-economic backgrounds.

[3] The relevance of APGAR and birth weight for adult outcomes has been investigated by Almond et al. (2005), Black et al. (2007) and Oreopoulos et al. (2006), among others. Other aspects of initial organic or psychosocial risk, such as neonatal complications, early parenthood or parental psychiatric disorder, have not been widely investigated.

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 risk factors.
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.

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



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

3 Basic abilities, social competencies and home resources

Cognitive, motor and noncognitive abilities

We choose to use the terms *cognitive*, *motor*, and *noncognitive* abilities to indicate three different, yet dependent and important dimensions of personality and human capital. Cognitive abilities include memory capacity, information processing speed, linguistic and logical skills, and general problem-solving abilities. Motor abilities are assessed as fine and gross motor skills and body coordination. The third dimension is related to noncognitive abilities, such as effort regulation, perseverance, persistence and self-discipline.

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 (Bayley, 1969). 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, 1987a, b) 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) mentioned above.

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*.[4] In MARS, this rating was one of nine temperamental dimensions made by trained raters[5] on several 5-point rating scales adapted from the New York Longitu-

[4] Thomas and Chess (1977), among others, emphasize the importance of the fit of childhood temperament with its surrounding, mainly parental educational styles, for the child's successful development. Although there is some evidence for a genetic basis of temperamental traits, continuity of temperament seems to be strongly shaped by early temperament-environment interactions (Heckman, 2008).

[5] 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 -

dinal Study NYLS (Thomas et al., 1968).[6] Until the age of 8, *P* is measured with the attention span 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.[7]

Figure 2 (for standard errors and test statistics see Table A3) contains summary statistics of the three basic abilities *IQ*, *MQ* and *P* in the nine risk groups of MARS at the ages of 3 months and 11 years. In line with the literature on risk research (Egeland et al., 1993; Kazdin et al., 1997; Masten, 1990, among others) and previous findings from MARS (see Laucht et al., 2004; Laucht, 2005), our results indicate that unfavorable consequences of initial organic and psychosocial risks persist until adolescence. Organic and psychosocial risk factors exhibit equally negative effects but are specific to the areas they affect. 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

---

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.

[6] We examined three further temperamental dimensions. *Approach* describes the initial reaction to a new stimulation, e.g. from being confronted with a stranger, with new food or unfamiliar surroundings. *Adaptability* describes the length of time needed to adapt to a new stimuli (at the age of 11 years the measure also includes aspects of manageability, such as the ability to cooperate with unpleasant occurrences, e.g. conflicts in the peer group or parental admonitions). The prevailing *mood* has been rated on a continuum from positive to negative. The negative expressions of the temperamental factors “mood”, “approach”, and “adaptability”, together with two further temperamental variables “intensity of reaction” and “rhythmicity of biological functions”, form the cluster of the “difficult child”. However, “rhythmicity of biological functions” frequently failed to be replicated in factor analyses, and “intensity of reaction” was shown to be strongly associated with early psychopathology, thus possibly reflecting more behavioral problems than a temperamental dimension. Accordingly, only the remaining three variables were included in this study to assess their impact on ability development and social achievement. Our econometric analysis revealed that these dimensions showed no systematic correlations with the cognitive abilities. Early studies on these measures show that adaptability at age 5 was associated to academic achievement throughout the first six grades in a study performed by Korn, cited by Thomas and Chess (1977). Persistence showed scattered significant correlations beyond the level of $p < 0.05$. None of the temperament measures were associated with the level of the *IQ* in that study (Thomas and Chess, 1977).

[7] Since persistence is associated with the economic concepts of time preference, our study contributes to preference development.

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 A3). The results for the *MQ* are 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, Figure 2), and the heterogeneity of the noncognitive ability increases along the risk dimensions.

Figure 2: Basic abilities and risk matrix at 3 months and 11 years (means)

3 months (*P*: 4.5 years)

Organic risk		Psychosocial risk: no-risk	moderate	high
no-risk	***IQ***	103*	102*	96*
	MQ	103*	102*	103*
	P	3.8*	3.5*	3.2
moderate	*IQ*	101*	99*	97*
	MQ	101*	98*	99*
	P	3.5*	3.4	3.2
high	*IQ*	95	93	88
	MQ	93	92	89
	P	3.6*	3.1	3.1

11 years

Organic risk		Psychosocial risk: no-risk	moderate	high
no-risk	*IQ*	108*	107*	100*
	MQ	104*	106*	104*
	P	4.8*	4.1*	3.8*
moderate	*IQ*	105*	98*	97
	MQ	97*	103*	98*
	P	4.0	3.9	3.6
high	*IQ*	101*	92	87
	MQ	98*	97*	86
	P	4.0*	3.7	3.6

MARS, 364 observations; *IQ* and *MQ* are normalized to mean 100 and SD 15 in the normative group at each age; *P* varies between 1.0, 1.1, … (low persistence) and … 4.9, 5.0 (high persistence). * indicates the significance of differences relative to the highest-risk group at the 5 percent level.

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. 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 A3). 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.[8]

[8] The difference is greater when compared to the difference between 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). This might be due to the high rate of mental retardation in the group of children with both high organic and high psychosocial risk.

To summarize, our findings reveal that initial risk conditions matter for inequality of cognitive, motor and noncognitive abilities and that organic and psychosocial risk are additively related, which means that the cumulative effect of both risks corresponds to the sum of the single risk effects.[9] Differences in average cognitive, motor and noncognitive abilities accelerate, and heterogeneity increases along the risk dimensions.

Social competencies

Social competencies of children were assessed from the ages of 4.5 to 11 by the Scales for Levels of Functioning (Marcus et al., 1993) 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*. 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 1 contains the means of the four social competencies variables evaluated at the age of 8 years for the cells of the risk matrix. Initial risk conditions matter for social competencies at the age of 8 years. Risk effects 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 high maturity and reliability in everyday life, pursuing various interests and popularity with peers, the initial psychosocial risk load seems to be, on average, more harmful than organic

[9] In previous research with MARS (see Laucht et al., 1997, 2000b, 2001) a number of single-risk factors were found to be associated with particularly poor outcomes. Among psychosocial risks, the best predictors of cognitive and social-emotional impairment at school age were teenage parenting, parental mental

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.

Table 1: Social competence at the age of 8 years evaluated for the children in the risk matrix (means)

		Psychosocial Risk		
		no-risk	moderate	high
		interests / autonomy		
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
		Peer Relations (expert- / self-rated)		
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.

