Public and Parental Investments and Children's Skill Formation

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Abstract

While the importance of the childhood environment for shaping opportunities later in life is well established, most previous studies focus on parental inputs or public policies separately. This paper addresses their interaction. We first show theoretically that whether public investments crowd out parental inputs depends on the elasticity of substitution between investments made at home and out-of-home in the skill production function. We then analyze long-run effects of a randomized control trial that increased public preschool quality, and interpret the results through our model. Improved public quality leads to heterogeneous parental investment reactions, which mediate the intervention's long-run effectiveness. For high-skilled parents, the intervention crowds out parental inputs, resulting in zero long-run effects on child skills. For low-skilled parents, the opposite parental response results in persistent increases of roughly a quarter of a standard deviation in child language-test scores. We show that these heterogenous responses are only compatible with home and out-of-home investments being substitutes. Our findings emphasize that increasing the quality of childcare can reduce skill gaps between children from different backgrounds, but with parents' responses as a crucial mediating mechanism.

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1 Introduction

The importance of the childhood environment and its quality for shaping opportunities later in life is well established (e.g., Heckman, 2006), and a large literature has documented effects of early childhood investments on skills and adult outcomes such as income, education, health, and crime, for example by studying the effects of childcare enrollment (e.g., Cascio and Schanzenbach, 2013; Cornelissen et al., 2018; Fort et al., 2020; Havnes and Mogstad, 2011). Early childhood education has, thus, also moved to the forefront of public policy discussions. However, an equally important margin today is the *quality* of childcare conditional on enrollment, as the preschool attendance rate of 3-5 year-olds in the OECD is almost 90%.[1] Yet, much less is known about the effects of childcare quality, and how these out-of-home investments interact with the investments parents make at home. This interaction affects both the overall effectiveness of public programs and interventions, and how public policies can address skill gaps between children from different backgrounds.

In this paper, we seek to fill this void by studying how children's skill formation is affected by the interaction between parental investments and public investments in the quality of institutions. We investigate this both theoretically and empirically. The paper first presents a general model of child skill formation where investments are made both at home and in institutional settings (e.g., preschools, schools), whose quality may be influenced by parents through sorting.

We then link this model to survey and register data for children that were part of a randomized controlled trial that increased preschool quality through a program that significantly improved preschool-teachers' training of language and (pre-)literacy skills. The survey measures and administrative register data allow us to assess parental investments, school choice, and children's later outcomes. The empirical setting focuses on children ages 3-9 in Denmark, which provides a policy-relevant setting to study parents' responses when

[1] Average preschool enrollment at age 3-5 is 90% in the EU, 60% in the U.S., and 87% for all OECD countries (OECD, 2019, Table B2.2).

institutional quality changes. We interpret the empirical findings on treatment effects and parental reactions through the lens of the model. This link allows us to go a step further than simply to state whether public investments crowd out parental ones, or whether parents meet increased public quality by also intensifying their own investment activities. Instead, the experimental data allows us to infer whether the two types of investments are substitutes or complements *in the production function*.

We present three main results. First, the *model* shows that the extent to which an increase in public investments actually boosts overall investments (and thus child skill outcomes) depends on how parents respond and whether investments made at home and out-of-home are complements or substitutes. The elasticity of substitution will be given by the relative marginal productivities of parents' time spent either investing at home or influencing institutional quality via sorting, which in turn depend on the specific home and education production functions. This result is very general, as it holds without any functional forms imposed on skill formation or production functions.

Second, the *RCT* shows that increasing the quality of childcare reduces skill gaps between children from disadvantaged and affluent backgrounds. For children with low SES parents, at ages 8-9 (3-5 years after the intervention), test scores remain 0.26 standard deviations higher in the treatment group than in the control group, while there are no treatment effects for children with high SES parents. The playing field is leveled, however, only due to differences in how parents respond to the institutional quality improvement. At baseline, high skilled parents provide more home investments than low skilled parents, and a substantial sorting exists where children with high-skilled parents attend better public schools.[2] But the RCT leads low-skilled parents to significantly increase home investments (around 0.2 of a standard deviation) whereas their school choices are unaffected, while high-skilled parents mainly

[2] In fact, we document a substantial sorting in schools both by both families *and teachers* (as also found in Pop-Eleches and Urquiola, 2013). We show that Danish public schools (a school system where expenses in each school are equated from a substantial redistribution as opposed to e.g., schools in the U.S.) are not only characterized by clustering of children from at-risk families and affluent families, teachers also sort based on the student-body. Thus, the most able teachers are most likely to work in schools with children from affluent background generating a Matthew-effect with a strong inequality of institutional quality.

"consume" some of the public investments by reducing their efforts put into institutional sorting.

Third, our model predictions show that the parental responses we find are only compatible with home and institutional investments being substitutes. We show that the intervention works as a progressive transfer increasing the low-skilled parents' utility most, even when one factors in the parental responses wheret affluent parents utilize the higher childcare quality to adjust their time inputs in their children's skill formation.

This paper expands earlier models of child skill development and parents' investments and provides an empirical test of the model's central relationships through a RCT.[3] We are not only the first to formulate and provide empirical evidence for a model that separates investments made at home and out-of-home in preschools or schools while i) allowing substitution or complementarity between these two types of inputs into overall investments, ii) allowing parents to affect institutional quality by sorting into higher quality neighborhoods and better preschools or schools, and iii) including parents' labor supply decisions in the trade-off between allocating time to leisure, time at home with children, and work. We are also among the first studies to use a RCT to provide insights into the parameters of a model of child skill formation (see also Attanasio et al., 2020; Chaparro et al., 2020).

We thereby complement the influential studies by Becker and Tomes (1986), Cunha and Heckman (2007), and later extensions that estimate human capital production functions including parents' investments and labor supply decisions (Attanasio et al., 2020; Bernal and Keane, 2010; Del Boca et al., 2014; Gormley et al., 2008), school inputs and skill development (Nicoletti and Rabe, 2014), socio-emotional development (Moroni et al., 2019), children's own investment decisions (Del Boca et al., 2019), and how mothers trade off the quantity and quality of maternal and non-maternal care against own labor supply (Chaparro et al., 2020). We can relate our model to Fort et al. (2020), who study children's skill formation in

[3] The baseline model takes a general setup with a minimum set of assumptions. But once we impose functional form assumptions about child skill production (a CES technology) later in the paper, the model becomes an extension of the skill formation model by Cunha and Heckman (2007).

a context of heterogeneous childcare quality offers, and who also let parents trade off time in the market with time spent at home.

We also add to the rather small empirical literature that studies how parents respond to changes in the quality of public investments in children, and reconcile an empirical puzzle where the few papers that exist for developed countries come to different conclusions regarding whether or not parents behave as if public and private investments are complements or substitutes (see a discussion in Rabe, 2019). Gelber and Isen (2013) find that randomization into the higher-quality Head Start increases parental involvement (interpreted as complementarity) but also reduces parental expenses on childcare, and Chang et al. (2020) find that highly educated parents increase their financial investments in reaction to being exposed to a higher-quality teacher, but slightly reduce their time investments. Bonesrønning (2004) finds that Norwegian parents reduce the time spent with their children on homework when class size increases. Fredriksson et al. (2016) find children are more likely to change school and those with high-income parents receive more help with homework when class size increases, and Pop-Eleches and Urquiola (2013) similarly find that school-quality and help with homework is inversely related (interpreted as substitutes). Our model highlights that whether the home and institutional investments are substitutes or complements cannot be answered by considering one adjustment in isolation. Instead, one has to consider the relative adjustments between parental inputs into home investments and sorting into institutions to determine whether they are substitutes or complements.

Moreover, by studying how family background moderates the effects of increasing the quality of universal childcare, our empirical findings and model predictions add to the large body of research into the effects of universal child care on later outcomes (e.g., Baker et al., 2008; Cascio and Schanzenbach, 2013; Cornelissen et al., 2018; Datta Gupta and Simonsen, 2010, 2012; Havnes and Mogstad, 2011, 2015). While homogeneous programs such as universal childcare may have heterogenous effects due to different counterfactuals (e.g., the quality of parental care), our findings also show that effects may differ across family background due to the trade-offs parents face between spending time with the child (thereby increasing home investments) or at work (increasing consumption but also facilitating residential sorting through increased income). As high-skilled parents are more productive both at home and at work, the overall productivity of investments in childrens' skill formation increase in parental skill level with the largest inequality when home and institutional investments are substitutes.[4] It follows from these predictions that public programs which change investments affect parents' trade-offs differently resulting in heterogeneous program effects. Thereby, we also complement the studies that revealed how the effects of policies such as Head Start are mediated by sorting and school quality (Ansari and Pianta, 2018; Currie and Thomas, 2000; Johnson and Jackson, 2019; Lee and Loeb, 1995), and we present evidence for the importance of school sorting even in a country such as Denmark, where inequality in disposable income is low and school expenses are equalized through the Danish welfare state.[5]

The paper progresses as follows: Section 2 presents the extended technology of skill formation that includes both parental and public investments, taking into account parents' labor supply decisions and sorting. Section 3 relates the model to the empirical setting of Danish preschools and schools, and introduces the randomized controlled trial. Section 4 describes the data and presents balancing tests confirming the randomization procedure. Section 5 produces the main empirical findings. Section 6 concludes.

[4]Our result that institutional investments also benefit high-SES families because high-SES parents have higher opportunity costs of providing home investments echoes the finding in Cornelissen et al. (2018); Kline and Walters (2016) that potential gains from program take-up and the take-up probability are inversely related.

[5]Furthermore, by showing that sorting into different schools plays a crucial role in parental investment choices, in addition to the time that parents spend with their children, our paper relates to studies of the importance of neighborhoods and how sorting creates "common goods" that parents can buy into (Bayer et al., 2007; Epple and Romano, 2011).

2 Framework and Background

We first outline our theoretical framework and then study how total investments in children are a function of parents' choices of home investments and institutional sorting. This section focuses on the key relations. Appendix B presents the model derivations in detail.

