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Day care quality and changes in the home learning environment of children

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ABSTRACT

Children's development is fostered by both high quality Early Childhood Education and Care (ECEC) settings and high quality home learning environments. As we know little about the interrelations between these two environments, we examine whether the child's attendance in a high quality ECEC arrangement relates to the quality of her home learning environment. Using rich NICHD Study of Early Child Care and Youth Development data, we show that ECEC quality is associated with the home learning environment, even after taking into account the lagged dependent variable and a rich set of control variables.

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1. Motivation

There is a large body of international research in economics and other social sciences examining the effects of Early Childhood Education and Care (ECEC)[1] on the cognitive and non-cognitive (socio-emotional) development of children. While many of these studies focus on quantitative aspects (i.e. whether and how long a child attends ECEC arrangements), several psychological and pedagogical studies emphasize that attendance, *per se,* is less predictive for child development than ECEC quality. This growing literature shows that attending ECEC services of higher quality is positively associated with children's development, with effects increasing with ECEC quality (e.g. Belsky et al. 2007; Heckman 2008; Sammons et al. 2008; Vandell et al. 2010; for an overview, see Melhuish et al. 2015). ECEC quality is also crucial for the magnitude and the long term persistence of beneficial effects (for international and US reviews, see, e.g. Gilliam and Zigler 2001; Gorey 2001; Anderson et al. 2003; Burger 2010; Camilli et al. 2010). In the economic literature, intervention studies demonstrate the beneficial effects of high quality ECEC (well-known interventions include the Perry preschool program and the Abecedarian program, e.g. Barnett and Masse 2007; Heckman, Pinto, and Savelyev 2013; Kautz et al. 2014), where children attend high ECEC quality programs as part of the intervention.[2]

In addition to the literature on the effects of ECEC quality, another strand shows that the home learning environment (HLE) and other parental investments are important for children's cognitive and non-cognitive development (see below). In these studies parental investments are often measured by financial inputs or time inputs, which are shown to produce a particular HLE. Fewer studies focus explicitly on activities parents undertake with their children, which however, are also inputs of the HLE production. This literature stresses the importance of parenting compared to parental income (for a recent study on this, see Carneiro and Ginja 2016).[3] Several studies present empirical evidence that mother's time is a crucial investment in the production of a child's HLE and thus in

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the process of child outcomes. Father's time is almost equally productive, especially during crucial stages of development (e.g. Carneiro and Rodriguez 2009; Del Boca, Flinn, and Wiswall 2014; Del Bono et al. 2016). However, the effects depend on the activities parents perform with their children: Hsin and Felfe (2014), for instance, show that the time mothers spend on educational and structured activities correlates positively with child outcomes, more than time spent on other activities.

Todd and Wolpin (2007) use a home environment index as a measure for parenting and find strong evidence that home inputs are important determinants of child cognitive development. Using the same scale, Blomeyer et al. (2013) also demonstrate that the HLE is strongly related to competencies during childhood and achievement in adulthood. The importance of high quality parenting for child development is further underlined by evaluations of few interventions that try to improve maternal skills to develop children's skills. This small literature suggests that such programs to increase the HLE quality are particularly effective when addressing disadvantaged mothers.[4]

Overall, benefits of high ECEC quality and high HLE quality on child development are well-established. Yet, we know little about the interrelations of these two important types of investments. In particular, there is almost no evidence on the relationship between high ECEC quality and changes in the quality of the HLE. However, it is crucial to understand how parents react to better ECEC quality. Do they substitute higher ECEC quality with lower HLE quality, do they complement higher ECEC quality with higher HLE quality, or is the provided level of HLE quality completely unrelated to the ECEC quality? The answer to this question is relevant for researchers and policy makers. If an increase in ECEC quality results in a lower HLE quality, investments in higher ECEC quality are not necessarily beneficial. The effect of higher ECEC quality is only unambiguously positive, if ECEC quality either leaves HLE quality unaffected or increases it.

There is some evidence that children require a minimum level of support from the home environment to benefit from higher ECEC (e.g. NICHD 2002; Vandell et al. 2010), while others argue that disadvantaged children especially benefit from high ECEC quality as it compensates for low HLEs (for an overview, see, e.g. Elango et al. 2015). A few studies describe the correlations between ECEC quality and the quality of the HLE in the social science literature (e.g. NICHD 1997; McCartney et al. 2007; Habibov 2012; Lehrl et al. 2014).[5] In the economic literature, this relationship is only studied by looking at very specific high quality interventions for disadvantaged families. Heckman and Mosso (2014) summarize evidence from the Nurse-Family Partnership (NFP, Olds et al. 2007), the Perry preschool program (Schweinhart, Barnes, and Weikart 1993), and the Abecedarian programm (Breitmayer and Ramey 1986). The NFP program provided home visits where teenage mothers were provided parenting training. The Perry preschool program offered home visits in addition to preschool attendance and the Abecedarian program interacted with parents of the treatment group at the day care centers. Walters (2015) shows that Head Start programs offering a home visiting program are more effective than those that do not. Apart from this, overall Head Start evaluations show that providing access to Head Start has benefits for both 3-year-olds and 4-year-olds in particular parenting domains. However, these benefits are largely absent by 1st grade for the program population as a whole (e.g. U.S. Department of Health and Human Services 2010). Another Head Start evaluation study by Carneiro and Ginja (2014) cannot rule out a zero relation between Head Start eligibility at age 4 and a measure of the home environment quality in the period subsequent to the program. Overall, the evidence generally supports complementary responses of parents to high quality interventions or targeted programs such as Head Start.[6] But apart from the mixed evidence of Head Start this evidence is mostly based on specific, high intensity, small-scale intervention studies that included a parental training component, sometimes next to child interventions. Our study is the first to analyze the relationship between ECEC quality in regular settings and the overall HLE of children in these ECEC programs that, typically, do not include an explicit parent component.[7]

Our analysis is based on very rich data of the Study of Early Child Care and Youth Development (SECCYD), which is administered by the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD). This dataset covers the great variety of day care arrangements available in the US[8] and is the most suitable data set for our research questions as it provides

comprehensive information about the child's HLE before and after being in ECEC. In addition, it covers detailed ECEC quality measures, which go far beyond simple structural characteristics (e.g. staff-child ratio or group size) as they are based on observations of professional raters. Moreover, the NICHD data set is a panel, thus allowing for children to be followed, tracking the environments in which they grow up.

We estimate value-added models and exploit the rich SECCYD data by including a wide range of additional variables controlling for other past and current inputs, including some variables (like non-cognitive skills) that are often unobservable to the researchers. We show that ECEC quality is positively related to the HLE of children, even after taking into account our rich set of control variables and the lagged dependent variable. The estimated coefficient is larger for ECEC quality experienced at ages two or later. Our results are robust to various model specifications, taking into account measurement and sample restriction issues. Moreover, applying the method proposed by Oster (2017) suggests that the degree of selection on unobserved variables must be even larger than the degree of selection on observed variables in order to drive the coefficient of ECEC quality to zero. Our estimates point to differences between subgroups: The long-run point estimates are larger for more advantaged children, white children, those of higher educated mothers, and those of non-single mothers. These results suggest an additional mechanism exerting the previously discussed 'Matthew Effect' in ECEC (Vandell et al. 2010). The potential of high ECEC quality to influence the HLE of children is certainly not fully explored and could be extended to more disadvantaged groups.

The structure of this paper is as follows. Section 2 explains the conceptual framework and discusses several mechanisms through which ECEC quality might impact the HLE. Section 3 introduces our empirical approach and the data. Section 4 presents our main results as well as robustness tests and heterogeneity analyses. Section 5 summarizes our findings and concludes.