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 (Figure 3). The relation between ability development and the quality of early interaction and stimulation in the socio-emotional family environment is at the core child development research (see Bradley, 1982, 1989; Heckhausen and Heckhausen, 2008; Murane et al., 1980, among others). In MARS, the socio-emotional home resources were assessed

illness, low parental educational level, and a single-parent family. Among the organic risks, seizures and very low birth weight were most closely related to disorders of cognitive and motor functioning.

with the Home Observation for Measurement of the Environment (HOME, Bradley, 1989).

Figure 3: Home resources at 3 months and 11 years (means)

3 months

Organic risk		Psychosocial risk: no-risk	moderate	high
no-risk	*H*	106*	102*	93
	Y	1,275*	1,122*	775
moderate	*H*	105*	100	95
	Y	1,293*	903	984
high	*H*	106*	100*	94
	Y	1,180*	927	863

11 years

Organic risk		Psychosocial risk: no-risk	moderate	high
no-risk	*H*	108*	105*	92
	Y	1,699*	1,632	1,256
moderate	*H*	107*	99	92
	Y	1,644*	1,325	1,325
high	*H*	106*	98	94
	Y	1,806*	1,425	1,355

MARS, 364 observations; *H* normalized to mean 100 and SD 15 to facilitate comparison; *Y*: monthly net equivalence income per head in DEM (1 DEM = 0.51129 EUR). * indicates the significance of differences relative to the highest-risk group at the 5 percent level.

The HOME in MARS uses the original subscales of the HOME[10] and modifications for the German living conditions. All items were evaluated by trained home visitors (interviewers) in contact with the primary caregiver. The items depend on the development stage. For example, parents compliment their child if it interacts independently, or parents speak in whole sentences to their child at age 2; parents were asked how many rooms they live in with their children and whether a garden is available, among other questions. For our current investigation we use the sum of all items, the total HOME score, *H*. A differentiated analysis relating specific dimensions of the emotional home resources to specific abilities is left for future research. Todd and Wolpin (2006) also use the total HOME score, while Cunha and Heckman (2008) use subscales, such as

[10] 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.

theatre and museum visits, the availability of musical instruments and books; they aggregate these into the “family investment factor”.

Both measures of a child’s home resources decline steadily along the psychosocial risk dimension (Figure 3, based on Table A4). 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 0.07. If economic resources were doubled, *H* would be 7 percent higher.

4 First-order temporal correlation in abilities, home resources and social competencies

Self-productivity is an essential feature in the process of ability formation (Heckman, 2007). The concept postulates that abilities acquired at one stage in the development process enhance ability formation at later stages. Varied experience in early childhood thus lays the foundation to some extent for success or failure in school and for human capital formation in later life. The time-varying model of ability formation by Cunha and Heckman (2007) in equation (1) (for a further elaboration see the next section), allows us to calculate the first derivative of the vector of abilities, Θ, in t with respect to the vector of abilities in $t\text{-}1$. If the own derivative is positive, it is said that this ability exhibits self-productivity. In the case of positive cross derivatives, there are synergies in the formation of these two abilities. For example, higher cognitive abilities may foster persistence and vice versa. Other factors responsible for ability formation and included in equation 1 are the initial conditions, *E*, and the economic and socio-emotional home resources, *I*.

$$\Theta_{t} = f_{t}\left(I_{t}, \Theta_{t-1}, E\right) \tag{1}$$

Our analysis of the stability of differences in interpersonal ability in this section is related to the concept of self-productivity. We utilize the longitudinal dimension of MARS and calculate the first-order temporal correlations for our cognitive, motor and noncognitive abilities. We extend this investigation to the first-order temporal correlation of the social competencies and the home resources, Table 2. Besides self-productivity in abilities, the socio-emotional environment of the child may exhibit a high degree of stability over time. With this extension, we intend a deeper empirical understanding of the relative contributions of self-productivity and investments in ability development among the children in MARS (compare also section 5).

Table 2: First-order temporal correlations in abilities, home resources and social competencies

	2 years/ 3 months	4.5 years/ 2 years	8 years/ 4.5 year	11 years/ 8 years
Basic abilities				
IQ	0.34	0.72	0.74	0.81
MQ	0.35	0.63	0.53	0.60
P	0.03	0.42	0.59	0.64
HOME score / monthly net equivalence income per head [a)]				
H	0.78	0.75	0.88	0.93
Y	0.82	0.86	0.77	0.79
Social competencies				
peers			0.31	0.65
interests			0.58	0.64
autonomy			0.33	0.56

MARS, 364 observations; a) correlations from a regression model including a constant; all coefficients are significant at the 5 percent level.

For the interpretation of temporal correlations, we take potential measurement errors into account. For instance, measurement errors decline with age for cognitive abilities (see Schrueger and Witt, 1989). A correlation coefficient between 0.25 and 0.49 indicates moderate stability, a value between 0.5 and 0.74 indicates stability and values above 0.74 indicate high stability of interpersonal differences over time.

Table 2 suggests that interpersonal differences in cognitive and motor abilities stabilize between the second and the fourth/fifth year. The correlations vary between 0.63 and 0.72, suggesting stability of *IQ*, which is in line with the literature (for a comprehensive summary see Heckman, 2008). The values of the first-order temporal correlations for persistence are lower. There is moderate stability until the age of 4.5 years and stability afterwards. For our measures of social competencies there is moderate stability between the ages 4.5 and 8 years and stability afterwards.

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 demonstrated. Children born into a favorable environment tend to experience a high degree of stability in these beneficial conditions, and children born into an adverse home environment experience a high degree of stability in the uneasy environment.

5 The technology of ability formation in the early life cycle

The econometric framework

In this section we discuss findings from econometric estimates of central parameters of the technology of ability formation (Cunha and Heckman, 2007). We focus on the relationship of basic abilities in *t* to the HOME score, *H*, in period *t* and the stock of basic abilities in period *t-1*. Since the technology of ability formation varies over the major stages of child development, separate estimates have been performed for infancy, toddlerhood, preschool age, elementary age and secondary school age, *t*. We assume that equation (1) can be represented in a Cobb-Douglas form. Taking the natural logarithm (written in lower case letters) yields the equation (2):

$$\theta^{j}_{t,i} = \alpha^{j,R}_{0,t} + \alpha^{h,j}_{t} \cdot h_{t,i} + \alpha^{j}_{t} \cdot \theta^{j}_{t-1,i} + \alpha^{k,j}_{t} \cdot \theta^{k}_{t-1,i} + \alpha^{l,j}_{t} \cdot \theta^{l}_{t-1,i} + \varepsilon^{j}_{t,i} \tag{2}$$

where *j*, *k*, *l* are indices for the three basic abilities *IQ*, *MQ* and *P*, and *i* = 1, …, N (=364) is an index for the children. The variable *R* contains all nine cells of the two-dimensional risk matrix in MARS, since the initial risk conditions may have a lasting direct association to ability in the early life cycle. The aim is to estimate the following parameters at all developmental stages:

$\alpha^{h,j}_{t}$: partial elasticity of HOME score for ability *j* in *t*,
α^{j}_{t} : partial elasticity of ability *j* in t-1 for ability *j* in *t*,
$\alpha^{k,j}_{t}$: partial elasticity of ability *k* in t-1 for ability *j* in *t*,
$\alpha^{l,j}_{t}$: partial elasticity of ability *l* in t-1 for ability *j* in *t*.