2.1 A Technology of Skill Formation with Home and Institutional Investments

We begin with a general model of skill formation across childhood, where a parent makes investment decisions maximizing their own utility, which is increasing in their child's skills. Skills evolve from period to period such that end-of-period skills θ_t are a function of past skills (θ_{t-1}) and the current period's investments I_t.[6]

$$\theta_t = j(\theta_{t-1}, I_t) \tag{1}$$

We next implement this paper's central notion: children's skill development is not only the target of direct parental inputs at home but also of inputs in out-of-home settings. To capture this effect, we define "total investments" I_t as a composite of two underlying investment types: Home investments made by parents P_t, and investments made in an institutional setting G_t (childcare, school):

$$I_t = m\left(P_t, G_t\right) \tag{2}$$

This general framework fits in essence the canonical model outlined in Becker and Tomes (1986) with the multiperiod skill formation and investments as in Cunha and Heckman

[6]Skills in period zero are a function of parental skills θ_P and in-utero investments I_0: $\theta_0 = j(\theta_P, I_0)$. Skills θ_t could be a vector of several types of skills. For simplicity, we here only consider one type of skills as a scalar in the framework, as our empirical section will focus on language skills.

(2007), with one important conceptual difference (expanded upon below): parents determine home investments, but they can also influence out-of-home investments through sorting.

To have a common unit of investments, we consider all parental decisions to relate to their *time use*. Parental home-investments P_t are a function of their time spent directly with their child (providing home-childcare x_t), where the quality of time input may vary with parents' skills (θ_P), determining effective time.[7] Institutional investments G_t are given by the following three inputs:[8]

1) There is a baseline public investment yielding an institutional quality, $\underline{G}$, throughout the education system, including preschool.[9] The baseline could be given by national guidelines, for example. To fix ideas, assume that parents simply take this for granted.

2) Within this overall national level, institutional quality may vary on the regional or local level. Parents can influence the institutional quality their child is exposed to by choosing where to live. Neighborhood level institutional quality, or neighborhood public goods, are associated with rent levels and real estate prices; institutional quality thus increases in parental income.[10] Parental wage income Y_t is a function of their labor supply h_t and their hourly wage rate $w(\theta_P)$. Parents take the wage rate as given, and income equals $Y_t = h_t w$. Parents spend fraction κ of Y_t on residential choice.

3) We include a third input, e_t, to institutional investments: time parents spend on school sorting within their neighborhood. Even within a given neighborhood, there are

[7] It is well-established that parents differ not only by how much time they spend with their children, but also *how* they spend the time together (Doepke and Zilibotti, 2017) and that these parenting styles display a socio-economic gradient (Cobb-Clark et al., 2019).

[8] We focus on institutional quality from parents' perspective when deciding where to send their child. A large literature has studied inputs in the education production function (see e.g., Hanushek, 2002, for a review) affecting child skills, including peer and teacher quality, class-sizes, buildings, etc. We do not study this. But, as we will describe below, imposing assumptions about the elasticity of substitution between P and G implicitly imposes assumptions about the education production function.

[9] We do not consider the funding of $\underline{\mathrm{G}}$ in the model. However, the model can be extended to include this by having an income tax, which will reduce the returns to labor supply. We return to this topic in Section 5.3.

[10] Black (1999), for example, shows a strong link between housing prices and local schools. We do not model general equilibrium effects of sorting and neighborhood specific public goods as Epple and Romano (1998) and Bayer et al. (2007), and we also abstain from modeling directly mechanisms such as peer effects (described in e.g., Blume et al., 2011; Epple and Romano, 2011) and the multidimensionality of schools' effects (Jackson and Beuermann, 2019).

typically several preschools and schools that children can attend. Thus, beyond the financial investment of housing expenditures associated with *neighborhood* quality, we empirically observe that parents can further influence the quality of public investments their children receive by choosing the right *school* within the neighborhood.[11,12] We posit that this school selection process costs time e_t (e.g., visiting schools, contacting administrative personnel, volunteering for after school activities, and other activities that parents can undertake to help their children access a specific school). Including this time spent on selection as an input in school selectivity that does not directly affect consumption (as labor supply does) implies that it has the same opportunity costs in terms of foregone leisure as time spent on home-investments (x_t). The input e_t thereby allows us to distill the productivity components in parents' trade-off when balancing home and institutional investments without having to make specific functional form assumptions for $G()$.

Taken together, the components of investments become

$$\begin{aligned} P_t &= p(x_t, \theta_P) \\ G_t &= g(\underline{G}, \kappa Y_t, e_t, \theta_P), \end{aligned} \tag{3}$$

where we assume that $P()$ and $G()$ are increasing in all of their inputs. Parents thus spend their time on work (h_t), leisure (l_t), investing in children directly (x_t), and on institution choice within neighborhood (e_t). Their total time is allocated as $1 = h_t + l_t + x_t + e_t$. While parents' investments are central to children's skill development, they also face trade-offs in determining how much to invest at a given time. One trade-off is how to balance the

[11] Walters (2018) analyzes sorting into Charter schools in the U.S. and how non-pecuniary sorting-mechanisms shape the type of children who are enrolled.

[12] In the Danish case that we use for our empirical part, there is free school choice as long as there is capacity. Public school capacity goes first to children who live within the school attendance boundary. Bjerre-Nielsen and Gandil (2020) show that even when attendance boundaries for public schools are re-drawn, especially high-resource parents defy reassignments to schools they perceive as lower quality. Thus, even with the intention of assigning children to specific schools, parents are effectively showing an ability to choose other schools. In other countries, sorting may be limited to only through residential choice, for example, if catchment areas are strongly enforced. This would have e drop out of the model, but the model's main predictions would be qualitatively similar.

time used for investments in children against leisure. Another is how to balance leisure and time spent at home with children against work. On the one hand, labor supply takes time that could have been spent on leisure activities or with one's children, but on the other hand income from work also finances consumption and allows for sorting into better (more expensive) neighborhoods with better institutions, thereby increasing investments via the preschool's or school's quality.

We consider two periods of skill formation where parental utility is derived from own consumption and leisure directly, and indirectly from children's future skills θ_2, because these skills translate into child's earnings and consumption.[13] All periods are discounted at factor β. To begin with, assume that parents have no access to borrowing, so that budget constraints each period impose that consumption and residential expenditures must equal labor income. We discuss below how allowing borrowing modifies the model's predictions. The main conclusions carry through regardless of credit opportunities. Parents' optimize

$$\max U(c_1, c_2, l_1, l_2, \theta_2) = u(c_1, l_1) + \beta u(c_2, l_2) + \beta^2 V(\theta_2) \tag{4}$$

subject to production functions in Eqs. (1) to (3) and budget constraints.

2.2 Equilibrium Conditions and the "Production" of Investments

The optimization of this very general problem yields a set of revealing equilibrium conditions (all first order conditions given in Section B.1). In optimum, parents equalize the marginal productivities of investing in their child either directly (x_t) or via school sorting (e_t):

$$\frac{\partial I_t}{\partial P_t}\frac{\partial P_t}{\partial x_t} = \frac{\partial I_t}{\partial G_t}\frac{\partial G_t}{\partial e_t}, \qquad \text{for } t \in \{1, 2\} \tag{5}$$

[13] This implies that there is no consumption value from time spent with children – an assumption we make to keep the focus on our central research question: how does the trade-off between different types of investments in *the production function* influence skill accumulation and the scope for public investments?

Hence, when parents allocate their time optimally, the marginal returns to child skills from increasing home investments through x_t and institutional investments through e_t are equal. They are indifferent between spending more time investing themselves through, say, reading with the child, and spending an extra minute on increasing institutional investments through optimizing the school choice. While this may seem like a standard set of first order conditions, Eq. (5) holds important implications. To see this, a slight re-arrangement yields:

$$\text{MRTS}(P_t, G_t) = \frac{\partial I(P_t, G_t)/\partial P_t}{\partial I(P_t, G_t)/\partial G_t} = \frac{\partial g(\underline{G}, \kappa Y_t, e_t, \theta_P)/\partial e_t}{\partial p(x_t, \theta_P)/\partial x}, \qquad t \in \{1, 2\}$$

The equation states that the marginal rate of technical substitution (MRTS) between home and institutional investments as inputs in total investments in human capital formation must equal the ratio between the marginal productivity of parents' time spent on investments at home and in an institutional setting. The elasticity of substitution between home and institutional investments is given by:

$$\varepsilon_{P,G} = \left[\frac{\partial \text{MRTS}(P, G)}{\partial (P/G)} \frac{P/G}{\text{MRTS}(P, G)}\right]^{-1}$$

The second term of this product will always be positive. Therefore, whether P and G are substitutes or complements in the "production" of investments (whether $\varepsilon_{P,G}$ is positive or negative) depends on the sign of the first term, which relates a change in the MRTS to an underlying change in the ratio of parental to public investments (P/G).[14] Or stated differently, the consequences for actual investment decisions depend on whether home-investments and institutional investments are substitutes or complements (which also affect how parents differentiate investment decisions according to their skill level as parents' skills enter both the productivity of home investments and institutional investments through sorting).

Therefore, a test for whether home-investments and institutional investments are substitutes or complements is not simply given by considering how one of the two changes when

[14]See Section B.1 for further derivations and discussion of the intuition behind this result.

public investments vary, as suggested in, for example, Fredriksson et al. (2016), Pop-Eleches and Urquiola (2013), or Gelber and Isen (2013), who consider how parents adjust one margin of investments when institutional quality varies. The answer depends on how parents adjust inputs in *both* home and institutional investments jointly. Equation (5) also highlights the crucial role of assumptions about how P_t and G_t interact in producing overall investments I_t: These assumptions about the "higher-level" or outer function of I_t have immediate implications for the micro-foundations or "inner" functions of sub-types of investments, by parental time e_t and x_t. The "outer" and "inner" parts of the production functions are inherently linked. For example, assuming a Cobb-Douglas or CES production technology for I_t, not only shapes $\frac{\partial I_t}{\partial P_t} / \frac{\partial I_t}{\partial G_t}$, but it also imposes implicit assumptions about institutional environments and the specific form of education production function as well as the functional form of family interactions at home.

In equilibrium, parents must be indifferent between allocating their time to additional leisure (giving direct utility), home investments in children or investments via school choice (giving indirect utility through future child skills), or labor (greater consumption and direct utility as well as improving neighborhood public goods that raise child skills). In period 2, for example, this yields

$$\frac{\partial u_2}{\partial l_2} = \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial P_2} \frac{\partial P_2}{\partial x_2} \quad = \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial e_2} = \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial h_2} + \frac{\partial u_2}{\partial c_2} w(1-\kappa). \quad (6)$$

Together with Eq. (5), this implies that how parents balance work and time spent with children is not only given by a trade-off between consumption and investments, but also by how income affects the potential to utilize institutional quality as a way to promote their children's skill accumulation. Furthermore, Eq. (6) also presents how the optimal marginal utility from labor supply differs from the optimal marginal utility of time spent with children, as the former also affect utility via consumption (given by the last term $\frac{\partial u_2}{\partial c_2} w(1-\kappa)$).