2. Conceptual framework and mechanisms

By analyzing the association between ECEC quality and the HLE of a child, we refer to the dynamic skill formation model by Cunha and Heckman (2007). In this framework, the dynamic complementarity of skills results from the fact that investments and skills at time t affect the skill level at $t + 1$ and so on. While this technology of skill formation focuses on the multiple distinct developmental periods in childhood and on multiple skills, it also emphasizes multiple forms of investments, including parenting and schooling (e.g. Francesconi and Heckman 2016). In the context of early childhood, schooling can be interpreted as a synonym for all non-parental formal care and education arrangements, covering ECEC services as well. While there is much research on how skills develop according to this model, less attention is paid to the relationship between the different investments. Do they influence each other, either directly or via the skill development of children? How is the relationship between parents, ECEC institutions, and children shaped? The fact that this is barely studied is surprising, as in the presence of dynamic complementarities in the production function for skills, the most effective remediation strategy for disadvantaged children, for instance, is to couple increased early investments in various environments with increased investments later. Extending the argument in Heckman and Mosso (2014), improving the HLE quality and improving ECEC quality can, be, thus, complementary investments and must not be substitutes.

There are several possible mechanisms how the children's HLE and, consequently, home investments might be affected by ECEC quality: On the one hand, there might be *direct links*. As it is a substantial feature of high ECEC quality that the ECEC staff interacts with the parents (e.g. Kluczniok and Roßbach 2014), educators might directly advise parents on how to improve the HLE – and educators from higher quality ECECs might give better advice. This is also suggested by early childhood educators who report that parents are informally and formally educated in day care arrangements (e.g. Bowman 1997): Some day care providers offer informal parent education during drop-off and pickup as well as formal parenting education, home visits, workshops, study groups, books,

organizational activities, or lectures, for example. If this is effective, it would result in a positive effect of ECEC quality on the quality of the HLE. However, there might be another direct effect, in the sense that parents alter their investments and behaviors to compensate for lower ECEC quality (see, e.g. Todd and Wolpin 2003 or Araujo et al. 2016). Such an effect can only occur if parents are able to judge ECEC quality properly. The small empirical literature on this shows that parents are weakly informed in this respect: On average they overestimate ECEC quality as rated by experts, but they are at least partially rational in the sense that they can distinguish between high and low quality, in particular if their child attends the center (see, e.g. Mocan 2007; Araujo et al. 2016; Camehl, Schober, and Spiess 2018). If parents' compensation behavior dominates, we would expect a negative effect of ECEC quality on the HLE quality.

One the other hand, there are several *indirect mechanisms*. For one, children at home talk about or re-enact their (high quality) ECEC experiences and their parents could learn indirectly from the ECEC educators about ways of dealing with their children as well as about new activities. Second, children benefiting from high ECEC quality might demand more stimulation at home, thus shaping their HLE (e.g. Scarr and McCartney 1983). Third, there might be indirect mechanisms that relate to the parents. High ECEC quality can also affect parental outcomes, such as parental well-being. There are a few studies focusing on the association between ECEC quality measures and maternal well-being: Higher ECEC quality might reduce work-family conflicts and ensure that children are in good hands (e.g. Kremer 2007; Poms et al. 2009; Payne, Cook, and Diaz 2011), consequently increasing parents' well-being.[9] In turn, increases in parental well-being can improve child development (e.g. Berger and Spiess 2011) and are likely related to improvements in the HLE.

All these mechanisms suggest a causal effect of ECEC quality on HLE quality. However, the empirical concern is that particular parents select high ECEC quality for their child and that these parents are those who are motivated to continually enhance the HLE of their child. Due to this particular selection problem, the relationship between (past) ECEC quality and (contemporaneous) HLE quality cannot be interpreted as causal. Although we do not claim a causal relationship for our results, there are arguments that the selection problem might be less relevant in the present case. First, there is empirical evidence suggesting that parents have incomplete information about quality in particular at the point of choosing an ECEC service (see e.g. Camehl, Schober, and Spiess 2018). As indicated above, on average parents overestimate ECEC quality (e.g. Cryer and Burchinal 1997; Cryer, Tietze, and Wessels 2002; Mocan 2007; for a summary, see Torquati et al. 2011). Second, parents only have access to the limited set of ECEC centers where they live. Moreover, on average, parents prefer ECEC near their homes or workplaces (e.g. Meyers 1993; Hofferth and Collins 2000; Stahl, Schober, and Spiess 2018). Third, we take into account an extensive set of variables that not only may influence the level of the HLE and changes in the HLE, but also possibly drive selection into ECEC quality. Fourth, we control for a baseline measure of the HLE, which helps to take into account selection on unobserved variables relating to the level of the HLE. However, this does not take into account selection on unobserved variables relating to changes in the HLE (e.g. specific characteristics of the neighborhood that relate to improvements in the HLE). Fifth, applying the method developed by Oster (2017) shows that our findings are robust to omitted variable bias in the sense that unobserved variables must be more important than observed variables in order to drive the coefficient of ECEC quality to zero.

3. Data and methods

3.1. Empirical approach

We estimate the association between ECEC quality and the HLE with a stepwise procedure. In the first step, we regress the HLE measure only on ECEC quality. We then subsequently add further control variables and examine how the estimated coefficient for ECEC quality changes. In the spirit of Todd and Wolpin (2003, 2007),[10] we distinguish between historical and contemporaneous inputs/

investments, and we also estimate value-added models (by adding a baseline measure of the outcome variable). In all specifications, we use contemporaneous HLE and past ECEC quality to mitigate concerns about reverse causality.

Our model is a value-added model with additional controls for past and current inputs:

$$\text{HLE}_t = \beta_0 + \beta_1 \text{ECEC quality}_{t-1} + \alpha \text{H}_{t-1} + \gamma C_t + \delta \text{HLE}_{t-1} + \varepsilon, \quad (1)$$

where HLE_t is the measure of the current HLE. The parameter of key interest is β_1 and it captures the *ceteris paribus* effect of past ECEC quality on current HLE. H_{t-1} denotes the vector of historical inputs and C_t the vector of contemporaneous inputs. HLE_{t-1} is the baseline measure of the HLE. As the contemporaneous inputs C_t are measured after the measure of the ECEC quality, issues of bad control variables might arise. Therefore, our main specification excludes C_t.[11] We estimate equation (1) and its variants using ordinary least squares and compute robust standard errors. We look at HLE quality at three different points in time relative to the child's age: 36 months, 54 months, and 9 years.

3.2. Data

Our analyses are based on data from the longitudinal NICHD Study of Early Child Care and Youth Development (SECCYD), formerly the NICHD Study of Early Child Care (SECC).[12] The study started as a birth cohort study in 1991, recruiting a diverse sample of 1,364 children at different study sites across the US.[13] The consortium applied a range of assessments (questionnaires, ratings, cognitive tests, observations, medical tests) to the sampled children, their families, other non-family caregivers, and school representatives. Measurements were initiated when the children were one month old and repeated at age 6 months, 15 months, 24 months, 36 months, 54 months, as well as annually in kindergarten, elementary, and middle school until grade 8 with a final assessment at age 15. This study mainly uses data from age 6 months to 9 years, (1991–2006), when most children were in grade 3. An advantage of the SECCYD is that panel attrition is rather low, e.g. in grade 3 (the final measurement point in our study, i.e. age 9) the sample still holds 1,076 children. Most important for the purpose of our study, the SECCYD provides detailed and elaborated measures of quality of the child's ECEC arrangement (e.g. center care arrangements, family day care, and nursing) and the HLE.