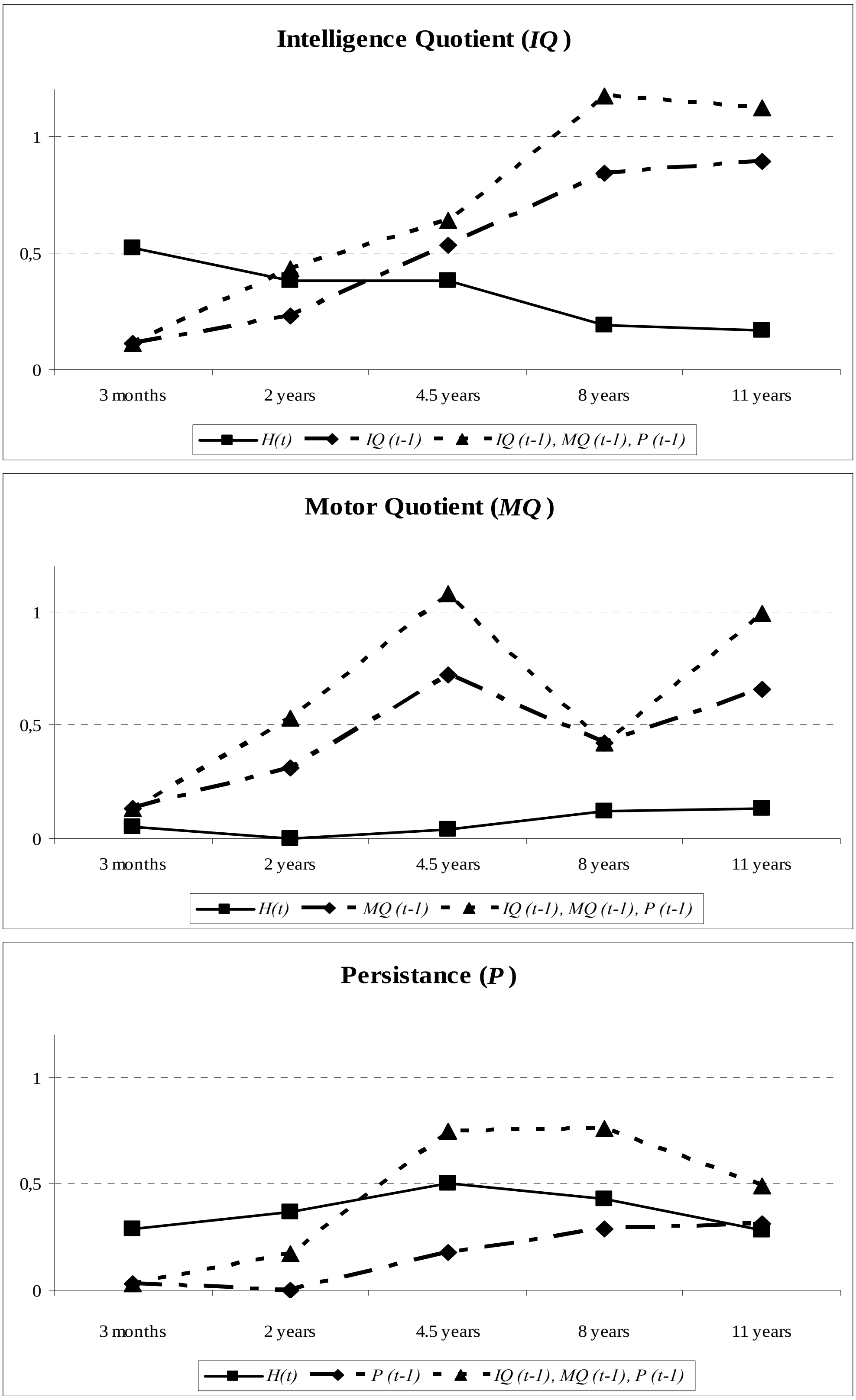
Equation (2) is similar to that of Cunha and Heckman (2008), who discuss further pros and cons of such a specification. All parameters can be interpreted as partial elasticity.

Our estimation method is OLS. A set of estimations with alternative methods was performed for robustness reasons and will be discussed later. If it turned out that the set of dummies from the initial risk matrix, *R*, was not jointly significant at the 5 percent level (a significance level of 5 percent has been chosen throughout the study), a second estimation was performed without *R*. Since there is some heteroscedasticity, standard errors have been estimated with robust techniques. The estimates indicate that *H* is significantly related to ability formation at all developmental stages (Table A5). However, the strength of the relationship differs between our three basic abilities and over time. Sex differences in the technology of ability formation are left for future research. If a sex indicator is included in the equations reported in Table A5 ff., the coefficients are sometimes significant, sometimes not. The other coefficients always remain unaffected.

Basic dimensions of personality and cognitive and noncognitive abilities are strongly related to the socio-emotional home resources, while motor ability is not. Our findings are illustrated in Figure 4 (based on Table A5). Figure 4 shows the partial elasticity of *H* with respect to the ability, the partial elasticity of the past value of the ability and the sum of the partial elasticity from all abilities, indicating the synergic aspect of ability development. The importance of home resources and self-productivity for ability formation changes in a way specific to the developmental stage.

Basic cognitive and noncognitive abilities are strongly related to the socio-emotional home resources, while the basic motor ability is not. *P* is always significantly associated with *H*, with the estimated partial elasticity varying around 0.4. The *IQ* is positively related to *H* until the age of 4.5 years, with an estimated partial elasticity varying around 0.4. At school age, the elasticity falls to 0.18 and is no longer significant. For the *IQ*, self-productivity estimated with the partial elasticity of the past and the current *IQ* increases steadily during development. At the age of eight and eleven years, the partial elasticity approaches 0.9, a value comparable with that of Cunha and Heckman (2008). Self-productivity of the *IQ* in MARS is smaller in early childhood. The importance of self-productivity for human capital formation from adolescence on highlights the role of inadequate home resources in early childhood (emphasized by Heckman, 2007, among others). Since *P* remains malleable during school age, self-productivity remains lower. We found evidence for synergies in ability formation among *P* and *IQ*.