2.3 Specific Model: Residential Choice and Functional Forms

The lessons above are based on a very general model which can be applied to many settings. While the model implemented the strictest version of credit constraints, the lessons also carry through when we allow for borrowing. Allowing for borrowing is necessary in order to compare predictions of our model for intertemporal allocation of investments as in, for example, Cunha and Heckman (2007). For this reason, and to be able to derive more explicit testable predictions of the model to use in our empirical setting, we therefore now continue with a more specific version of the model above, introducing three alterations (Sections B.2 and B.3 provide detailed derivations): Free borrowing,[15] a more realistic constraint to residential choice, and specific functional forms.

The residential choice of the general model would allow parents to optimize their residential choice every period. Yet this is not observed in practice. Instead, we note that the vast majority of parents choose where to live before their child starts school, and then remain there throughout the child's compulsory schooling (see Section 5.2, Fig. A.1, and Cholli et al., 2020). We model this stickiness by having parents' residential choice as a function of fraction κ of their income early in the child's life, so that residential quality for *all* periods is determined by $\kappa Y_1 = \kappa h_1 w(\theta_P)$, which makes investments from the institutional setting $G = g(\underline{G}, \kappa h_1 w(\theta_P), e_t, \theta_P),\ t \in \{1, 2\}$.

This lock-in of early residential choices, together with unlimited borrowing at the discount rate between period 1 and 2, generates intertemporal differences in the marginal returns to

[15] Since we are interested in how parents react in the second (and last) period of the 2-period model, they cannot re-optimize their borrowing behavior in absence of leaving negative bequests in any case. Therefore, the assumption of borrowing is less consequential in comparison to shutting down this channel than it may seem.

parental investments.[16] Across periods, parents optimally allocate their time uses as:

$$\frac{\partial \theta_2}{\partial x_1} = \frac{d_w}{\beta} \frac{\partial \theta_2}{\partial x_2} \tag{7}$$

$$\frac{\partial \theta_2}{\partial e_1} = \frac{d_w}{\beta} \frac{\partial \theta_2}{\partial e_2} \tag{8}$$

$$\frac{\partial u_1}{\partial l_1} = \frac{d_w}{\beta} \frac{\partial u_2}{\partial l_2} \tag{9}$$

where $d_w = \frac{(\beta\kappa w + (1-\kappa) - \beta\kappa)}{(1-\kappa w)}$ is a term that depends on fixed parameters as well as the parental wage rate $w(\theta_P)$, and is increasing in parental quality θ_P. Therefore, higher-quality parents will have a larger ratio of the productivity of early relative to that of late investments in expected optimality. Parents with higher θ_P have a productivity of late investments (both direct x_2 and via school choice e_2) that is smaller, relative to the productivity of early investments, than parents with low θ_P. The same is true for the relative marginal utilities of leisure, which will be smaller in period 2 relative to period 1 for the high-θ_P parents.

Functional Forms As stated, the equilibrium conditions Eq. (5) and Eq. (6) hold in a very general set-up. When we want to study precisely how parents react to changes in the quality of institutions, the specific interactions between the types of parental investments become crucial. Therefore, we continue with functional forms for the production functions. We assume that skills and investments follow a nested CES-structure over the two periods (derivations in Appendix Section B.3). Note that this structure does not take a stance on the sign of the elasticity of substitution and therefore remains flexible allowing us to infer substitution or complementarity from outcomes rather than imposing it ex ante. Child skills

[16] Note that we obtain specific relationships of marginal productivities over time when introducing an additional assumption that the marginal productivities of parental time in generating institutional investments, via school choice and labor supply, are proportional (such as $kw \cdot \partial g/\partial e_t = \partial g/\partial h_t$). This can be obtained without specific functional form assumptions, see Eqs. (A.30) to (A.32) in Section B.3.

are produced with existing child skills and overall investments I_t.

$$\theta_t = [\gamma\theta_{t-1}^{\phi} + (1-\gamma)I_t^{\phi}]^{1/\phi}, \qquad t \in \{1,2\} \tag{10}$$

The parameter γ captures the effect of self-productivity (skills beget skills, Cunha et al., 2006), and $(1-\gamma)$ reflects the importance of investments made in period t.[17] The elasticity of substitution between the different inputs in the skill formation is given by $\frac{1}{1-\phi}$. The inputs will be perfect substitutes if $\phi \to 1$ and perfect complements as $\phi \to -\infty$.

The inner part of the model – the "production" of total investments – is given by:

$$I_t = [\pi P_t^{\sigma} + (1-\pi)G_t^{\sigma}]^{1/\sigma}, \qquad t \in \{1,2\} \tag{11}$$

where the rate of substitution between home and institutional investments (in the "production" of total investments) is given by $\frac{1}{1-\sigma}$, while π defines the relative importance of the two investment types. There will be a high degree of substitutability $\sigma \to 1$ if investments overlap (e.g., if pedagogues read with the children in the same way as the parents do). If, however, the two investment types are very different in nature or parents' investments at home become more productive as the institutional investments increase, then $\sigma \to -\infty$.

Furthermore, we assume that investments take the form $f(x_t\theta_P) = (x_t\theta_P)^a$ and $g(\underline{G}, \kappa Y_1, e_t, \theta_P) = (\underline{G} + \kappa w h_1 + e_t)^b$, where $0 < a, b < 1$.[18] The ratio of early to late investments in private and institutional settings becomes

$$\frac{x_1}{x_2} = \left[\frac{\underline{G} + \kappa w h_1 + e_1}{\underline{G} + \kappa w h_1 + e_2}\right]^{\frac{1-b\sigma}{1-a\sigma}}. \tag{12}$$

If we further - for expositional purposes - align the functional form of investments in private

[17] This setup simplifies Cunha et al. (2010) as we consider a time invariant elasticity of substitution.

[18] The careful reader will notice that function $G(.)$ combines inputs of different units: time e_t, monetary contributions to neighborhood selection $\kappa w h_1$ (which multiplies time h_1 with its financial return), and a term of unknown unit $\underline{G}$. Not modeling the production of institutional investments with a "return" on parents' time spent on school choice e_t amounts to assuming that all parents share a common effectiveness of their time of 1.

and public by setting $a = b$, the full production function can be expressed as:

$$\theta_2 = \left\{ \gamma^2 \theta_0^{\phi} + \gamma(1-\gamma) \Big[H(\theta_P) x_1^a \Big]^{\phi} + (1-\gamma) \Big[H(\theta_P) x_2^a \Big]^{\phi} \right\}^{1/\phi} \tag{13}$$

where $H(\theta_P) = \theta_P^a \pi^{\frac{1}{\sigma}} \left[1 + \frac{\pi}{(1-\pi)}^{\frac{1}{a\sigma - 1}} \theta_P^{\frac{a\sigma}{a\sigma - 1}} \right]^{1/\sigma}$ is an **investment multiplier** capturing that parents' investments become more effective as their skills increase in the first term in the brackets and in the second term that parents' investment choices depend on whether investments at home or in an institutional setting are substitutes or complements.[19] Thus, $H(\theta_P)$ captures the inequality in total investments in a given period for a given level of parental home investments x_t.

Equation (13) furthermore shows how this paper's framework nests the original technology of skill formation from Cunha and Heckman (2007). As the *outer frame*, the technology can be expressed as a function of initial child endowments, θ_0, parental investment decisions, x_t and skills θ_P, and between-period elasticity of substitution $\frac{1}{1-\phi}$ with both static and dynamic complementarity of investments. But underlying this, parents optimize conditional on an *inner core* that is both determined by the productivity of their own time investments relative to the out-of-home investments, and the between and within period marginal utility of consumption and leisure. This inner core extends the previous literature by yielding two main insights:

i) Parents spend less time with their children than they would without time constraints where today's labor and residential choices affect the future possibility of school choices. This finding arises as parents optimize conditional on the marginal utility of consumption relative to the marginal utility of leisure, such that $c_1 = w \frac{\alpha}{1-\alpha} d_w l_1$, and the marginal utility of leisure across periods yields $l_2 = d_w l_1$.[20] The adjustment by d_w reflects the cross-period dependence of neighborhood choice.

[19] $\frac{\partial H}{\partial \theta_P} > 0$ as long as $1 + \frac{a\sigma}{a\sigma - 1} \theta_P^{\frac{a\sigma}{a\sigma - 1}} > 0$ which it will be in all but a few special cases where θ_P is close to 0 and $a\sigma$ is close to 1.

[20] The two latter terms are obtained assuming that $u(c_t, l_t) = \alpha ln(c_t) + (1-\alpha) ln(l_t)$.

ii) How parents distribute investments between their own time inputs and that from an institutional setting depends on parents' skills (or income) and the elasticity of substitution between investments at home and in the institutional setting.

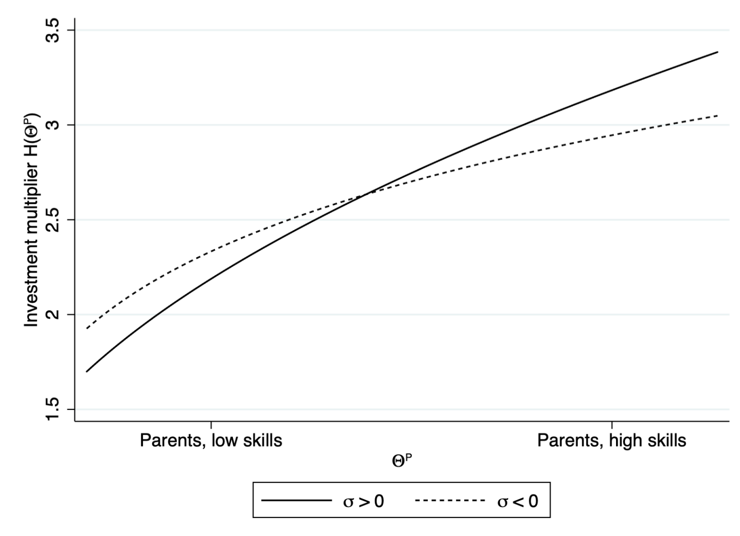
While insight i) points to the general challenges faced by families with small children, insight ii) has important implications for inequality and the role of public investments. We illustrate this in Fig. 1. It plots the investment multiplier $H(\theta_P)$ for different values of parental skills θ_P and σ. For a given level of parental time investments x_t, greater *substitutability* between home and institutional investments *increases* inequality in total investments between high- and low-skilled parents. The gradient is smaller when home and institutional investments are complements. The reason is that highly skilled parents will not align institutional and home investments because their large investments in the institutional setting, which originate from high income, are not met by equivalent amounts of home investment due to the time constraints they face.