Outcome (HLE_t). The quality of the HLE is assessed with the Home Observation for Measurement of the Environment (HOME; Caldwell and Bradley 2003). The HOME is a well-established tool implemented worldwide and used, for instance, by Brooks-Gunn, Klebanov, and Duncan (1996), Aughinbaugh and Gittleman (2003), Todd and Wolpin (2007), Blomeyer et al. (2013), and Carneiro and Ginja (2016). It combines interviewer observations with parental answers to specific interview questions. It is used to assess the cognitive stimulation and emotional support children receive in their home environment. Families' interactions adapt to children's age; thus there are age-specific adaptations of the HOME (age 0–3, age 3–6, age 6–11, age 11–15 years). The version for ages 0–3 includes 45 items and delivers a comprehensive score describing children's upbringing conditions regarding the following dimensions: responsivity (in an emotional, physical or communicative sense), acceptance (avoiding restrictions and punishment), organization (providing adequate, predictive structure), learning materials (providing opportunities for the child to learn through play), involvement (parents engage with the child), and variety (balancing different experiences). Versions for older ages add further aspects of learning and language stimulation as well as modeling and encouraging maturity. Examples of items of the various dimensions are listed in the respective data collection of instruments, such as NICHD (1996b, 740). In order to make the scaling of the HOME comparable across ages, we standardize the HOME at each age using all observations with a valid HOME score, so that at each age the HOME has a mean of zero and a standard deviation of one at each age.

Main explanatory variable. The quality of the ECEC arrangement ($\text{ECEC quality}_{t-1}$ in equation 1) is assessed with the ORCE, the Observational Ratings of the Caregiving Environment (NICHD 1996a).

During two half-day visits within a two-week interval, trained observers visit the day care arrangements and rate the frequency and quality of interactions between caregivers and children. At each visit, the observer completes two observation cycles, concentrating on the following aspects of interaction: the degree of caregivers' sensitivity and reactivity to the children's social signals and (non-)distress, caregiver intrusiveness, their expression of positive feelings toward the infant, their emotional and physical detachment and disengagement, the degree of stimulation targeted at the child's cognitive development, and finally the expression of negative regard for the child as well as flatness of caregiver's affect (NICHD 1996a). Altogether, the scale comprises 13 items each ranging from 1 to 4 (1 indicating rather insensitive caregiving, 4 indicating frequent sensitive and responsive caregiving). The items of the various aspects of interaction are listed in the respective data collection of instruments, such as NICHD (1996b, 416). SECCYD collects information on the ORCE if the care arrangement lasts for at least 10 hours per week.[14] As for the HOME, we take into account the overall total scores including all items and aspects of quality for the ORCE. Again, we standardize the ORCE at each age using all valid SECCYD observations. The literature shows that the ORCE is a reliable measure and shows predictive validity for child development (see, e.g. NICHD and Duncan 2003).

For the purpose of our analyses, we restrict the sample to children who are in day care at the described points in time. Table A1. in the appendix provides a comparison of children who participate in ECEC with children who do not participate. As expected, the percentage of children having a working mother at baseline is larger among ECEC-attenders then among the others. Children who participate in ECEC also have higher educated mothers. Therefore, it is not surprising that the HLE of children in ECEC at baseline is slightly higher than that of children who do not participate in ECEC. Our results apply only to children who attend ECEC arrangements and we cannot make any conclusions regarding children who do not attend ECEC arrangements. The day care situation of the children in ECEC in our sample can be described as follows:[15] At the age of 24 months, around 35% of all children attend day care arrangements provided by non-relatives for more than 10 hours/week. At this age, these arrangements cover center care (43%), family day care (42%), and in-home care by non-relatives (15%).[16] At the age of 54 months, the share of children attending day care increases to 71%, covering 90% of children in center care, 8% in family day care, and 2% in in-home care by non-relatives. Overall, the weekly time spend in day care arrangements also changes over time. At 36 months, the average was about 35 hours/week, decreasing to 25 hours/week when the children are 54 months. With respect to structural quality measures in observed day care arrangement, we can, for example, observe that the child-adult-ratio increases from an average of 3.4 at 15 months to almost 7 at 54 months. In addition, the group size of the day care arrangement increases over time from 5 to 13 other children. The average weekly costs for the observed arrangements decreased from US$92 to US$54.[17]

Control variables. Our estimation strategy also considers other past and contemporaneous inputs (see Table 1 for an overview of the included variables). In the selection and coding of these control variables, we closely follow NICHD and Duncan (2003). We distinguish between two sets of past inputs (H_{t-1}), which we subsequently introduce in the estimation of equation (1). While the first set constitutes basic sociodemographic information and measures of the family structure, the second set consists of information regarding the mother's attitudes as well as personality traits of mother and child. The first set of past inputs includes ethnic group (Hispanic, Black, White, other), age at birth (and its square), education (in years), marital status at child birth, employment status of the mother, as well as child gender, number of siblings, an indicator for being firstborn and the birth mode (vaginal delivery, planned C-section, emergency C-section) of the child. Additionally, this first set of past inputs includes some characteristics of the mother's partner (presence of a partner, employment status, years of education) and some household level characteristics (income to poverty ratio, household size, and dummies for each of the 10 sites of data collection[18]). The second set of past inputs consists of the mother's general and education-related attitudes (which might affect occupational behavior, parent-child interactions, and the inclination to place the child in a non-family care arrangement) as well as mother's and child's

Table 1. Summary statistics.

Variable	Mean	Std. Dev.	N
Measures of the dependent variable			
HOME total score at 6 months (raw)	36.999	4.34	721
HOME total score at 36 months (raw)	42.311	7.132	710
HOME total score at 54 months (raw)	46.564	5.146	688
HOME total score in grade 3 (raw)	46.970	6.220	721
Measures of the main explanatory			
ECEC quality (ORCE 36 months, raw)	2.791	0.459	422
ECEC quality (ORCE 54 months, raw)	3.013	0.562	656
ECEC quality (ORCE 36 & 54 months, raw)	2.952	0.481	721
Historical inputs I (measured at or before age 6 months)			
Maternal characteristics			
White	0.803	0.398	721
Black	0.105	0.307	721
Hispanic	0.049	0.215	721
Other non-white	0.043	0.203	721
Mother's age	29.082	5.435	721
Mother's age sq.	875.248	315.506	721
Mother's education (in years)	14.73	2.406	721
Married at birth	0.814	0.389	721
Mother is employed and currently working	0.669	0.471	721
Child characteristics			
Female child	0.510	0.500	721
No. of siblings	0.813	0.905	721
Firstborn	0.459	0.499	721
Vaginal delivery	0.784	0.412	721
Planned C-section	0.078	0.268	721
Emergency C-section	0.139	0.346	721
Paternal characteristics			
Partner lives at home	0.889	0.314	721
Partner's education	14.982	2.527	721
___Missing	0.065	0.247	721
Partner is employed and currently working	0.828	0.378	721
Household characteristics			
Income to poverty threshold ratio	4.103	3.262	721
___Missing	0.008	0.091	721
HH size	3.932	1.079	721
Site: University of Arkansas	0.094	0.292	721
Site: University of California at Irvine	0.122	0.328	721
Site: University of Kansas	0.11	0.313	721
Site: Wellesley College	0.086	0.281	721
Site: University of Pittsburgh	0.105	0.307	721
Site: Temple University	0.093	0.291	721
Site: University of Virginia	0.090	0.287	721
Site: University of Washington	0.108	0.311	721
Site: Western Carolina Center	0.094	0.292	721
Site: University of Wisconsin	0.097	0.296	721
Historical inputs II (measured at or before age 6 months)			
Maternal neuroticism	29.597	7.035	721
___Missing	0.010	0.098	721
Maternal extraversion	42.683	5.642	721
___Missing	0.010	0.098	721
Maternal agreeableness	46.493	5.129	721
___Missing	0.010	0.098	721
Maternal depression	8.968	8.359	721
___Missing	0.001	0.037	721
Maternal sensitivity	9.339	1.729	721
___Missing	0.004	0.064	721
Maternal assessment of child temperament	3.149	0.403	721
Mother's separation anxiety	68.435	12.951	721
___Missing	0.014	0.117	721
Parental Locus of Control	48.227	7.217	721
___Missing	0.015	0.123	721
Attitude: Benefits of maternal employment	19.317	3.047	721

(*Continued*)

Table 1. Continued.