Figure 4: The partial elasticity of *H* and past abilities with current abilities



MARS, 364 observations, all variables in a natural logarithm; coefficients from OLS regressions performed for each period, including a constant; heteroscedastically robust standard errors, see Table A5 for the details.

Further evidence

To take into account that *H* might be related to cognitive ability (parents choose the optimal investment, see Cunha and Heckman, 2007) we performed a two–stage, least squares estimate (TSLS) using two measures of monthly net equivalence income per head (current and permanent) and the initial risk conditions as an instrument variable for *H*. Table A6 reports the results for t=4.5 years. The TSLS estimates turned out to be higher, 0.57 or 0.50, compared to OLS, 0.38, if the instrument is *Y*. 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. Since the economic resources are not directly related to abilities, using it as an instrument reduces the bias. However, it turns out that standard errors for the TSLS are too large to make strong statements. We conclude that OLS may be a lower bound of the partial elasticity of *H* with respect to the *IQ*. Using the initial risk conditions as an instrument reduces the estimate to 0.27. However, they are a not a valid instrument, since the dummies are no longer (partially) related to the *IQ* at the age of 4.5.

To control for endogeneity, we included all lags of the basic abilities available in the OLS framework (see Wooldridge, 2005, Table A6). The point estimates do not change much, with the exception when children are 11 years old. At that age point estimates are lower. However, even for this developmental stage the decline does not change our conclusions when we take the standard errors into account.

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. Results for the *IQ* are reported in Table A7. The estimates suggest that the partial elasticity of *H* with respect to the *IQ* is slightly lower at the tails of the IQ distribution. However, standard errors do not allow sharp conclusions. At the age of 11 years and only for the 50^{th} and 60^{th} percentile of the *IQ* distribution we find a significant partial elasticity of *H* with respect to the *IQ* with the quantile regression and not with the OLS (Table A7).

Finally, we run different regressions for the verbal and nonverbal *IQ* to investigate whether there is evidence for sensitive investment periods specific to either group of 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. We conclude that more fundamental aspects of cognitive abilities, such as logical reasoning, seem to have a less significant relationship to the home resources than do language-based cognitive abilities. The window of formation seems to be shorter with respect to the nonverbal aspects of cognitive abilities. Helping children to improve their analytical capabilities needs to start in infancy (or earlier).

6 Complementarities: Abilities as predictors of social competence

We discuss the findings from four linear regression models predicting social competencies at primary school age. The estimation equation includes the current home resources, *H* and *Y*, and the level of *IQ*, *MQ* and *P* measured at preschool age. The results from OLS estimates with and without all additional lags of the abilities are summarized in Table 3. Both specifications show similar results and demonstrate significant differences between the four competencies. There are significant associations between the indicator of social competence, *peers*, and *H*, the past *MQ* and *P*. *Interests*, indicating hobbies and desired activities, are additionally associated with the *IQ* from the past period. *Autonomy*, measuring maturity in everyday life, is solely linked with the past *MQ*, while there is no significant coefficient in the perceived peer acceptance equation at all.

Our estimates demonstrate substantial complementarities between the basic abilities acquired during childhood and social competencies a child achieves at elementary school age. Contemporary *H* strongly enhances both popularity among peers, *peer relations*, and the variety of actively followed interests, *interests*, according to expert ratings in MARS. Children from adverse home environments therefore appear to suffer double, due to poor investments in their abilities during preschool age and due to insufficient support during school age.

Interestingly, none of these observables are related to the child's self-rating with respect to social relationships and friendships (last column, Table 3). 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. 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.

Table 3: The partial elasticity of abilities and home resources for social competencies at the age of t=8 years

	interests		*autonomy*		*peer relations: expert-rated*		*peer relations: self-rated*	
		lags[a)]		lags[a)]		lags[a)]		lags[a)]
H (t)	1.44*	1.46*	0.07	0.10	0.76*	0.85*	0.27	0.30
Y (t)	-0.00	-0.00	-0.04	-0.05	-0.00	-0.00	0.03	0.03
IQ (t-1)	0.54*	0.49*	0.07	-0.23	0.12	0.06	0.13	0.12
MQ (t-1)	0.21*	0.15*	0.65*	0.44*	0.29*	0.24*	0.05	0.04
P (t-1)	0.13*	0.14*	-0.06	-0.09	0.21*	0.22*	0.05	0.07
Adj. R^2	0.61	0.62	0.24	0.30	0.30	0.32	0.05	0.08
No. of Obs.	364	364	364	364	363	363	352	352

MARS, OLS regressions with heteroscedastically robust standard errors; including a constant; all variables in natural logarithm; [a)] the specification contains all available additional lags in abilities, albeit not reported here; * indicates significance at the 5 percent level.

7 Abilities as predictors of school achievement

On average 45 percent of the children in MARS attend a *Gymnasium*, which is the highest-track/grammar school in Germany.[11] For attending the *Gymnasium*, the initial risk matrix matters significantly, as in Figure 5 (based on Table A8). 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 tow exceptions observed for children born without any psycho-social risk and without any organic risk. In the former case, there seems to be no differ-

[11] Thirty percent attended a *Realschule*, 16 percent a *Hauptschule* (lowest secondary school track) and 8 percent more specific school types (*Förderschule*, *Waldorfschule*). A *Förderschule* is a school type for children with learning disabilities or who are disabled. On average, MARS children are enrolled in school at the age of 6.7 years and 93 percent of the children attended kindergarten in the year prior to school entry. 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 *Waldorfschule*). We conclude that in MARS more children attend higher secondary school compared to the average in Baden-Württemberg for class 9. One major reason is that in MARS children with severe handicaps were excluded and that children from immigrant families with poor German language skills are not included.

ence between the moderate and the high organic risk groups and, in the latter case, between the no-risk and the moderate psychosocial risk groups.

Figure 5: Children's school achievement at age 8 and 11 years

Psychosocial risk

Mean grades in math at age 8

Organic risk	no-risk	moderate	high
no-risk	2.1*	2.1*	2.4*
moderate	2.2*	2.4	2.7
high	2.3*	2.6	2.9

Attending the *Gymnasium* at age 11 (percent)

Organic risk	no-risk	moderate	high
no-risk	74*	77*	43
moderate	45	38	33
high	54*	27	15

MARS, 357 observations; grades in Germany vary from 1.0 (excellent), … to 6.0 (insufficient). * indicates the significance of differences relative to the highest-risk group at the 5 percent level.

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* 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. There is not much variation between the average grades in these three subjects in each cell of the risk matrix.