To phrase this differently, high-skilled parents (and their children) will benefit more if it is possible to increase working hours, consumption, and institutional sorting without reducing total investments in children if home and out-of-home investments are close substitutes, a result that speaks to the finding that the children who are most likely to be enrolled in beneficial public programs are the ones with the lowest returns (Cornelissen et al., 2018; Kline and Walters, 2016).

2.4 The Effects of Increasing a Public Input into Institutional Investments

The main equilibrium condition Eq. (5) of the general set-up already tells us how parents *could* react, and what would happen to children's skill formation when an intervention randomly increases public inputs $\underline{G}$: In optimality, the marginal productivity of home investments should equal the marginal productivity of institutional investments. Increasing institutional quality through higher public inputs $\underline{G}$ will lower the marginal product of the

Figure 1: Parental skills and investment multiplier



Note: Figure shows simulated values of $H(\theta_P) = \theta_P^a \pi^{\frac{1}{\sigma}} \left[1 + \frac{\pi}{(1-\pi)}^{\frac{1}{a\sigma-1}} \theta_P^{\frac{a\sigma}{a\sigma-1}}\right]^{1/\sigma}$ assuming that $a = b$ and $\pi = 0.5$, and $\sigma = -0.7; 0.7$, respectively.

inputs to $g()$, and thereby generate a parental response either through x_t and/or e_t to satisfy the optimality condition again. Parents can thus respond either by *increasing* home investments (i.e. spend more time with their child) or by becoming less sensitive to the increased institutional quality and *reducing* time spent on sorting. These model predictions of offsetting possible reactions do not yet depend on any functional form assumptions or borrowing. The specific response, however, depends on parents' skills and the whether the two investment types are substitutes or complements.

More precise predictions are made by the more specific model of Section 2.3 (and setting $a = b$): The equilibrium condition becomes $x_2 = \frac{\pi}{1-\pi}\theta_P^{\frac{a\sigma}{1-a\sigma}}(\underline{\mathrm{G}} + \kappa h_1 w + e_2)$.[21] The term $\theta_P^{\frac{a\sigma}{1-a\sigma}}$ defines whether adjustments to an increase in $\underline{\mathrm{G}}$ will be easiest by increasing x_2 on the left-hand side or by decreasing parental input e_2 into institutional quality on the right-hand side. If $\sigma > 0$, $\theta_P^{\frac{a\sigma}{1-a\sigma}}$ will be increasing in θ_P, meaning that for high-skilled parents, a small decrease in e_2 goes further in re-establishing balance than increases in x_2, which would have to be relatively large. In other words, this will make parents with high skills (income) more

[21] This is in addition to Eq. (12). Derivations in Sections B.3 and B.4, particularly Eq. (A.39).

inclined to reduce the sorting rather than meet higher public investments with higher own investments (as would be suggested by complementarity between home and institutional investments). If $\sigma < 0$, the scaling term will be decreasing in θ_P, making high skilled parents more inclined to adjust their home investments. Thus, how high and low-skilled parents react to an increase in $\underline{G}$ will point to whether σ is positive or negative, and thus whether parental and institutional investments are rather functioning as complements or substitutes.

Linking the model to the empirical test In the next section, we will formally introduce the empirical setting we use to identify the sign of σ. However, we first outline the theoretical implications from the model.

We consider a randomized controlled trial (RCT) in the preschool setting (period 1) – that is after parents have made their residential choice through $\kappa h_1 w$. The RCT exogenously increases the quality of public institutions (for a given institutional choice in period 1). Hence, from the parents' perspective, the basic quality of educational institutions $\underline{G}$ appears s higher in the treatment group than in the control group (for the treated, period 1 institutional investments then amount to $(\underline{G} + s + \kappa h_1 w + e_1)$. The observation that the basic quality of educational institutions is $\underline{G} + s$ in the treatment group and $\underline{G}$ in the control group, in period 1, implies that parents in the treatment and control groups now make their period 2 investment decisions based on different assumptions about the quality of public institutions. Returning to the general version of the model,[22] the long run effect of the RCT increasing $\underline{G}$ in period 1 on children's skills equals

$$\underbrace{\frac{\partial \theta_2}{\partial \underline{G}}}_{\substack{\text{Long run}\\ \text{effect}}} = \underbrace{\frac{\partial \theta_2}{\partial \theta_1}}_{\substack{\text{Self-}\\ \text{productivity}}} \underbrace{\frac{\partial \theta_1}{\partial \underline{G}}}_{\substack{\text{Immediate}\\ \text{treatment}\\ \text{effect}}} + \underbrace{\left(\frac{\partial x_2}{\partial \underline{G}} + \frac{\partial e_2}{\partial \underline{G}}\right)}_{\substack{\text{Parents'}\\ \text{adjustment}\\ \text{of inputs}}} \underbrace{\frac{\partial j}{\partial I_2}\frac{\partial I_2}{\partial P_2}\frac{\partial P_2}{\partial x_2}}_{\substack{\text{Marginal}\\ \text{productivity}\\ \text{of parents'}\\ \text{adjustments}}} \tag{14}$$

[22] That means, the set-up of Section 2.1, leading to equilibrium condition Eq. (5) without specific functional forms and irrespective of borrowing.

The effect consists of two overall components. The first is the self-productivity from the direct treatment effect on children's post-trial skills and how that affects skill accumulation (skills beget skills). The second is through parents' responses after the intervention on home investments and institutional sorting. Equation Eq. (14) thereby stresses the importance of determining whether home and institutional investments are complements or substitutes. While the first component suggests a positive long run effect, the sign of the second component is not given. The final term $\frac{\partial j}{\partial I_2}\frac{\partial I_2}{\partial P_2}\frac{\partial P_2}{\partial x_2}$ is positive and likely decreasing in parents' skills (if production functions are concave). However, the sign and magnitude of $\left(\frac{\partial x_2}{\partial \underline{G}} + \frac{\partial e_2}{\partial \underline{G}}\right)$ is not given; it will be increasing in parents' skills if home and institutional investments are complements and decreasing if they are substitutes. And perhaps more importantly, only if they are substitutes will the intervention increasing public investments level the playing field.

In sum, our general framework predicts that – as the marginal returns to home investments and investments in an institutional setting must be equal – parents will increase time put into home investments and/or reduce effort put into school choice. In Section 5 we will show that these are exactly the responses we observe in the data following the intervention.

Our more specific model with functional form assumptions (such as in Eq. (10) and Eq. (11)) then provides us with a simple test of whether home and institutional investments are substitutes or complements:

- Public and private investments are substitutes ($\sigma > 0$) if the RCT shows highly skilled parents reducing their sorting efforts after the RCT (i.e. in period 2: school) more than low skilled parents, while low skilled parents adjust their home investments relatively more.

- The two investment types are complements ($\sigma < 0$) if the RCT shows highly skilled parents increasing their home investments more than low skilled parents.

3 The Empirical Setting

3.1 Daycare in Denmark and the Intervention

Daycare in Denmark is heavily subsidized, and municipalities are obliged to provide daycare slots for all children. There is virtually no private market for daycare in Denmark. The typical child will start attending daycare at about 12 months old and preschool begins at age 3. Preschool enrolment rates of all 3- to 5-year-old children are near-universal at 97%. Preschool classrooms comprise around 20 children with a educator-child ratio of around 1:7 (Slot et al., 2018). The majority of the preschool staff are trained pedagogues (60%) with a 3.5 year college degree, and the remainder either have short courses in pedagogy or are unskilled.

Preschools are organized by and placed under the responsibility of local municipalities, who are obliged to ensure the availability of preschools (Datta Gupta and Simonsen, 2010).[23] While Danish daycare centers are characterized by a high level of public expenditure compared to other countries (Esping-Andersen et al., 2012), substantial sorting by parental income and wealth is already apparent by this point in the child's life (Landersø and Heckman, 2016).

As discussed in e.g., Slot et al. 2018, Danish preschools operate from broad "learning schedules" and not from a single formal curriculum. The learning schedules focus on comprehensive personal development, social relations, motor skills, outdoor life, and culture, values, and relationships (Danish Ministry for Children and Social Affairs, 2018). Slot (2018) finds that Danish preschool-children generally have higher quality interactions with their peers, while interactions with preschool teachers display a lower quality compared with countries such as Germany and the U.S.

Within this setting, a language and literacy intervention took place that randomly im-

[23]Redistribution between municipalities ensures that expenses do not vary strongly across municipalities.

proved the quality of teacher interaction with the children. The intervention **LEAP** (Language Education Activities for Preschoolers; *Fart på sproget* in Danish) provided training of language and (pre-)literacy skills with children age 3-5 in preschool (parents were not treated, Bleses et al., 2018). Its main components were a 20 weeks where teachers incorporated play-based activities, sequence and scope, and scaffolding (targeting specific learning objectives as outlined in Justice et al., 2015; Justice and Mcginty, 2012) in the everyday. The intervention formally consisted of 40 half-hour lessons of high quality language training to children, but teachers were encouranged to continue using the intervention's components subsequently as well. Bleses et al. (2018) present the average short run effects (i.e. after around six months) of the intervention, which we also reproduce below. Each lesson was delivered in small groups with around six children and one educator. On average, there were four groups and two educators per classroom. The groups were organized by the educators, but the educators were subsequently randomly assigned to one or two groups. During the intervention, the groups and educators remained unchanged.

Prior to the intervention, educators were trained during two days where they also received instructions in how to identify the different learning objectives, and discussed how the specific content could be implemented. During the intervention, the curriculum was kept open such that the intervention provided teachers with teaching material, examples, and professional supervision and instruction, but ultimately allowed each teacher to keep some discretion on how the lessons should be organized. Thus, educators also had autonomy to vary the focus of specific learning objectives. Educators in the control group participated in a one-day workshop on topics relevant to the daily routines in a preschool. Furthermore, the intervention involved an initial introduction letter to parents (both treatment and control), but other than that parents were not informed about the activities or intervention.