Variable	Mean	Std. Dev.	N
Progressive ideas for raising kids	33.125	3.391	721
___Missing	0.003	0.053	721
Contemporaneous inputs for Panel C (measured in grade 3)			
Income to poverty threshold ratio	4.723	3.609	721
___Missing	0.058	0.234	721
HH size	4.238	1.040	721
___Missing	0.015	0.123	721
No. of siblings	2.335	0.920	721
___Missing	0.015	0.123	721
Partner lives at home	0.817	0.384	721
___Missing	0.015	0.123	721
Mother is employed and currently working	0.768	0.422	721
Partner is employed and currently working	0.763	0.426	721

Note: The table provides summary statistics for selected variables. 'Missing' indicates the share of observations with missing values for the specific variable. Missing values are set to the respective variable means. If all respondents provided valid information for a given variable, no 'missing'-indicator is listed.
Source: Own calculations based on NICHD SECCYD data.

personality characteristics, which might influence parent-child interactions. The variables in this set are included in the SECCYD data and also used by NICHD and Duncan (2003), but these variables are often not observed in other studies. More specifically, this set includes measures of the mother's neuroticism, extraversion, agreeableness, depression, and sensitivity as well as a measure of the child's temperament (all measured when the child was six months old). Furthermore, this set includes measures of the mother's separation anxiety and locus of control as well as her attitudes toward work and toward progressive ideas for raising kids (measured when the child was one month old).

The set of contemporaneous inputs (C_t) includes measures of the current values of those historical inputs that vary over time (i.e. income-to-poverty ratio, household size, number of siblings, presence of a partner at home, employment status of the mother and her partner).[19] In order to avoid losing observations due to missing single items on control variables and in favor of working with a constant sample size, we include a missing dummy indicator for each control variable (and set missing values to the respective variable means).

As SECCYD repeatedly assessed the quality of stimulation in children's home environment as well as the ECEC quality, we not only have the opportunity to control for past HLE quality but we can also

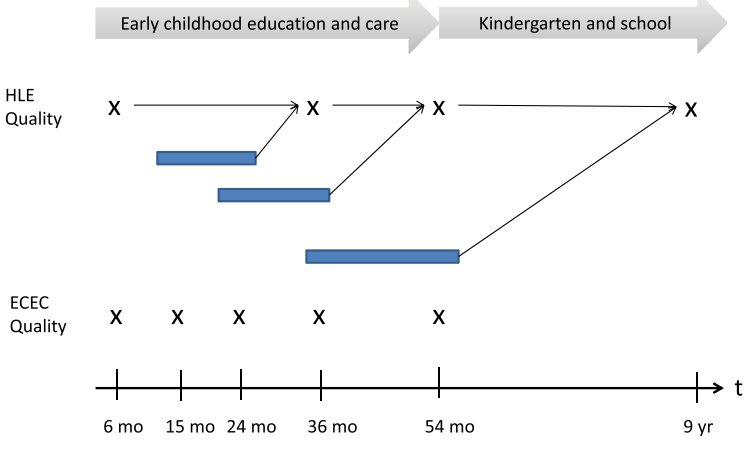

Figure 1. Overview over the study design.

Note: The figure provides an overview over the study design. In particular, it shows the timing of the measurement of the quality of the early education and care arrangement as well as the quality of the home learning environment.

examine the relationship between HLE quality and ECEC quality at various points in time. More specifically, we can look at the HLE quality as an outcome variable at three different points in time (when the child is 36 months, 54 months, and about 9 years, respectively). In order to reduce measurement error, in our main specification we average the ECEC quality over the two assessments that precede the respective HLE measure.[20] Figure 1 provides an overview over this timing and the points in time in which our two quality measures are collected. The figure also shows that in our main specifications, we relate (i) HLE quality at 36 months to ECEC quality averaged over the measures at 15 and 24 months; (ii) HLE quality at 54 months to ECEC quality at 24 and 36 months; and (iii) HLE quality at 9 years to ECEC quality at 36 and 54 months. In the robustness section, we also work with different time spans.[21] In the main specification, we use the HLE quality collected at age 6 months as baseline measure. Again, we work with different baseline measures in the robustness section. By relying on these time spans and baseline measure, we make sure that our quality measures are collected in a clear temporal sequence: ECEC quality is measured after the baseline HLE measure but before the respective outcome HLE measure.

Descriptive statistics. Table 1 provides summary statistics for the historical and contemporaneous inputs as well as for the measures of ECEC and HLE quality. Summary statistics are displayed for the sample that we use in estimating the association of ECEC quality on the HLE at age 9 (i.e. in grade 3).[22] The mean of the HLE is higher when the child is aged 9 compared to the baseline measure at month 6. However, this does not indicate that the HLE improved over time but the higher value is rather due to the different scaling of the HOME scale in the different years; which is why we standardize our quality measures at each measurement point. About 80% of the mothers in our sample are white and 10% are black. Mothers were on average 29 years at the birth of the child and 67% of them are working at baseline, i.e. when the child was six months old. On average, mothers have 14.7 years of education and about 89% of them live together with a partner at baseline. The table further shows that 46% of the children are firstborn and on average, they have 0.8 siblings at baseline.

Table 2. Main results: ECEC quality and the home learning environment.

	Raw correlation (1)	(1) + Historical inputs 1 (2)	(2) + Historical inputs 2 (3)	(3) + Value added Model (4)	(4) + Contemp. Inputs (5)
Panel A: HLE at age 36 months					
ECEC Quality	0.231***	0.027	0.043	0.040	0.031
	(0.044)	(0.037)	(0.037)	(0.035)	(0.035)
N	486	486	486	486	486
R^2	0.06	0.45	0.48	0.50	0.52
Panel B: HLE at age 54 months					
ECEC Quality	0.262***	0.082*	0.078*	0.078**	0.080**
	(0.045)	(0.042)	(0.040)	(0.039)	(0.038)
N	494	494	494	494	494
R^2	0.07	0.48	0.52	0.54	0.56
Panel C: HLE in grade 3					
ECEC Quality	0.218***	0.092**	0.094***	0.088**	0.072**
	(0.042)	(0.036)	(0.035)	(0.035)	(0.035)
N	721	721	721	721	721
R^2	0.04	0.41	0.44	0.45	0.51
Historical 1:	no	yes	yes	yes	yes
Historical 2:	no	no	yes	yes	yes
Baseline HOME:	no	no	no	yes	yes
Contemporaneous:	no	no	no	no	yes

Note: The table displays the coefficient of ECEC quality (measured by the standardized ORCE). The dependent variable is the home learning environment (HLE; standardized) at various points in time, as indicated in the panel header. Further sets of control variables are included as stated in the table's lower part. ECEC quality is averaged over the measures at 15 and 24 months for Panel A, the measures at ages 24 and 36 months for Panel B, and the measures at ages 36 and 54 months for Panel C. Robust standard errors in parentheses: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Source: Own calculations based on NICHD SECCYD data.