We discuss findings from linear regression and probit models predicting school grades and secondary school attendance (Table 4). 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 a further model, the *IQ* is divided into two aspects, the verbal and the nonverbal abilities, *V-IQ* and *NV-IQ*, respectively.

This procedure leaves us with six regressions for the grades (Table 4) and six further regressions if all lags are included (Table A9). Note that a negative coefficient 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 4). *Persistence* is important for achievement in school with a lower coefficient compared to the *IQ*.

Table 4: The partial elasticity of abilities in t-1 and home resources in t for school grades [a] at the age of t=8 years

	reading		*spelling*		*math*	
	IQ	*V-/NV-IQ*	*IQ*	*V-/NV-IQ*	*IQ*	*V-/NV-IQ*
H (t)	-0.11	-0.05	-0.64	-0.62	-0.49	-0.56
Y (t)	-0.02	-0.02	-0.06	-0.07	-0.04	-0.05
IQ (t-1)	-0.84*		-0.60*		-0.66*	
NV-IQ (t-1)		-0.96*		-1.18*		-1.11*
V-IQ (t-1)		-0.26		0.16		0.19
MQ (t-1)	-0.17	0.009	-0.21	0.001	-0.10	0.08
P (t-1)	-0.32*	-0.23	-0.29*	-0.19*	-0.25*	-0.17
R^2	0.21	0.25	0.21	0.28	0.17	0.22
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.

The findings are in line with Duckworth and Seligman (2005) if *P* in MARS has a close relationship with self-discipline. 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, non-verbal cognitive and noncognitive abilities tend to be more important for predicting school achievement at the primary school level than verbal cognitive abilities. Our conclusions remain unchanged if the available lags for all abilities are included (Table A9).

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 the bias from endogeneity (Wooldridge, 2005) (Table 5).

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 *Y* is also relevant. 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 5) further reduces some of the coefficients in the probit equation. The reduction does not change our conclusions.

Table 5: Average marginal effects for attending the Gymnasium

	IQ	*IQ*; add. lags [a)]	*NV-IQ* / *V-IQ*	*NV-V-IQ* / add. lags [a)]
H (t)	0.82*	0.60*	0.90*	0.88*
Y (t)	0.15*	0.18*	0.16*	0.17*
IQ (t – 1)	1.03*	0.84*		
NV-IQ (t-1)			0.74*	0.57*
-IQ (t-1)			0.51*	0.42*
MQ (t - 1)	0.37*	0.33*	0.36*	0.26
P (t – 1)	0.49*	0.38*	0.46*	0.38*
Pseudo R^2	0.29	0.32	0.29	0.31
Observations	357	357	357	357

MARS, [a)] this specification contains 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 illustrate the importance of abilities and *H* (all values are taken from the estimation with all lags included). If the *IQ* 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* were 3.3 instead of 3, the average marginal probability increased by 3.8 percent. If *H* were 110 instead of 100 the average marginal probability increased by 6 percent and if *Y* increased by 10 percent the marginal increase in the probability would be 1.8 percent.

The attendance of higher-track secondary school and basic abilities

Finally, we analyze whether attending Gymnasium is related to cognitive, motor and noncognitive abilities. To account for the simultaneity bias OLS and TSLS methods are employed. In the TSLS, *Y* is used as an instrumental variable for *Gymnasium*. The estimates (Table A10) demonstrate that *Gymnasium* is not associated with any of our basic abilities at secondary school age. The coefficient of *persistence* is significantly different from 0 in the OLS estimate (0.06). However this is not the case for the TSLS estimate. The OLS estimate is biased upward. At secondary school age, self-productivity and *H* dominate. However, our results do not imply that higher-track secondary school has no relationship to competencies trained at the *Gymnasium*. The basic abilities predict school achievement. Basic abilities, however, are no longer influenced by higher-track secondary school attendance.

Assessing alternative stage specific improvements in H for ability development

Table A11 presents an assessment of all direct and indirect improvements of our three basic abilities at the developmental stages resulting from a successful improvement of *H* of one percent at various developmental stages. The estimates suggest that the first four years are optimal for fostering basic cognitive and motor abilities, while the window for improving noncognitive abilities widens until adolescence.

8 Concluding remarks

Deep-seated capabilities formed in early childhood have long-term implications for human development and personality. This paper contributes to uncovering the relationship between home resources and self-productivity during the development of basic abilities in childhood. We investigate complementarities between the basic abilities and children’s 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 and personality formation across child development. The strength of the relationship differs between our three basic abilities and over time, which is in line with Heckman (2008). The importance of home resources and self-productivity for ability formation changes specific to the developmental stage. Basic cognitive and noncognitive abilities are closely related to the socio-emotional home resources, while the basic motor ability is not. The initial inequality of abilities increases between the ages of three months and 11 years. Noncognitive abilities are associated with favourable home resources until school age, cognitive abilities until the age of 4.5 years. Basic abilities at primary school age and home resources combine to predict social competencies and school achievement at secondary school age.

The other side of the coin of inequality evolution in the early life cycle is the stability of home resources. Advantages from favourable home resources and disadvantages from poor home resources cumulate across development. Starting with risk and growing up in an unfavourable environment impedes the development of basic 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 resources create an additional barrier. Consequences for lifetime inequalities in Germany are discussed in Pfeiffer and Reuß (2008).

We regard our study as a starting point for research on competence formation and the significance of sensitive and critical investment periods. According to Laucht et al. (2004) characteristics of the early parent-child-interaction, such as infant smiling and maternal responsiveness, as well as early language abilities and the child’s self-esteem, contribute to resilience in children growing up in family adversity. Future research based on economic models will focus on the wide range of parental guidance and their stage-specific relationship with personality and development.

References

Angermaier, Michael (1974). *Psycholinguistischer Entwicklungstest*, Beltz, Weinheim.

Asendorpf, Jens B., and Marcel A.G. van Aken (1993). “Deutsche Versionen der Selbstkonzeptskalen von Harter.” *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, 25 (1), 64-96.

Almond, Douglas, Kenneth Y. Chay, and David S. Lee (2005). “The Cost of Low Birth Weight.” *Quarterly Journal of Economics*, 120 (3), 1031-1083.

Bayley, Nancy (1969). *Bayley Scales of Infant Development*, Psychological Corporation, New York.

Beckett, Celia, Barbara Maughan, Michael Rutter, Jenny Castle, Emma Colvert, Christine Groothues, Jana Kreppner, Suzanne Stevens, Thomas O'Connor, and Edmund J. S. Sonuga-Barke (2006). “Do the Effects of Early Severe Deprivation on Cognition Persist Into Early Adolescence? Findings from the English and Romanian Adoptees Study.” *Child Development*, 77 (3), 696-711.