3.2 Primary School in Denmark

In Denmark, compulsory school starts at grade 0 (corresponding to Kindergarten in the U.S.) at age 6, and the vast majority of Danish school-age children attend public schools.[24] All Danish public schools have one common curriculum and there is no tracking during primary and lower secondary school. Schools are financed by local municipalities, but regulated via a per pupil expenditure rate that is made possible via a strong progressive redistribution between municipalities. Thus, there is not as strong of a link between local area public finances and school expenditure as in, for example, the U.S. In fact, as Danish schools receive higher rates for special needs children, the schools with the largest budgets are the most disadvantaged ones. The Danish distribution of school expenditures is very compressed while the U.S. counterpart has large tails both above and below the average expenditure level (see Fig. A.2a in the appendix). Moreover, teacher wages in Denmark are set by collective bargaining and schools cannot attract higher quality teachers by increasing wages. Most teachers earn within ±5% of the median wage (see Fig. A.2b), which corresponds to the roughly 5% variation in bargaining for different regions in Denmark to align purchasing power between rural and urban areas. Moreover, there is virtually no association between teachers' academic skills (proxied by their own high school GPA) and their hourly wages.

Yet, this does not imply that parents and teachers do not sort into different schools. Access to a specific school is determined via school catchment areas. Thus, the main eligibility criterion is based on home-address. Moreover, most schools will have a few open slots for children from outside the catchment area, and access via this channel is mainly a function of parents' efforts.

Children's average high school completion and college attendance rates are strongly positively associated with the average family income of the child's school cohort (excluding the child's own family). Landersø and Heckman (2016), of which Fig. A.3a is reproduced in our

[24] In 2017, 83% of children in grade 0 and 1 attended public schools, and private school enrolment in the lowest grade levels is concentrated mainly in schools that cater to religious minorities in Denmark such as Muslims or Catholics.

appendix, already demonstrated a strong positive association between school peers' family income and own educational outcomes. In schools with many low income families, high school completion rates are below 50% and few attend college, whereas in the most affluent areas high school completion rates are close to 100% and almost all attend college. Crucially, there is a similar pattern for teachers. There is an almost linear relationship between a school's average teacher quality proxied from teachers' background characteristics such as GPA and employment history (which we will use as a proxy of a school's quality, see Section 4) and the average property values in the corresponding school's catchment areas (see Fig. A.3b). This is a finding we will underscore further when we consider the association between school quality estimated from teachers' characteristics, children's outcomes, and parents' education below. This indicates that – since there is no discretion in wage setting – teachers instead sort based on the type of children they will teach and use this as a non-pecuniary return to work. More fundamentally, this shows that while school expenditures are heavily regulated in Denmark, there is still strong variation in school quality in terms of both the body of students and teachers, generating a Matthew-effect where children from the most affluent families attend schools with higher-quality teachers.

4 Data

We construct a novel data set that combines the following three components (sources and data construction detailed in Appendix C).

Intervention Data First, the intervention provides the exogenous shock to the quality of public investments. The intervention data itself contains measures of child skills via language and literacy test scores and survey information collected before, during, and after the intervention.

The intervention included all preschools from 8 municipalities,[25] constituting more than

[25] Aabenraa, Faxe, Gentofte, Halsnaes, Copenhagen, Lejre, Rudersdal, and Skive.

1% of all preschoolers in Denmark during that year. In total, 2,300 children from 73 preschools were part of the study; 1,150 children in the treatment group (36 institutions) and 1,150 children in the control group (37 institutions), respectively. The randomization was at the institution level and stratified within municipalities. Since the intervention focused on language for native-speakers, our sample excludes immigrants.

Before and after the intervention, language tests were collected, mostly by the staff in the daycare centers. We label these pre-trial and post-trial test scores, respectively. The language tests follow the official language screening used in Danish preschools (Bleses et al., 2018). In addition, the data includes information about the exact date of the tests and unique preschool identifiers (allowing us to link all children from each preschool).

Follow-up Survey Around three years after the initial intervention, we designed a follow-up survey to collect information from the parents. The invitation to participate in the follow-up survey was sent via secure email to both treatment and control groups. Parents who did not fill out the survey within 10 days were subsequently contacted via telephone-follow-up calls. We obtained a response rate of 60%. There are no significant differences in survey response by treatment status. We do not condition on survey response when estimating the paper's main results.[26]

Tailoring the questionnaire to our model was a unique possibility, as we ask parents to report on their investment activities. This crucial element to studying skill formation is typically not available in administrative data. We construct a measure for parental direct time investments in their children with confirmatory factor analysis, combining six items, such as "I enjoy reading for my child.", "I am often too busy or too tired to read to my child.", or "How many times last week has your child been read to (or read with) at home?" (see Section C.4 in the appendix).

[26]See Section C.1 for more information and the detailed set of questions.

Register data We link each child and their parents to full population register data using the unique individual identifier of the children's social security number. The registers provide rich information, which we utilize in three dimensions to obtain a unique data set on not only the intervention but also the children's family and local environment.

i) Child skills: We obtain a longer-run measure of child skills from compulsory test scores in 2nd grade (age 8–9) testing children's reading, language and literacy skills.[27]

ii) Parent characteristics: The register data also include unique links to parents' individual identifiers allowing us to link each child to their family, place of residence, and parents' income, employment status, and education. Moreover, having access to full population register data, we are not only able to characterize each child's family, we also observe the environment they grow up in: the neighborhoods they grow up in, the schools they attend, how their peers perform in school, and their peers' background characteristics. We proxy parental quality by their education, where we categorize them by their highest recorded years of schooling, classifying parents where none has at least 14 years of schooling as "Less than college" (around 35% of our sample), and those where at least one has 14 or more years as "College or higher" (around 65%).

iii) School quality: We define this as a measure of how the average characteristics of teachers working at a given school predict that the children at the school do well in compulsory (externally scored) tests. We base this on a unique dataset linking all teachers in Denmark and the schools they work at from 2010-2016. From the unique individual identifier, we merge teachers to information on their age, tenure, year of graduation, high school GPA, high school GPA in language subjects, teacher college GPA, and unemployment spells, and calculate the school averages. We link each school with the individual standardized (and externally scored) language test scores for all children from grade 2-8 for all children during

[27]The tests take place near the end of the school year and are computerized adaptive tests in which questions are determined by the student's performance earlier in the test. The tests are scored electronically without teacher input. They measure three underlying constructs: Reading comprehension, decoding, and language comprehension. Following Sievertsen et al. (2016) and Beuchert and Nandrup (2018), we standardize these three individual scores, take the simple average, and re-standardize them within year.

the years in question, and regress children's test scores on the average teacher characteristics in the school they attend. We rank the predictions from this regression from 0 to 1, with 0 being the schools with the teachers with the least favorable observable characteristics and 1 the school with the teachers with the most favorable observable characteristics.[28]

We plot average test scores against the estimated school quality, by year and school, in Fig. 2a. The figure shows that average test scores in schools increase by roughly one standard deviation from the "worst" to the "best" schools as defined by teachers' observable characteristics. Next, Fig. 2b plots by year and school, parents' average years of schooling against the estimated school quality. There is a strong association between parents' education and teacher characteristics. On average, parents with children in the "worst" schools hold almost 2 years less education than parents with children in the "best" schools.[29]

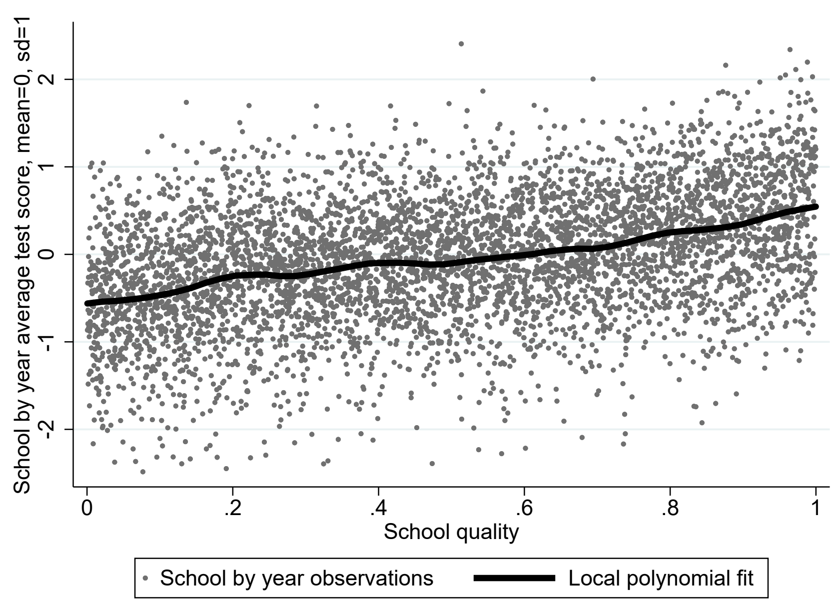
Table 1 gives an overview of when the different main variables of our analysis were measured. The pre-trial test scores were collected a few weeks before the intervention, and the post-trial test scores shortly after. Then, in 2016, around three years after the intervention started, the parent survey was collected and in 2017 or 2018 we measure children's language test scores and rank the schools they attend by the teacher characteristics.

[28] School quality is estimated based on 94,770 individual teachers (around 50,000 teachers each year from 2010-2016) linked to 5,557 school by year observations for a total of 1,526,234 observations of children's standardized test scores.

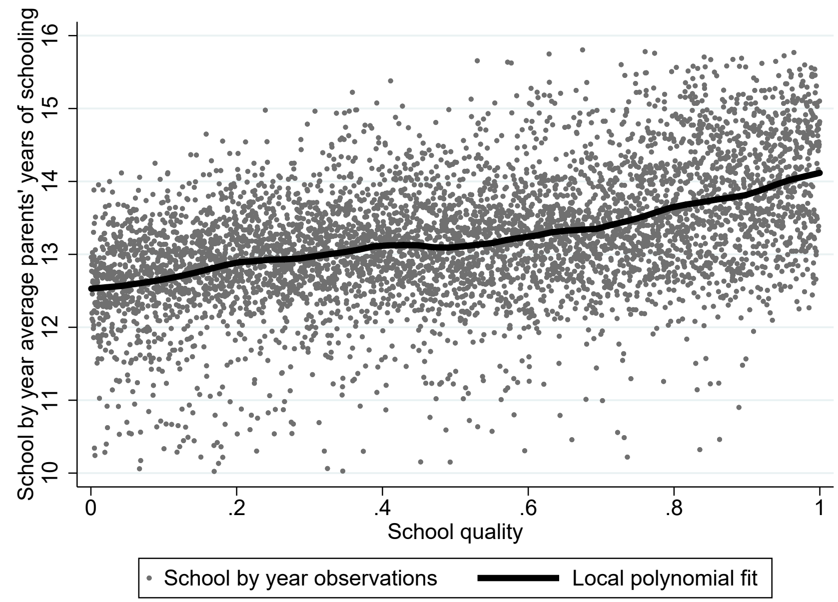
[29] Table A.1 shows by deciles of school quality the 10th percentile, median, and 90th percentile of the standardized test scores. Within each decile of school quality, the 10th and 90th percentiles of average test scores differ by approximately 1.7 standard deviations. Also, note that the estimated school quality is also strongly correlated with parents' statements of satisfaction with their child's school from the survey, see Fig. A.4.