4. Results

4.1. Main results

Table 2 presents the main results of our linear regression models. The first column shows that the quality of the HLE at various ages is positively associated with past ECEC quality. Young children who experience better conditions in their ECEC arrangement also find similar favorable quality stimulation and care at home (see e.g. NICHD and Duncan 2003). An increase in the ECEC quality by one standard deviation is associated with an increase in HLE by between 0.22 and 0.26 standard deviations, depending on the time window.

When we include controls for basic sociodemographic information and family structure in column (2), the coefficients decrease, as we would expect. However, the coefficients are still positive and statistically significant in two of the three panels. In column (3) we add mother's and child's personality characteristics and attitudes of the mother. This does not alter the coefficients meaningfully compared to the previous specification. Similarly, adding the baseline measure of our outcome HLE in column (4) only marginally changes the estimated coefficients (but the estimates gain slightly in precision). Hence, the value-added specification and the specification controlling for other historical inputs yield the same conclusion. According to column (4), an increase in the ECEC quality by one standard deviation is related to an improvement of the HLE by 0.08 and 0.09 standard deviations in the second and third panel, respectively. While these two coefficients are statistically significant at the 5%-level, the coefficient in the first panel is not significantly different from zero. The coefficient of 0.03 is smaller than the other two coefficients but not statistically different from them. The overall picture is very similar when we add controls for other contemporaneous inputs in column (5). This is, however, not our preferred specification as these additional controls are measured after the measure of the ECEC quality and might, therefore, be endogenous.[23]

4.2. Robustness

The first robustness check focuses on the relevance of potentially omitted control variables. For this purpose, we rely on the method newly developed by Oster (2017). The idea of this approach is that coefficient movements due to observed variables are informative about how much the estimated coefficient would change if unobserved variables were also considered. Specifically, this approach looks at how much the coefficient of interest changes with the inclusion of control variables and relates this change to the increase in the R-squared, thereby taking into account the explanatory power of the control variables. Oster (2017) suggests the following approximation of the bias-adjusted coefficient, β_1^*:[24]

$$\beta_1^* \approx \tilde{\beta}_1 - \delta[\dot{\beta}_1 - \tilde{\beta}_1]\frac{R^2_{max} - \tilde{R}^2}{\tilde{R}^2 - \dot{R}^2}$$

where $\dot{R}^2$ and $\dot{\beta}_1$ refer to R-squared and estimated coefficient of interest from the baseline regression without control variables. Similarly, $\tilde{R}^2$ and $\tilde{\beta}_1$ denote R-squared and estimated coefficient from the full model including all observed control variables. However, the bias-adjusted coefficient is not only a function of these four estimated quantities, but it also depends on the values chosen for R^2_{max} and δ. R^2_{max} is the R-squared from the (hypothetical) regression of the outcome on all observed and unobserved explanatory variables. It is generally smaller than one if there is measurement error. Therefore, Oster (2017) suggests $R^2_{max} = \min\{1.3 \cdot R^2, 1\}$ as a rule of thumb, which we also apply in our setting. δ is the so-called 'coefficient of proportionality' and indicates the relevance of observed versus unobserved control variables. $\delta = 1$ means that the degree of selection on unobserved variables is as large as the degree of selection on observed variables, while $\delta > 1$ marks a situation in which the unobserved variables are more important.

Based on these considerations, Oster (2017) recommends two ways to report on the robustness to omitted variable bias. Following these recommendations, Table 3 reports (i) a lower bound β_1^* for the coefficient of ECEC quality on HLE assuming $\delta = 1$ (see column 3) and (ii) the value of δ, for which β_1^* would equal zero (see column 5). The results show that – under the assumption that the selection on unobserved variables is as strong as on observed variables (i.e. $\delta = 1$) – the coefficient of ECEC quality is still positive and within the 95% confidence interval of the original point estimate for Panels B and C (columns 3 and 4). Moreover, columns (5) and (6) suggest that unobserved variables must be more important than observed variables in order to drive the coefficient of ECEC quality to zero. This is particularly noteworthy, as the assumption of equal selection might be rather conservative in our setting because our set of observed control variables picks up many of the variables that are used in related studies and also include the lagged dependent variable. For the first panel, however, the coefficient would already be zero if the degree of selection on unobserved variables was 0.63 of the selection on observed variables. For this panel, the lower bound value is also negative. Overall, the results in Table 3 suggest that the significant associations in our main specification are robust to omitted variables based on the method by Oster (2017).[25]

The second set of robustness checks deals with the sensitivity of our results to different measures of the baseline HLE and to different periods over which we average ECEC quality. While in our main specification, we measure the baseline HLE when the child was 6 months old, Table 4 shows that our findings are robust to controlling for baseline HLE at age 15 months (column 2) and at ages 6 and 15 months together (column 3). For the third panel, we additionally rely on the HLE measure at age 36 months as baseline measure. Controlling for this baseline measure (column 4) or controlling for all three baseline measures (column 5) does not change the overall pattern of results or our conclusions.[26] In the main specification, we averaged ECEC quality over the two assessments that precede the HLE measure. Our results are robust to averaging ECEC quality over the preceding three (column 6) or four assessments (column 7; computation possible only for Panel C).

While the main specification includes only children who were cared for by *non-family* members for at least *10 hours* per week, in the following we work with alternative sample restrictions (see Table 5).

Table 3. Assessing the potential bias due to omitted variables.

			Bounds of β_1		Proportionality	
	Raw correlation (1)	Main model (2)	Lower bound (3)	In 95%-c.i. band (4)	δ (5)	$\lvert\delta\rvert > 1$ (6)
Panel A: HLE at age 36 months						
ECEC Quality	0.231***	0.040	−0.024		0.630	
	(0.044)	(0.035)				
R^2	0.06	0.50				
Adj. R^2	0.05	0.45				
Panel B: HLE at age 54 months						
ECEC Quality	0.262***	0.078**	0.015	✓	1.223	✓
	(0.045)	(0.039)				
R^2	0.07	0.54				
Adj. R^2	0.06	0.49				
Panel C: HLE in grade 3						
ECEC Quality	0.218***	0.088**	0.044	✓	1.970	✓
	(0.042)	(0.035)				
R^2	0.04	0.45				
Adj. R^2	0.04	0.42				

Note: The first column shows the coefficient for ECEC quality from the model without any control variables (model (1) from Table 2), while the second column shows the ECEC quality coefficient from our preferred specification (the value-added model, i.e. model (4) from Table 2). Based on the approach outlined in Oster (2017), the third column shows the lower bound of $\beta 1$ and the fourth column checks whether this value is within the 95% confidence interval of the estimated coefficient. The fifth column reports the value of proportionality δ and shows how strong the influence of unobserved variables has to be compared to observed variables to pull the estimated coefficient to zero. The last column checks whether $\delta > 1$. Robust standard errors in parentheses: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Source: Own calculations based on NICHD SECCYD data.

Table 4. Robustness I: different model specifications.