Black, Sandra E., Paul J. Devereux, and Kjell Salvanes (2007). “From the Cradle to the Labor Market? The Effect of Birth Weight on Adult Outcomes.” *Quarterly Journal of Economics*, 122 (1), 409-439.

Bradley, Robert H. (1989). “The Use of the HOME Inventory in Longitudinal Studies of Child Development.” In: Marc H. Bornstein, and Norman A. Krasnegar (Eds.), *Stability and continuity in mental development: Behavioral and biological perspectives*. Hillsdale, New Jersey: Lawrence Erlbaum, 191-215.

Bradley Robert H. and Bettye M. Caldwell (1980). “The Relation of Home Environment, Cognitive Competence, and IQ among Males and Females,” *Child Development*, 51 (4), 1140-1148.

Bradley Robert H. and Bettye M. Caldwell (1982). “The Relation of Infants’ Home Environments to Achievement Test Performance in First Grade: A Follow Up Study,” *Child Development,* 55 (3), 803-809.

Burgemeister, Bessie, Lucille Blum, and Irving Lorge (1972). *Columbia Mental Maturity Scale,* Harcourt Brace Jovanovich, New York.

Cattell, Raymond B. (1960). *Culture Fair Intelligence Test, Scale 1 (Handbook). 3 ed.,* IPAT, Champaign, Ill.

Coneus, Katja, and Friedhelm Pfeiffer (2007). “Self-Productivity in Early Childhood.” *ZEW Discussion Paper* #07-053.

Cunha, Flavio, and James J. Heckman (2007). “The Technology of Skill Formation.” *The American Economic Review*, 97 (2), 31-47.

Cunha Flavio, and James J. Heckman (2008). "Formulating, Identifying and Estimating the Technology of Cognitive and Noncognitive Skill Formation." *Journal of Human Resources*, 43 (4).

Duckworth, Angela L., and Martin Seligman (2005). "Self-Discipline Outdoes IQ in Predicting Academic Performance in Adolescents." *American Psychological Society*, 16, 939-944.

Egeland, Byron, Elizabeth A. Carlson, and Alan Sroufe (1993). "Resilience as Process." *Development and Psychopathology*, 5, 517-528.

Esser, Günter, Manfred Laucht, Martin Schmidt, Walter Löffler, Arnulf Reiser, Rosa-Maria Stöhr, Diana Weindrich, and Hiltrud Weinel (1990). "Behaviour problems and developmental status of 3-month-old infants in relation to organic and psychosocial risks." *European Archives of Psychiatry and Neurological Sciences*, 239 (6), 384-390.

Gebel, Michael, and Friedhelm Pfeiffer (2007). "Educational Expansion and its Heterogeneous Returns for Wage Workers." *ZEW Discussion Paper*.

Harter, Susan, and Robin Pike (1984). "The Pictorial Scale of Perceivded Competence and Social Acceptance for Young Children." *Child Development*, 55 (6), 1969-1982.

Heckhausen, Heinz, and Jutta Heckhausen (2008). *Motivation and Action*. Cambridge, Cambridge University Press.

Heckman, James J. (2000). "Policies to Foster Human Capital." *Research in Economics*, 54, 3-56.

Heckman, James J. (2007). "The Economics, Technology and Neuroscience of Human Capability Formation." *Proceedings of the National Academy of Sciences*, 104 (3), 132250-5.

Heckman, James J. (2008). "The Economics and Psychology of Inequality and Human Development." *Marshall Lecture European Economics Association August 29, 2008,* Milano.

Heckman, James, J., Lance J. Lochner, and Petra E. Todd (2008). "Earnings Functions and Rates of Return." *Journal of Human Capital*, 2 (1), 1-31.

Kazdin, Alan E., Helena C. Kraemer, Ronald C. Kessler, David J. Kupfer, and David R. Offord (1997). "Contributions of risk-factor research to developmental psychopathology." *Clinical Psychology Review*, 17 (4), 375-406.

Kiphardt, Ernst J., and Friedhelm Schilling (1974). *Körperkoordinationstest für Kinder (KTK)*, Beltz, Weinheim.

Kirk, Samuel A., James J. McCarthy, and Winifred D. Kirk (1968). *Illinois Test of Psycholinguistic Abilities,* University of Illinois Press, Urbana.

Köhler, Götz, and Heinz Egelkraut (1984). *Münchner Funktionelle Entwicklungsdiagnostik für das 2. und 3. Lebensjahr: Handanweisung*, Institut für soziale Pädiatrie und Jugendmedizin der Universität, München.

Laucht, Manfred, Günter Esser, and Martin H. Schmidt (1997). "Developmental outcome of infants born with biological and psychosocial risks." *Journal of Child Psychology and Psychiatry*, 38 (7), 843-854.

Laucht, Manfred, Günter Esser, and Martin H. Schmidt (2000a). "Längsschnittforschung zur Entwicklungsepidemiologie psychischer Störungen: Zielsetzung, Konzeption und zentrale Ergebnisse der Mannheimer Risikokinderstudie." *Zeitschrift für Klinische Psychologie und Psychotherapie*, 29 (4), 246-262.

Laucht, Manfred, Günter Esser, Martin H. Schmidt, Lioba Baving, Martin Gerhold, Ingrid Hoesch, Wolfgang Ihle, Petra Steigleider, Birgit Stock, Rosa-Maria Stöhr, and Diana Weindrich (2000b). "Behavioral sequelae of perinatal insults and early family adversity at 8 years of age." *Journal of the American Academy of Child and Adolescent Psychiatry*, 39 (10), 1229-1237.

Laucht, Manfred, Günter Esser, and Martin H. Schmidt (2001). "Differential development of infants at risk for psychopathology: The moderating role of early maternal responsivity." *Developmental Medicine and Child Neurology*, 43 (5), 292-300.

Laucht, Manfred, Martin H. Schmidt, and Günter Esser (2004). "The development of at-risk children in early life." *Educational and Child Psychology*, 21 (1), 20-31.

Laucht, Manfred (2005). "Die langfristigen Folgen früher Entwicklungsrisiken: Ergebnisse der Mannheimer Längsschnittstudie zu Risiko- und Schutzfaktoren." In Peter Arnoldy und Birgit Traub (Hrsg.), *Sprachentwicklungsstörungen früh erkennen und behandeln*, Loeper, Karlsruhe, 169-183.

Marcus, Alexander, Bernd Blanz, Günter Esser, Joachim Niemeyer, and Martin H. Schmidt (1993). "Beurteilung des Funktionsniveaus bei Kindern und Jugendlichen mit psychischen Stoerungen." *Kindheit und Entwicklung*, 2, 166-172.