Figure 2: Children's standardized test scores and parents' years of schooling, by estimated school quality

a) Children's test scores



b) Parents' years of schooling



Note: Figure shows school by year average test scores (for children from grade 2-8) (a) and their parents' years of schooling (b) plotted against the estimated school quality measure from teacher's observable characteristics. Test scores have been standardized to mean 0 and standard deviation 1 at year and grade level. The figure also shows a local polynomial smooth of the relationship between average test scores / parents' years of schooling and estimated school quality.

Table 1: Timeline of Outcome Measurements

Timing	Age	Event	Data
-3 – -6 months	3–5	Baseline data collection	Language test scores θ_0
0 – +5 months	3–6	*Intervention*	Changing $\underline{G}_1$
+10 months	4–7	Endline data collection	Language test scores θ_1
+3 years	6–8	Parent survey	Parents' investments x_2
+4 – 5 years	7–9	In school tests	Language test scores θ_2
+4 – 5 years	7–9	Register data	School characteristics / quality $\underline{G} + \kappa h_1 w + e_2$

Note: Timing is relative to the intervention.

4.1 Descriptives and Balancing

Table 2 presents background characteristics for all children in Denmark born during the same years as our main sample (Column 1) and for our control and treatment groups (Columns 2 and 3). The table also presents tests for mean differences between the treatment and control groups (Column 4). The mean characteristics of children in our sample, overall, correspond to the average characteristics of children in those cohorts, but parents in our sample are marginally older, have 0.2 years more schooling, and the mothers have higher employment rates compared to the average parent in the overall population.

Children's pre-trial test scores and their age during the intervention are almost identical between the treatment and control groups. Other characteristics such as mothers' weight (measured before the birth of the child in question), parents' education, parents' employment rates (measured before the intervention), parents' age, and household income (measured the year after the intervention) show no significant differences between the treatment and control groups. Overall, there are no differences that are statistically significant at a 10% level or stricter.

In a joint test where treatment status is regressed on all the covariates, three of the 54 tests are significant at a 5% level and two at a 10% level (Table A.2). The main concern would be that any imbalance in treatment assignment – whether statistically significant or not – leads to variation in the child outcomes and endogenous variables of interest. We show that there is no substantial variation in predicted outcomes from covariates across treatment status; irrespective of whether we consider the full sample, or by parents' education (see Table A.3). The actual treatment-control differences in post-trial test scores are substantial while the predicted differences due to covariates are barely visably detectable (see Fig. A.5).

Figure 3 presents the distributions of the key variables by parents' education for the control group. There are substantial differences between language skills in preschool, and they grow as the children reach school. The distribution of the parental investment factor also differs across parents' education (Fig. 3c). Similarly, the rank of school quality of the children's schools is also strongly associated with their parents' education level (Fig. 3d).

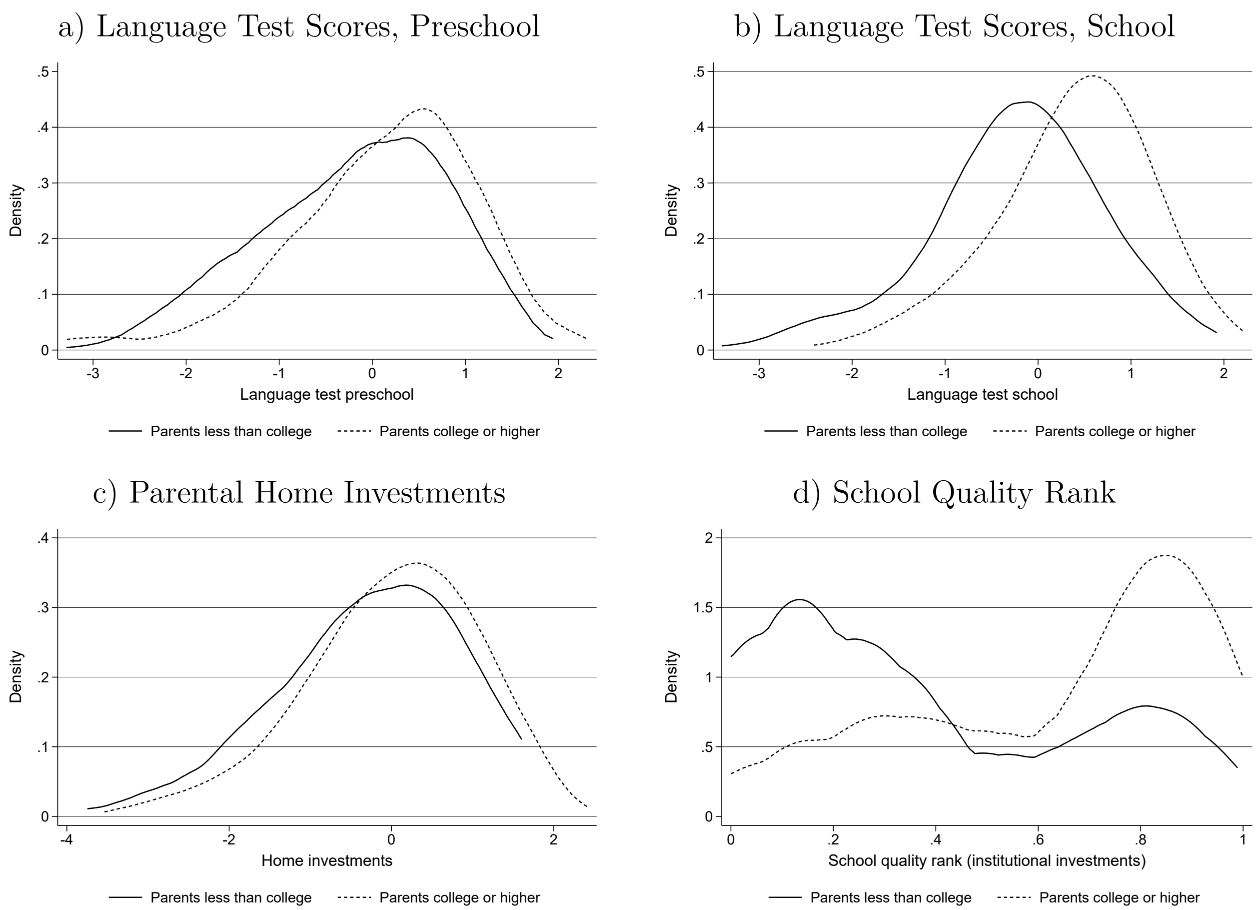
In the control group, children's pre-trial test scores are positively associated with both later test scores, parental investments, and school quality, but also time spent out of home and parents' hours of work (Table A.4). Parents' age, education, employment levels, and household income are highly predictive of the outcomes.

Table 2: Balancing of Estimation Sample by Treatment

	(1) General Pop	(2) Control Avg.	(3) Treated Avg.	(4) Diff Treat-Control
Pre-trial Test		-0.037	0.039	0.076
		(0.994)	(1.013)	(0.087)
Child's age at pretest	4.044***	4.086***	4.041***	-0.045
	(0.840)	(0.849)	(0.851)	(0.044)
Born in 2007	0.253	0.191	0.174	-0.017
	(0.434)	(0.393)	(0.379)	(0.046)
Born in 2008	0.256	0.330	0.330	-0.001
	(0.436)	(0.471)	(0.470)	(0.023)
Born in 2009	0.246	0.295	0.331	0.037+
	(0.430)	(0.456)	(0.471)	(0.022)
Born in 2010	0.246	0.177	0.157	-0.021
	(0.431)	(0.382)	(0.364)	(0.043)
Male	0.514	0.537	0.504	-0.032
	(0.500)	(0.499)	(0.500)	(0.026)
Child's birth weight, kg	3.478***	3.517***	3.464***	-0.053*
	(0.604)	(0.482)	(0.520)	(0.024)
Gestation length, weeks	39.627***	39.775***	39.698***	-0.078
	(1.945)	(1.555)	(1.593)	(0.080)
Apgar score	9.863***	9.852***	9.876***	0.023
	(0.620)	(0.591)	(0.594)	(0.029)
Number of siblings	1.382	1.390	1.323+	-0.067
	(0.851)	(0.860)	(0.786)	(0.058)
Mother's weight, kg	67.569+	66.498***	67.471***	0.973
	(38.923)	(16.691)	(15.626)	(1.258)
Mother years of schooling	13.934***	14.180***	14.113***	-0.067
	(2.457)	(2.510)	(2.435)	(0.305)
Mother's age, 1/9-17	39.153***	39.876***	39.821***	-0.054
	(5.050)	(5.111)	(4.973)	(0.555)
Mother employed in 2012	0.788+	0.830*	0.845*	0.016
	(0.409)	(0.376)	(0.362)	(0.025)
Father years of schooling	13.678***	13.949***	13.863***	-0.086
	(2.438)	(2.419)	(2.422)	(0.296)
Father's age, 1/9-17	41.531***	42.395***	41.997***	-0.398
	(5.777)	(6.020)	(5.637)	(0.525)
Father employed in 2012	0.872**	0.889**	0.886**	-0.003
	(0.334)	(0.315)	(0.318)	(0.022)
Household wage income 2017, $1,000	89.241	100.056	99.375	-0.681
	(58.087)	(72.152)	(61.301)	(8.310)
N	2,744	1,150	1,150	2,300

Note: Standard deviations of the variables in parentheses for columns 1-3, standard errors clustered at institution level for column 4. No differences (treatment-control) were statistically significant at ($p < 0.1$) or lower. The general population (column 1) consists of the 2018 register of all children born in 2007-2010.

Figure 3: Children's Test Scores and Parents' Investment Measures, by Treatment Status



Note: The figure shows distributions of the key measures; children's language test in preschool (after treatment) and school (a and b) in standard deviations from the mean, the parental home investment factor (c) in standard deviations from the mean, and school quality rank (d), by highest education of parents. If the highest of the two parents' years of education is below 14 years, they are classified as "Parents less than college", vs "College or higher." The figure is based on data for the control group.