		Baseline HOME at month				ORCE averaged over	
	Main model (1)	15 (2)	6, 15 (3)	36 (4)	6, 15, 36 (5)	3 periods (5)	4 periods (7)
Panel A: HLE at age 36 months							
ECEC Quality	0.040	0.000	0.001			0.049	
	(0.035)	(0.033)	(0.032)			(0.037)	
N	486	480	480			522	
R^2	0.50	0.55	0.56			0.51	
Panel B: HLE at age 54 months							
ECEC Quality	0.078**	0.065*	0.066*			0.132***	
	(0.039)	(0.036)	(0.036)			(0.038)	
N	494	490	490			531	
R^2	0.54	0.57	0.57			0.54	
Panel C: HLE in grade 3							
ECEC Quality	0.088**	0.075**	0.073**	0.084**	0.071**	0.084**	0.089**
	(0.035)	(0.035)	(0.035)	(0.034)	(0.034)	(0.036)	(0.036)
N	721	712	712	710	701	741	762
R^2	0.45	0.47	0.48	0.48	0.49	0.46	0.46

Note: The table displays various robustness tests for the coefficient of ECEC quality. The dependent variable is the home learning environment (HLE) at various points in time, as indicated in the panel header. All specifications control for historical inputs and a baseline measure of the home learning environment (at age 6 months for columns 1, 6 and 7). For columns (1)-(5), ECEC quality is averaged over the measures at 15 and 24 months for Panel A, the measures at ages 24 and 36 months for Panel B, and the measures at ages 36 and 54 months for Panel C. For columns (6) and (7), ECEC quality is averaged over the previous three and four periods, respectively. Robust standard errors in parentheses: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Source: Own calculations based on NICHD SECCYD data.

Table 5. Robustness tests II: different sample restrictions.

		Care		at least X hours/week of care					
	Main	Non-parent.	All	≥ 15	≥ 20	≥ 25	≥ 30	≥ 35	+ Cost
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: HLE at age 36 months									
ECEC Quality	0.040	0.051*	0.070**	0.056	0.061*	0.060	0.070*	0.056	0.040
	(0.035)	(0.031)	(0.028)	(0.036)	(0.037)	(0.039)	(0.040)	(0.042)	(0.036)
N	486	615	762	471	448	427	403	369	486
R^2	0.50	0.51	0.51	0.51	0.51	0.51	0.52	0.52	0.50
Panel B: HLE at age 54 months									
ECEC Quality	0.078**	0.088**	0.112***	0.093**	0.084**	0.085*	0.093*	0.099*	0.072*
	(0.039)	(0.037)	(0.034)	(0.040)	(0.042)	(0.044)	(0.047)	(0.051)	(0.040)
N	494	588	697	478	461	438	401	365	494
R^2	0.54	0.51	0.50	0.54	0.54	0.54	0.55	0.53	0.54
Panel C: HLE in grade 3									
orce	0.088**	0.100***	0.117***	0.094**	0.084**	0.074*	0.086**	0.080*	0.088**
	(0.035)	(0.035)	(0.034)	(0.039)	(0.039)	(0.041)	(0.042)	(0.044)	(0.035)
N	721	774	828	644	604	563	520	477	721
R^2	0.45	0.46	0.46	0.45	0.45	0.44	0.44	0.44	0.46

Note: (1) repeats the main results. (2) includes measures of all ECEC caregivers except parents. (3) includes ECEC quality measures of any caregiver (including family members). Columns (4)-(8) include only children who have at least a specific number of hours of care per week by non-family members in one of the periods in which the ECEC quality is measured, where the specific number is indicated by the column header. Robust standard errors in parentheses: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Source: Own calculations based on NICHD SECCYD data.

We repeat the analyses and include children who were cared for by non-parental family members (column 2) and children who were cared for by their parents or other family members (column 3). Columns 2 and 3 confirm that the results found in our main analyses are not dependent on our sample restrictions. In fact, taking into account the quality of parental interactions observed via the ORCE also leads to an increase of coefficients and, thus, underlines our first main results. However, these specifications are likely to suffer from endogeneity bias.

In the next set of robustness tests, we study whether the results depend on any minimum amount of care or if they hold only for a limited dosage of care. The SECCYD data includes information on the ECEC quality if the care arrangement lasts for at least 10 hours per week; while we use this definition in our main specification, for robustness purposes we restrict the sample to those children who attend their care arrangements for at least 15, 20, 25, 30, and 35 hours per week, respectively. Results for analyses that studied different dosages of care separately are displayed in columns (4)-(8) of Table 5. Again, these analyses confirm the positive conditional association between ECEC quality and the quality of the HLE.

As a further robustness check, we included ECEC costs as additional control variable; it could be considered as a further contemporaneous input. As higher quality ECEC might be more costly, this might affect parental well-being, as there might be a trade-off between better quality and higher ECEC expenses. Nevertheless, once this information is included the results do not differ substantially (column 9). Thus, we find no evidence that our main specification leads to biased results when we do not control for ECEC costs. We also worked with an alternative way of computing the standard errors. The standard errors are almost identical when clustering them by the sites of data collection.[27]

4.3. Further analyses

Discussions about targeting ECEC to certain subgroups and results about differential effectiveness of ECEC evoke considerations that the above reported results might not hold for all children but favor certain subpopulations in particular. Moreover, we know that high ECEC quality is particularly important for the development of disadvantaged children, as it could compensate for a lower quality of the HLE. If higher ECEC quality could additionally lead to an increase of the quality of the HLE this would be even more than a pure compensation effect. Thus, we are especially interested in the relationship between ECEC quality and changes in the HLE for disadvantaged groups.

Therefore, the next series of analyses studies whether the associations between ECEC quality and changes in the HLE differ between certain subgroups. We take into account the child's gender and ethnicity (Caucasian white vs. other) as well as maternal education ($\leq$ 14 years of education vs. > 14 years of education) and whether the primary caregiver's partner was living in the home or not. Thus, we focus on children of low-educated mothers and single mothers who could be considered as disadvantaged on average.[28] However, these subgroup analyses partially suffer from rather small sample sizes (compared to the large number of controlling covariates included in the model). Thus, we focus on the overall results and highlight deviating patterns.

The first set of results in Table 6 indicates that both boys' and girls' HLE is equally related to high ECEC quality. None of the differences is statistically significant.[29] The picture is more diverse for the comparison of Caucasian white children vs. other ethnicities. While in the short run (time window 6–36 months), the coefficient of high ECEC quality for non-white children is larger, analyses for the time windows 6–54 months and 6 months—age 9 display negative, nonsignificant coefficients. The pattern is reversed for white children's HLE. There is a small negative, non-significant conditional association between ECEC quality and the HLE for the shortest time window (6–36 months), but larger positive and significant coefficients for the longer time windows. This indicates that, in the long-run, high ECEC quality is related to the largest improvements of the HLE for Caucasian white children. This difference is statistically significant.

Results for subgroup analyses looking at maternal education show that the ECEC coefficients for low-educated mothers are not significant and smaller than those for higher educated mothers. All

Table 6. Subgroup analyses.