Masten, Ann S., Karin M. Best, and Norman Garmezy (1990). "Resilience and development: Contributions from the study of children who overcome adversity." *Development and Psychopathology*, 2, 425-444.

Michel, Walter, Yuichi Shoda, and Philip K. Peake (1988). "The Nature of Adolescent Competencies Predicted by Preschool Delay of Gratification." *Journal of Personality and Social Psychology*, 54 (4), 687-696.

Murnane, Richard J., Rebecca A. Maynard, and James C. Ohls (1980). "Home Resources and Children's Achievement." *The Review of Economics and Statistics*, 369-377.

Oreopoulos, Phil, Mark Stabile, Randy Walld, and Leslie Roos (2006). "Short, Medium, and Long Term Consequences of Poor Infant Health: An Analysis Using Siblings and Twins." *NBER Working Paper* No.11998.

Pfeiffer, Friedhelm, and Karsten Reuß (2008). "Age-Dependent Skill Formation and Returns to Education." *Labour Economics*, 15 (4), 631-646.

Rutter, Michael, and David Quinton (1977). "Psychiatric disorder – ecological factors and concepts of causation." In *Ecological factors in human development* (pp 173-187), edited by Harry McGurk. North Holland, Amsterdam.

Schneider, Wolfgang, and Franz E. Weinert (1999). "Individual Development From 3 to 12: Findings From the Munich Longitudinal Study." *Cambridge University Press*, Cambridge.

Schrueger, James M., and Anita C. Witt (1989). "The temporal stability of individually tested intelligence." *Journal of Clinical Psychology*, 45 (2), 294-302.

Todd, Petra E., and Kenneth L. Wolpin (2006). "The production of cognitive achievement in children: Home, school and racial test score gaps." *Manuscript*, University of Pennsylvania.

Thomas, Alexander, and Stella Chess (1977). *Temperament and Development*, Brunner/Mazel, New York.

Weiss, Rudolf, and Jürgen Osterland (1977). *Grundintelligenztest CFT 1,* Westermann, Braunschweig.

Weiss, Rudolf (1987a). *Grundintelligenztest CFT 20*, Hogrefe, Göttingen.

Weiss, Rudolf (1987b). *Wortschatztest WS. Ergänzungstest zum Grundintelligenztest CFT 20,* Hogrefe, Göttingen.

Wooldridge, Jeffrey M. (2005). "Simple Solutions to the Initial Conditions Problem in Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity." *Journal of Applied Econometrics*, 20, 39-54.

Zimmer, Renate, and Meinhart Volkamer (1984). *Motoriktest für 4-6jährige Kinder (MOT 4-6)*, Beltz, Weinheim.

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	38
10	neonatal complications	treated neonatally for ≥ 7 days seizures respiratory therapy sepsis	83

[a]The pH-value measures an acid or basic effect of a hydrous solution. For individuals a low pH-value indicates less oxygen in the blood. [b]Lactic acid, also known as milk acid, is a chemical compound that plays a role in biochemical processes. [c]A CTG (cardiotocograph) measures the child's heartbeat during pregnancy and labor. [d]An edema, also known as hydropsy, is the increase of interstitial fluid in any organ during swelling. [e]Proteinuria is an indicator of possible severe damage to metabolism or of kidney disease. [f]Hypertonia is an indicator of a possible disease of the blood vessel system. [g]Cerclage 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 $\leq 50\ m^2$	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 $\leq$ 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

[a]The DSM-III-R is the Diagnostical and statistical manual of mental disorder, third edition, revised form.

Table A3: Children's abilities at 3 months and 11 years evaluated in the risk matrix (means and SD)

		Psychosocial Risk					
		no-risk		moderate		high	
		IQ (Intelligence Quotient)					
		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
		MQ (Motor Quotient)					
		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
		P (Persistence score) (4.5 years instead of 3 months)					
		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 varies 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.

Table A4: *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	
		H: HOME score					
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	106* 12.9	108* 6.5	102* 12.9	105* 10.2	93 17.0	92 19.8
	moderate	105* 14.2	107* 6.9	100 12.9	99 12.6	95 14.1	92 21.7
	high	106* 10.5	106* 9.1	100* 12.7	98 10.8	94 18.6	94 16.6
		Y: monthly net equivalence income per head					
		3 months	11 years	3 months	11 years	3 months	11 years
Organic Risk	no-risk	1,275* 775	1,699* 681	1,122* 542	1,632 832	775 465	1,256 643
	moderate	1,293* 649	1,644* 627	903 239	1,325 555	948 774	1,325 641
	high	1,180* 403	1,806* 629	927 295	1,425 495	863 344	1,355 636

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.

Table A5: The partial elasticity of *H* and the stock of abilities from t-1 for abilities in t

Ability	*IQ (t-1)*	*MQ (t-1)*	*P (t-1)*	*H (t)*	Ad. R^2
		t = 11 years			
IQ (t)	0.89*	0.13*	0.10*	0.17	0.76
MQ (t) [a]	0.34*	0.66*	-0.01	0.13	0.56
P (t)	0.31*	0.03	0.31*	0.28	0.53
		t = 8 years			
IQ (t)	0.84*	0.26*	0.07	0.19	0.63
MQ (t) [a]	0.00	0.42*	0.01	0.12	0.40
P (t)	0.27*	0.20*	0.29*	0.43*	0.37
		t = 4.5 years			
IQ (t)	0.53*	0.09*	0.02	0.38*	0.59
MQ (t)	0.26*	0.72*	0.11*	0.04	0.57
P (t)	0.61*	-0.04	0.18*	0.50*	0.33
		t = 2 years [a)]			
IQ (t)	0.23*	0.08	0.12*	0.38*	0.29
MQ (t)	0.07	0.31*	0.15*	0.00	0.26
P (t)	0.12*	0.13*	-0.08	0.37*	0.13
		t = 3 months (8 risk indicator, relative to maximum risk[1])			
IQ (t)	(0.12*, 0.10*, 0.04, 0.11*, 0.10*, 0.02, 0.07, 0.09*)			0.55*	0.12
MQ (t)	(0.14*, 0.11*, 0.03, 0.13*, 0.08*, 0.02, 0.15*, 0.10*)			0.16	0.14
P (t)	(0.02, 0.07, 0.06, 0.06, 0.09*, 0.03, 0.05, 0.08)			0.29*	0.04

MARS, 364 observations, all variables in natural logarithm; coefficients from OLS regressions including a constant and performed for each ability; heteroscedastically robust standard errors;

[a] the equations for 2 years also contain variables indicating a cell in the initial risk matrix, as is the case for the *MQ* equation at 8 and 11 years; * indicates significance at the 5 percent level; [1]describes the degree of organic and psychosocial risk: (0,0), (1,0), (2,0), (0,1), (1,1), (2,1), (0,2), (1,2), (2,2).