5 Results

5.1 Main Effects on Test Scores

Figure 4 shows the distributions of child language skills, measured at baseline, after the daycare intervention, and in the longer-run follow-up in grade 2, split by treatment status and by parental education. These distributions set our expectations for the formal treatment analysis and its heterogeneity: there are no treatment/control differences in pre-trial language test scores. There are clear treatment effects immediately after the trial, in both parent groups. By 2nd grade, however, any treatment difference between the language test scores of children of parents with a college degree or more has vanished.

Figure 5 presents the summary, average treatment-control differences in language test scores for the pre-trial test, the post-trial test, and longer run test, respectively. These are the β of a regression

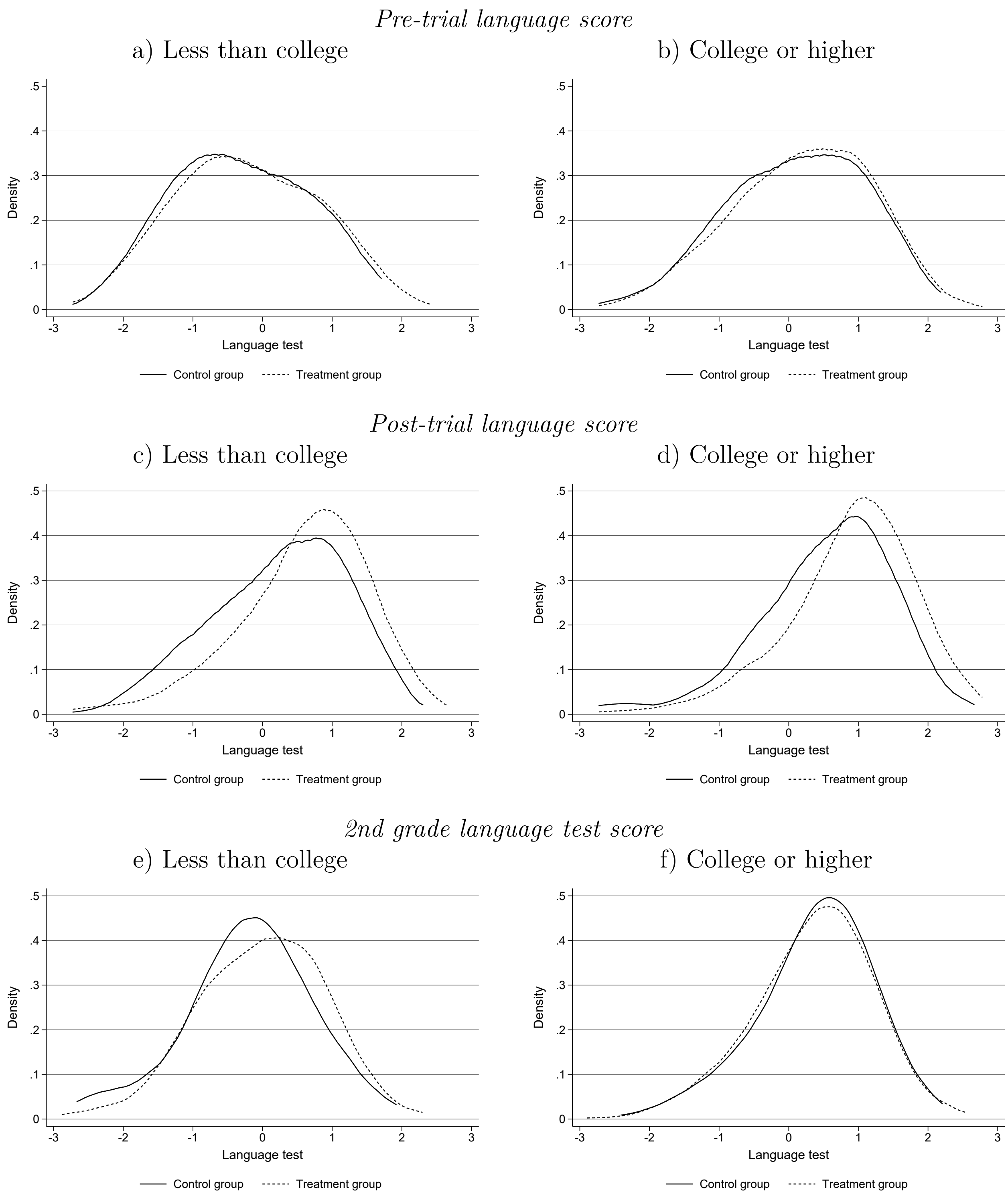
$$y_{it} = \alpha + \beta_t T_i + \varepsilon_{it}$$

where y are language scores at the different time points t and T is the treatment indicator.[30] The left panel of Fig. 5 shows a small and insignificant difference in mean test scores prior to the intervention, followed by a large treatment effect of roughly 0.35 of a standard deviation in the language test score shortly after the trial (which reproduces the findings from Bleses et al., 2018). This treatment effect is remarkable and it roughly corresponds to the difference in baseline test scores between children of parents with and without a college degree. The intervention, thus, provides an ideal setting for studying parents' responses and longer run effect on children's skills.

As a natural next step, the final bar in the figure presents treatment-control differences

[30] We also repeat this regression in Fig. A.6 with additional controls (namely, all covariates in Table 2). But since this effectively conditions on covariates such as parental age, employment, and income, these are correlated with parental education. Conditioning on covariates that are correlated with the variables that determine heterogeneous treatment effects was not warranted. Nevertheless, the results remain qualitatively the same, unsurprisingly given the successful balancing tests of Section 4.1.

Figure 4: Test Score Distributions, by Treatment Status and Parental Education



The figure shows pre-trial, post-trial and 2nd grade test score distributions for the control and treatment group by parents' education, in standard deviations from the mean. Parents where neither of them has at least 14 years of schooling are classified as "Less than college" vs "College or higher." Note that the sample can vary from the two pre-and post-trial tests to the 2nd grade language test score.

in 2nd grade test scores. While the large average treatment effect has completely faded out on average, this zero-finding in the long run hides an important heterogeneity by parental education.

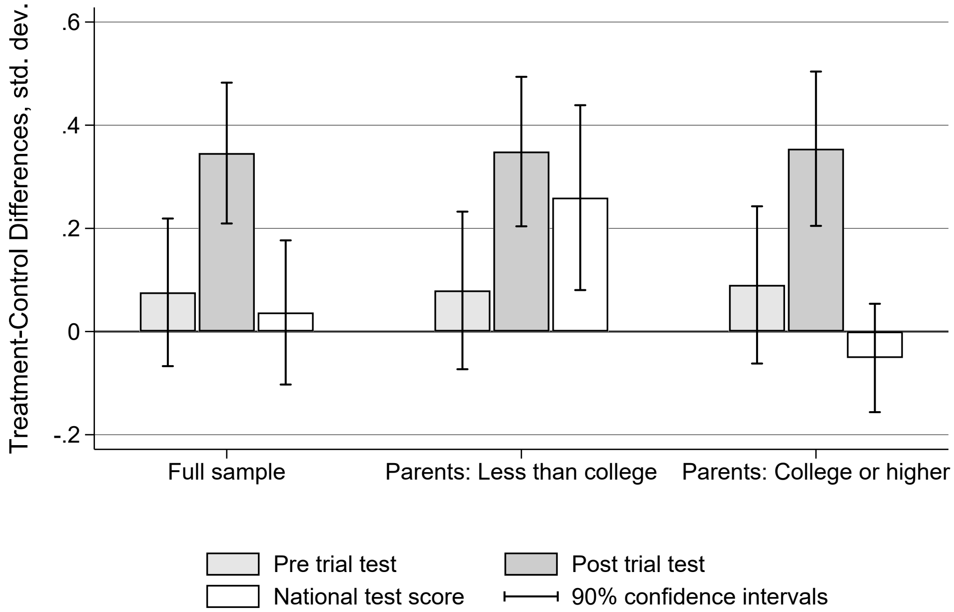
In the figures' two right panels, the effects are separated by parents' highest completed education. While the short run average treatment effects are similar between more and less educated parents (post-trial test), by 2nd grade the effects have faded completely for children with parents with at least a college degree, while they remain sizeable at around 0.26 of a standard deviation for children with less educated parents, which corresponds to almost 40% of the baseline test score gap across parental education.[31] The long-run treatment effects are significantly different between the parental education groups. This remarkable heterogeneity evokes the results found in Havnes and Mogstad (2011), among others, where effects of an increased coverage of formal public child care improved long-run outcomes much more for children of less educated mothers. The heterogeneous long-run treatment effects represent a push towards more intergenerational mobility: children of less educated parents saw their skills increased in the long run, thus breaking the dependence on their parents' skills. In the long-run, the association of parental years of schooling with child language scores is much stronger in the control than in the treatment group (see Fig. A.7).[32]

The longer run results present a striking heterogeneity. While treatment effects fade completely for children whose parents have a college degree, they remain sizeable for children with low educated parents. This also holds when breaking down these longer run effects by the specific test-dimension, showing positive treatment effects on both language comprehension, decoding, and text comprehension in 2nd grade for children whose parents had not completed college (Fig. A.8 in the appendix).

[31] While the treatment effect for children with low educated parents is almost as large in 2nd grade as during preschool (0.26 vs. 0.35), test score gaps across parental background have doubled from preschool to 2nd grade.

[32] Intergenerational dependence between child and parent skills can be expressed as: $\frac{\partial \theta_2}{\partial \theta_P} = \frac{\partial \theta_2}{\partial \theta_1}\frac{\partial \theta_1}{\partial \theta_P} + \frac{\partial \theta_2}{\partial I_2}\left(\frac{\partial I_2}{\partial P_2}\frac{\partial P_2}{\partial \theta_P} + \frac{\partial I_2}{\partial G_2}\frac{\partial G_2}{\partial \theta_P}\right)$, which stresses that heterogeneous changes to parental investment decisions both in terms of home and institutional investments also affect intergenerational mobility in skills.

Figure 5: Baseline Balancing, Short-Run, and Longer Run Treatment Effects



Note: The table plots estimates of the Treatment-Control differences (β_t) in test scores y_{it} from $y_{it} = \alpha + \beta_t T_i + \varepsilon_{it}$ with 95% CIs on the treatment indicator. Standard errors are clustered at the institution level. Note that the sample can vary from the two pre-and post-trial tests to the 2nd grade language test score. Table A.5 presents the regression output.