	Child is				Maternal education			
	female		white		> 14 years		Partner at home	
	no	yes	no	yes	no	yes	no	yes
Panel A: HLE at age 36 months								
ECEC Quality	0.022	0.022	0.221*	−0.014	0.050	0.021	0.094	0.010
	(0.050)	(0.059)	(0.129)	(0.037)	(0.054)	(0.047)	(0.295)	(0.036)
N	250	236	76	410	248	238	53	433
R^2	0.56	0.54	0.79	0.48	0.52	0.34	0.90	0.50
p-value	1		.01		.66		.53	
Panel B: HLE at age 54 months								
ECEC Quality	0.036	0.084	−0.048	0.092**	0.073	0.104**	0.190	0.060
	(0.060)	(0.053)	(0.132)	(0.040)	(0.066)	(0.045)	(0.460)	(0.038)
N	246	248	87	407	260	234	51	443
R^2	0.61	0.56	0.72	0.50	0.50	0.40	0.84	0.52
p-value	.51		.16		.66		.49	
Panel C: HLE in grade 3								
ECEC Quality	0.110**	0.076	−0.104	0.134***	0.051	0.156***	−0.081	0.098***
	(0.055)	(0.048)	(0.100)	(0.037)	(0.049)	(0.050)	(0.147)	(0.035)
N	353	368	142	579	413	308	80	641
R^2	0.54	0.44	0.58	0.41	0.42	0.34	0.61	0.44
p-value	.62		.01		.11		.01	

Note: The table shows the coefficient of ECEC quality for various subgroups. The dependent variable is the home learning environment (HLE) at various points in time, as indicated in the panel header. The sample is split according to the grouping variable as indicated by the column header. Robust standard errors in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations based on NICHD SECCYD data.

coefficients are positive. The highest coefficients are observed for the group of children of higher educated mothers in the long-run. This suggests advantages of children in households with better educated mothers, although the difference is borderline insignificant with a p-value of 0.11. A better quality in their ECEC arrangement is related to the strongest increases in their HLE. Finally,

Table 7. Discretized version of the ORCE.

	ORCE highest tertile (1)	ORCE lowest tertile (2)
Panel A: HLE at age 36 months		
Highest tertile	0.075	—
	(0.070)	
Lowest tertile	—	−0.004
		(0.070)
N	486	486
R^2	0.50	0.50
Panel B: HLE at age 54 months		
Highest tertile	0.060	—
	(0.062)	
Lowest tertile	—	−0.086
		(0.074)
N	494	494
R^2	0.53	0.53
Panel C: HLE in grade 3		
Highest tertile	0.141**	—
	(0.060)	
Lowest tertile	—	−0.106*
		(0.064)
N	721	721
R^2	0.45	0.45

Note: The table presents results based on our main specification where instead of a continuous measure of the home learning environment a discretized version is used. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations based on NICHD SECCYD data.

comparisons for single-parent households vs. two-(social)parents households reveals only one deviation from the overall picture found in our main analyses. Coefficients for both subgroups are positive, albeit not always significant and strongest for the group of children of two-parent households in the long-run (time window 6 months—age 9).[30] The only negative but non-significant coefficients in this series of analyses can be found for single-parent households in the longest time frame under study. Generally, we conclude that the associations hold for both subgroups with the exception of single-parent households in the long-run.

The last set of analyses examines potential non-linearities in the relationship between the quality of the ECEC environment and the HLE. For this purpose, we split ECEC quality in every sample in three equally large groups (tertiles) to study whether very low or very high levels of ECEC quality are particularly relevant. The first column of Table 7 shows that the coefficient for being in the highest tertile of ECEC quality (vs. being in the lower two tertiles) is positive in all three panels. Similarly, the coefficient for being in the lowest tertile (vs. the upper two tertiles) is negative in all panels.[31] The coefficients in columns 1 and 2 are of similar magnitude in absolute terms, providing no evidence of non-linearities. This suggests that both high and low levels of ECEC quality are relevant for the changes in the HLE.

5. Conclusion

Although there is a large literature on the effects of high ECEC quality, on the one hand, and high quality of the HLE, on the other, on child development, we know little about the interrelations of ECEC quality and the HLE – this applies in particular to regular day care settings. This study attempts to fill this gap by analyzing a sample of the well-known NICHD SECCYD. To our knowledge, this is the most suitable data set for this research questions as it covers several quality measures of ECEC and HLE quality at different points in times. Our empirical framework is built on the models of Todd and Wolpin (2003, 2007), who distinguish between historical and contemporaneous inputs. We add a baseline measure of the outcome variable and, thus, estimate value-added models. We run various robustness checks related to measurement issues and sample restrictions. Moreover, we consider heterogeneity in the association – in particular, we analyze if the relation between day care quality and changes in the HLE differs between disadvantaged and non-disadvantaged children, especially in the long-run.

Overall, we find significant positive conditional associations between ECEC quality and the HLE at later stages. This is particularly true for the ECEC quality that children experience when they are two years or older. For earlier points in time, the relationship is also positive, though not statistically significant.

Our positive conditional association could be explained by direct and indirect mechanisms: A direct mechanism relates to a more effective interaction between ECEC staff and parents, as one important part of high ECEC quality, which leads to a better quality at home. This interaction might be more effective for relatively older children than for the very young. The closer children get to kindergarten or school entry, the more attention parents might pay to education. Moreover, the longer the child uses ECEC services the more parents may adapt their knowledge and attitudes about childrearing due to interactions with the teachers (e.g. Halgunseth et al. 2009). The finding of hardly any negative conditional association between ECEC quality and the HLE at later stages might indicate that parents do not display compensating behavior at home. Furthermore, there could be indirect effects, in the sense that children talk about their ECEC experience at home and, thus, might evoke or 'demand' higher home quality. Our results, particularly those in the analyses considering ECEC measures for relatively older children, support this assumption. Additionally, higher ECEC quality might improve maternal well-being, which in turn raises the HLE.

Heterogeneity analysis indicates that the associations differ between subgroups: Our results show that high ECEC quality is most strongly related to the HLE of more advantaged children, at least when we consider the long-run. With respect to ethnicity, there are different results in the short-run, which

do not last. The estimated coefficients for the long-run are largest for white children, for children with higher educated mothers, and for children whose mother lives with a partner. Our results suggest that children who might benefit most from high ECEC quality might experience smaller improvements in their HLE. This might imply an inefficient allocation of ECEC quality. Inequalities in early live circumstances, which exist from the very beginning, might further increase (for such an argumentation, see, e.g. Francesconi and Heckman 2016).

Assuming that our results can at least partially be interpreted as causal, we can recommend the following to policymakers seeking to improve the HLE of disadvantaged children: Investments in improving the interaction between parents and ECEC staff are one important avenue. Likewise, more effort could be made to improve access to higher quality ECEC for disadvantaged children, e.g. through state regulations, subsidies, and parental education. In principle, this can lead to an increase in the HLE. In any case, such an increase in ECEC quality seems reasonable, as, for example, only 56% of the sampled children were in center-based care programs that met the child-staff ratio standard of 7:1, as defined by the American Public Health Association (McCartney et al. 2007).

However, the design of such measures would benefit from an even better understanding of the mechanisms behind the relationship between ECEC quality and the HLE. Although we control for a wide range of past and contemporaneous inputs and show that our findings are robust to omitted variable bias according to the method of Oster (2017), we do not claim that the estimated coefficients reflect the true causal effects of ECEC quality on HLE quality. Further, given our limited sample size and limited information on potential channels, we cannot identify precise mechanisms. Future studies employing larger data sets and information on channels of the relationship suggested by our study could work on disentangling different mechanisms. Another limitation of our study is that we could not distinguish between different ECEC modes – thus we could not run separate estimations for specific ECEC programs, such as Head Start. Further research is needed to deepen our understanding of the effectiveness of different ECEC services with respect to their effects on HLE of various groups of children.

With these limitations in mind, our results provide promising new evidence suggesting that ECEC quality could be an important pathway to improve the HLE of children, not only the other way round. It emphasizes the importance of addressing the quality of various child environments and it emphasizes the necessity of a systematic understanding of the interrelations between ECEC and HLE quality.