Table A6: The partial elasticity of *H* and the stock of abilities from *t-1* for abilities in *t*, lags included

Ability	*IQ (t-1)*	*MQ (t-1)*	*P (t-1)*	*H (t)*	Ad. R^2
			t = 11 years		
IQ (t)	0.77*	0.01	0.10*	0.17	0.77
MQ (t) [a)]	0.24*	0.40*	0.01	0.21	0.66
P (t)	0.33*	-0.03	0.27*	0.24*	0.54
			t = 8 years		
IQ (t)	0.78*	0.20*	0.06	0.19	0.63
MQ (t) [a)]	-0.06	0.36*	0.01	0.16	0.39
P (t)	0.21	0.16*	0.27*	0.38	0.36
			t= 4.5 years		
IQ (t)	0.53*	0.09*	0.02	0.38*	0.58
MQ (t)	0.26*	0.70*	0.10*	0.03	0.57
P (t)	0.60*	-0.06	0.19*	0.50*	0.32

MARS, 364 observations, all variables in natural logarithm; coefficients from OLS regressions, the specifications contain all available additional lags in abilities, albeit not reported here; [a] the equations for the *MQ* equation also contain variables indicating a cell in the initial risk matrix at 8 and 11 years; * indicates significance at the 5 percent level.

Table A7: Further estimates of the partial elasticity of *H* and the stock of abilities at *t-1* for cognitive abilities in *t*

Two stage least square estimate for *H* at *t* = 4.5 years [a)]

	OLS [b)]	TSLS: current *Y*	TSLS: permanent *Y*	TSLS: risk matrix
H (t)	0.38*	0.57*	0.50*	0.27
IQ (t -1)	0.53*	0.48*	0.50*	0.56*

Quantile regressions for the *IQ* [c)]

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

The partial elasticity of *H* on the nonverbal (*NV-IQ*) and the verbal (*V-IQ*) intelligence [d)]

ability	2 years	4.5 years	8 years	11 years
NV-IQ	0.22	0.26*	-0.07	0.02
V-IQ	0.42*	0.49*	0.34*	0.16
IQ [b)]	0.38*	0.38*	0.19	0.16

MARS, 364 observations, all regressions include a constant, all variables in natural logarithm; [a)] regression model also contains *MQ (t-1)*, *P (t-1)*, not reported here, because results do not differ from OLS; [b)] taken from Table A5 to facilitate comparison; [c)] regression model also contains *MQ (t-1)*, *P (t-1)*, not reported here; [d)] Coefficients from OLS regression including a constant and *IQ (t-1)*, *MQ (t-1)*, *P (t-1)* not reported here, because results do not differ from those in Table A5; * indicates significance at 5 percent level.

Table A8: School achievement (grades) at age 8 and higher-track secondary school attendance at age 11

		Psychosocial Risk		
		no-risk	moderate	high
Grades in reading, spelling and math [a] at age 8				
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
Higher-track secondary school attendance Gymnasium / Realschule / Andere [b] at age 11 (in percent)				
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 Waldorfschule, *indicates significant mean differences relative to the high-risk group at the 5 percent level.

Table A9: The partial elasticity of abilities in *t-1* and home resources for school grades [a] at the age of 8 years, lags included

	reading		*spelling*		*math*	
	IQ	*NV-IQ/ V-IQ*	*IQ*	*NV-IQ/ V-IQ*	*IQ*	*NV-IQ/ V-IQ*
H (t)	0.02	0.05	-0.59	-0.57	-0.44	-0.55
Y (t)	-0.01	-0.02	-0.05	-0.06	-0.03	-0.05
IQ (t-1)	-0.88*		-0.58*		-0.59*	
NV-IQ (t-1)		-0.95*		-1.10*		-1.10*
V-IQ (t-1)		-0.37		0.20		0.19
MQ (t-1)	-0.32*	-0.13	-0.34*	-0.14	-0.18	0.01
P (t-1)	-0.29*	-0.20	-0.27*	-0.19	-0.22*	-0.16
Adj. R^2	0.23	0.28	0.23	0.30	0.18	0.22
Observations	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, heteroskedasticity robust standard errors, all variables in natural logarithm;
* indicates significance at the 5 percent level.

Table A10: The attendance of the *Gymnasium* depending on basic abilities

	GYM.	*H (t)*	*IQ (t-1)*	*MQ (t-1)*	*P (t-1)*	Adj. R^2
			OLS without lags			
IQ (t)	0.01	0.16	0.90*	0.15*	0.09	0.77
MQ (t)	-0.02	0.13	0.36*	0.61*	0.02	0.56
P (t)	0.07*	0.37*	0.18*	-0.06	0.28*	0.39
			OLS, lags included			
IQ (t)	0.02	0.17	0.78*	0.01	0.08	0.80
MQ (t)	-0.002	0.21	0.24*	0.40*	0.02	0.65
P (t)	0.06*	0.37*	0.29*	-0.08	0.23*	0.43
			TSLS, lags included			
IQ (t)	-0.03	0.23*	0.78*	0.01	0.11*	(0.76)
MQ (t)	0.20	0.14	0.18*	0.34*	-0.03	(0.44)
P (t)	0.13	0.49*	0.27*	-0.10	0.21*	(0.39)

MARS, 364 observations, all variables in natural logarithm; coefficients from OLS regressions, heteroscedasticity robust standard errors, including a constant and performed for each ability; * indicates significance at the 5 percent level.

Table A11: The estimated direct and indirect effects of a successful one percent increase in H, in percent

		One percent gain in H at stage				
increase at stage		3 months	2 years	4.5 years	8 years	11 years
3 months	*IQ*	0.55				
	MQ	0.15				
	P	0.28				
2 years	*IQ*	0.72	0.38			
	MQ	0.29	0.00			
	P	0.34	0.37			
4.5 years	*IQ*	0.83	0.59	0.38		
	MQ	0.44	0.14	0.04		
	P	0.46	0.67	0.50		
8 years	*IQ*	0.96	0.82	0.74	0.19	
	MQ	0.50	0.19	0.06	0.12	
	P	0.55	0.84	0.76	0.43	
11 years	*IQ*	1.11	1.06	1.10	0.42	0.17
	MQ	0.56	0.31	0.19	0.26	0.13
	P	0.60	0.96	0.94	0.65	0.40