Notes

1. In the following, we use the terms ECEC and day care interchangeably.
2. There are a few studies by economists explicity analysing the effects of the quality of average ECEC programs that are open to all children: For instance, Araujo et al. (2016) study ECEC centers in Ecuador, while Bauchmüller, Gørtz, and Rasmussen (2014) and Jensen, Jensen, and Würz Rasmussen (2015) use samples of Danish ECEC centers. Other economic studies focus on targeted programs, like the US-Head Start program, and analyse the effectiveness of inputs to these programs. Inputs are either measured as public funding (e.g. Ludwig and Miller 2007) or quality related measures (e.g. Walters 2015). The study of Currie and Neidell (2007) uses both inputs in their analysis of the effects of Head Start quality on children.
3. High-quality parenting can be available to a child even when the family experiences adverse financial circumstances, although higher income facilitates and often goes along with good parenting. In part, this observation accounts for the success of children from certain cultural and ethnic groups raised in poverty who nonetheless receive strong encouragement from devoted parents and succeed (Cunha and Heckman 2009).
4. The Nurse Family Partnership Act, which intervenes solely with pregnant teenage mothers and teaches them mothering and infant care, has substantial effects on the adult success of the children of disadvantaged mothers (Cunha and Heckman 2009). Olds (2002) documents that perinatal interventions to reduce mother's potential risky behavior have substantial long-term effects on cognition, socioemotional skills, and health, and have high economic returns.
5. There are a few descriptive studies on the relationship between non-parental care use and parental time in activities with children. For instance, Bittman, Craig, and Folbre (2004) examine the relationship between non-parental

care and the amount and quality of parental engagement using Australian data, while Booth et al. (2002) use the same data as we do to study the use of childcare for 300 hours or more and the mother-infant interaction. However, these studies do not consider day care quality; they only focus on the dose of care.

6. Heckman and Mosso (2014) report intervention effects on a set of various measures of parenting quality, by children's gender and program duration.
7. A study by Araujo et al. (2016) investigates the effect of universal kindergarten teachers' quality on child outcomes in Ecuador. Their analysis on the mechanisms shows that kindergarten teachers' quality not only does not change parental investments and behavior toward children, but also that parents can distinguish between high and low quality teachers. However, the study only focuses on teacher quality and not on overall ECEC quality.
8. Not only is there a wide variety of day care providers (a large share of which are for-profit organizations), but there are also many different formats (group-based, individual, home-based, center-based etc.), programs (e.g., curricula or learning standards), and care intensities (hours per week). Furthermore, there are substantial differences in the age of the child at onset of care and the underlying parental reasons why a certain day care arrangement is chosen.
9. Parental, or more precise maternal, well-being can be operationalized as life-satisfaction, stress, or depressive symptoms (e.g., Benasich, Brooks-Gunn, and Clewell 1992; Gordon et al. 2011).
10. The models by Todd and Wolpin (2003, 2007) originally relate to the production of children's cognitive achievements. We use their terminology and apply it to the production of the home learning environment.
11. Moreover, we make sure that we use measures of H_{t-1} and HLE_{t-1} that are measured before the ECEC quality is measured (see Figure 1 and Section 3.2), in order to avoid issues of bad control variables.
12. This study was conducted by the NICHD Early Child Care Research Network supported by NICHD through a cooperative agreement that calls for scientific collaboration between the grantees and the NICHD staff. For further information, see https://www.nichd.nih.gov/research/supported/Pages/seccyd.aspx and NICHD (1993, 1994).
13. The children were sampled in Charlottesville, Virginia; Irvine, California; Lawrence, Kansas; Little Rock, Arkansas; Madison, Wisconsin; Morganton, North Carolina; Philadelphia, Pennsylvania; Pittsburgh, Pennsylvania; Seattle, Washington; and Boston, Massachusetts.
14. SECCYD is mostly interested in non-maternal care. However, in some cases the observed caregiver is the mother of the child. This can be the case if the mother works in a day care center or if she cares for further children besides her own child. For endogeneity reasons, we only include children in our main analysis who are cared for by non-family members, thus excluding all children where the observed caregiver is the mother or another family member.
15. All reported figures are based on own calculations by the authors.
16. Due to sample size restrictions, we cannot examine effects separately for different care arrangements.
17. These numbers correspond to a change from about US$165 to about US$90 in 2018 US Dollars.
18. The site fixed effects also account for economic, political, and cultural differences at the regional level.
19. The mother's personality traits and attitudes are surveyed only when the child was one month and six months, respectively. Therefore, we cannot include them as contemporaneous inputs. However, this should not be a major issue as personality traits are often assumed to be stable over time (e.g., Cobb-Clark and Schurer 2012).
20. If a measure for the ECEC quality is only available for one of the two periods, we use this ECEC measure. In the robustness section, we also work with alternative ways of combining different ECEC measures.
21. Sample sizes differ between the three versions as the analyses include only children who were cared for by non-family members for at least 10 hours per week (at least at one of the two measurement points of the ECEC quality).
22. The summary statistics for the other two samples are very similar.
23. Therefore, the robustness tests in the section are based on the specification applied in column (4) of Table 2. Using column (5) as baseline for the robustness tests produces almost identical results (not shown).
24. For the estimation of β_1^* with $\delta = 1$, see Oster (2017) for details.
25. Note that this robustness check only relates to the situation in which the relationship between ECEC quality and observed variables is informative for the relationship between ECEC quality and unobserved variables.
26. When estimating our main specification on the sample of column 5, the results are almost identical to column 1. The small difference between columns 1 and 5 is not driven by different samples.
27. More specifically, in the three panels the standard errors for the main specification are 0.034, 0.042, and 0.032 (instead of 0.035, 0.039, and 0.035).
28. Another group that could be considered disadvantaged are children living in income poor households. However, given our relatively small sample size, this group is too small to obtain meaningful results.
29. The p-values in Table 6 are based on hypotheses testing using seemingly unrelated regressions.
30. The largest coefficient in these analyses appears for single-parent households in the medium length time window (6–54 months). This analysis builds on a very small sample and produces imprecise estimates. Therefore, we refrain from putting too much emphasis on its interpretation.
31. The two coefficients are statistically significant in Panel C (time window 6 months–age 9), while they are not statistically significant in Panel B. This is likely due to the information loss associated with the discretization of the continuous ECEC quality measure.

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No potential conflict of interest was reported by the authors.

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Appendix

Table A1. Characteristics of children by ECEC attendance.

	At age 15 months			At age 54 months		
Variable	Not in ECEC	in ECEC	Difference	Not in ECEC	in ECEC	Difference
Firstborn^{C}	0.43	0.49	−0.07**	0.43	0.46	−0.04
Female^{C}	0.49	0.47	0.02	0.47	0.50	−0.03
White^{M}	0.74	0.83	−0.09***	0.72	0.81	−0.09***
Age^{M}	27.63	29.73	−2.10***	27.20	28.98	−1.78***
Married at birth^{M}	0.74	0.86	−0.11***	0.72	0.82	−0.10***
Higher education^{M}	0.31	0.49	−0.19***	0.25	0.43	−0.17***
Currently working^{M}	0.52	0.84	−0.32***	0.56	0.65	−0.09***
Currently working^{P}	0.77	0.84	−0.07***	0.73	0.83	−0.09***
Lives at home^{P}	0.85	0.89	−0.04*	0.82	0.89	−0.07***
HOME total score (raw)	36.37	37.18	−0.81***	35.94	37.07	−1.13***
Observations		1269			1136	

Note: The table compares variable means between children who participate in ECEC with those children who do not participate. All variables are measured at or before age 6 months. "C" indicates variables that relate to the child, "M" to the mother, and "P" to the partner of the mother. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Source: Own calculations based on NICHD SECCYD data.