However, as parental education and children's pre-trial test scores are highly correlated, it could be that the heterogeneity in effects by grade 2 only reflects heterogeneity across initial child skill level. This is not the case. When we split the long-run treatment effects by the child's pre-trial test scores, they are also uniformly low, despite larger immediate treatment effects for weaker students (see Table A.6). Even children in the lowest tercile of pre-trial language ability do not see their long-run skills improved significantly as a group by grade 2 when we ignore parental education. Therefore, we interpret the heterogeneous treatment effects really stemming from differences in parental quality.

5.2 Parents' Responses

What explains the disconnect between the almost uniform treatment effects initially, and differences in the fade-out across parental education? As a first step, Figure 6a shows the treatment-control differences in the parental investment factor by parents' education; normalized relative to the lowest education category in the control group. The black bar shows a substantial difference in parental investments in the control group where the investment factor is almost 0.3 of a standard deviation higher among college educated parents compared to parents with less than college. Moreover, the figure documents a significant increase in parental investments following the language intervention when comparing the treatment and control groups; an increase that is largest for parents with low education levels. While the treatment effect of improved school quality leads to an increase of around .2 of a standard deviation for the least educated parents and children with lowest test scores, it is only half of that for the better educated parents and children with higher initial test scores (although the difference is not statistically significant). This provides the first suggestive evidence to whether parental and institutional investments are substitutes or complements, as low skilled parents appear to adjust their time investments slightly more than high skilled parents. These findings (and measure of parental investments) are closest related to the finding in Gelber and Isen (2013) that parental involvement increased by 6% after Head Start access. While Fredriksson et al. (2016), in contrast, report that higher class size (i.e. lower quality) increases parents' involvement, this is driven by high-income parents, which bears close resemblance to the heterogeneity we document in Figure 6.[33]

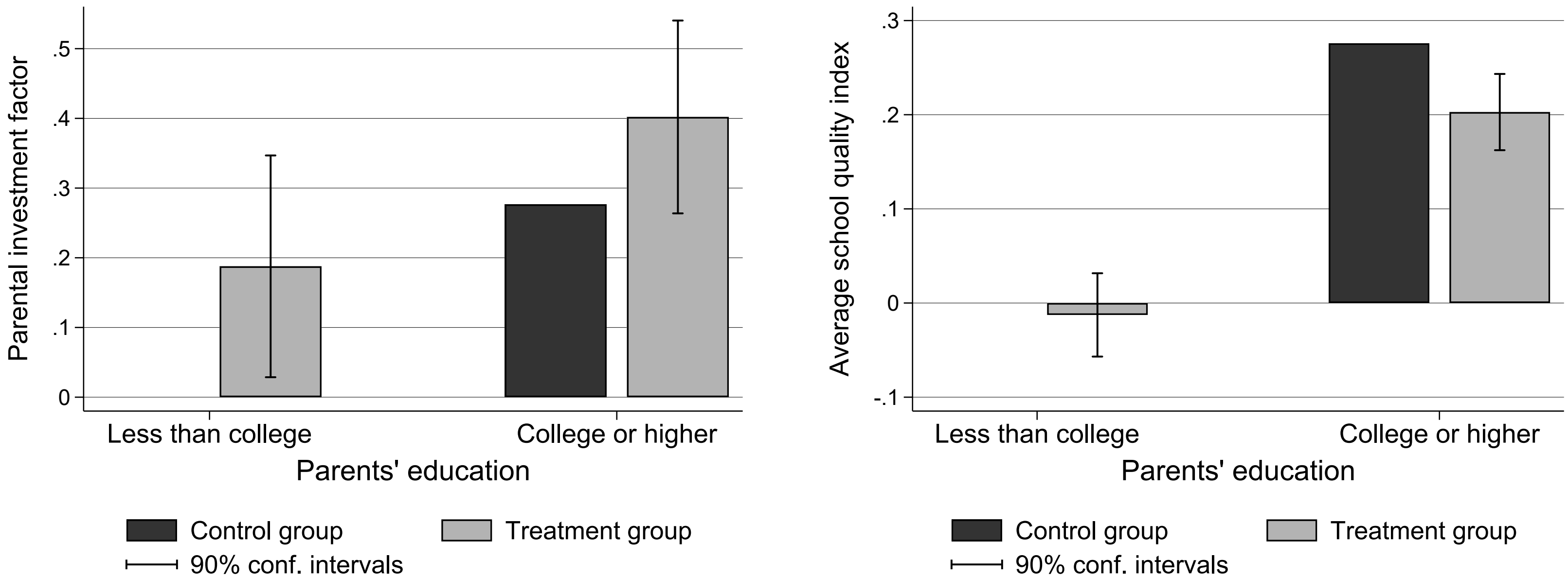
Figure 6b broadens the previous finding for parental investments by considering the quality of the elementary school that children now attend. The figure shows the average rank of school quality by treatment and control group and parents' education levels. Children of highly educated parents in the treatment group attend significantly *worse* schools. In contrast, there is no change to the schools children with low educated parents attend, which implies a strong (statistically significant) heterogeneous response across parental education.

[33]Point estimates from other studies such as Pop-Eleches and Urquiola (2013), are not directly comparable to ours as the outcome (e.g., help with homework) and treatment environment differ.

Figure 6: Treatment Effects on Investments

a) Parental Investment Factor

b) School Quality



Note: Figure a) shows average of parents' investment factor by treatment status and parental education, with children in the control group with low educated parents as reference category. Figure b) shows average estimated school quality by treatment status and parental education, with reference category children in the control group and low educated parents. See Table A.9 for details.

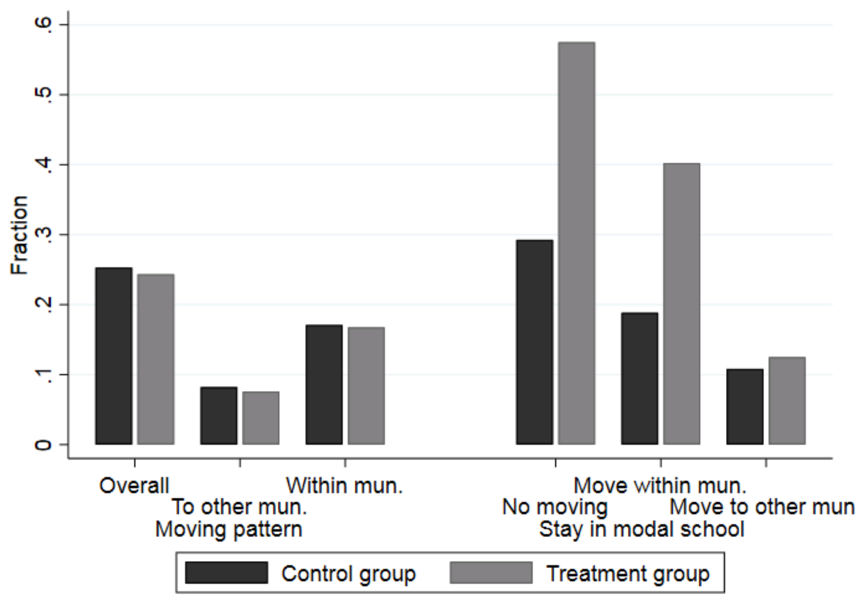
Such a finding, of course, raises the subsequent question of how parents (children) select into different schools. The left half of Fig. 7 shows, by treatment status, the share of families who move to a new address between preschool and primary school, and whether movements happen between municipalities (longer distance) or within municipalities (relatively short distance). There are no differences between moving patterns across treatments status. The right half of the figure shows the fraction of children who stay in the school that most children in the preschool attend (i.e. the modal school the preschool is a feeder for), for those who do not move to a new address between preschool and school age, those who move within the municipality, and those who move to another municipality. Children in the treatment group who either do not move or move to a new address within the same municipality (i.e. they move a relatively short distance) are much more likely to attend school with their preschool peers. In other words, parents in the treatment group become less selective in their school choice. As a placebo test, the figure also considers school choices for the children who have moved to another municipality. These are children who, in general, will be unable to attend the school their preschool is a feeder for irrespective of treatment status. Here, we – reassuringly – find no treatment-control differences (and that very few stay in the modal school).

Figure 7 thus follows prediction 2 from page 19, that public and private investments are substitutes if the RCT shows highly skilled parents reducing their sorting efforts. Moreover, reduced segregation by background characteristics during school appears to be a bi-product of the increased public investments during preschool.[34] This reduced effort into sorting by highly educated parents may be surprising, but two facts help us reconcile this finding with strongly held priors. First, note that children of highly educated parents still attend better-quality schools after the treatment, in levels. They just do so to a smaller degree among parents who experienced a better-quality preschool because of the randomized treatment. Second, while reduced effort in school sorting could also be used to increase parents' leisure,

[34] Fredriksson et al. (2016) also find that parents respond to changed school quality by mobility.

we find suggestive evidence that highly educated parents use some of the time freed up from the reduced sorting effort by increasing their labor supply.[35] Our survey contains a rough measure of average hours worked during a day that we use for a simple analysis in Table A.9. While the treatment effects are not statistically significantly different from zero, the point estimates are negative for less educated parents and positive for highly educated parents. Thus, less educated parents who already work fewer hours per day than high-educated parents to begin with, seem to reduce their average hours worked during the day, while highly educated parents increase their labor supply.

Figure 7: Mobility from Preschool to 2nd Grade and School Choice, by Treatment Status



Note: The figure shows mobility in residence (left half of the figure) and school choice (right half of the figure) by treatment status. The *left half of the figure* shows the fraction of the sample who lives at a different address when they attend school relative to when they attended preschool. It shows the fraction that moves overall, and whether this is a move within the municipality (i.e. a relatively short distance) or to another municipality. A move within the municipality does not necessarily lead to a change in public institutions. A move to a new municipality in general does. The *right half of the figure* shows the fraction of children who attend the modal school (defined as the school that their preschool is primarily linked to), for those who do not move between preschool and school age, those who move within the municipality, and those who move to another municipality.

[35] It should be noted that many parents may not have full discretion over hours spent on work in practice (as opposed to e.g., parents' home investments in their children).

5.3 Progressiveness of public investments and treatment heterogeneity

In sum, our empirical results show that while the intervention had large initial positive effects on language skills across all backgrounds, the longer-run effects are mediated by parental responses. The intervention in this sense is progressive from the children's perspective: Children with low skilled parents benefit more than children with high skilled parents. However, this is a result of differences in parents' responses.

These findings beg the question of whether the intervention increasing public investments $\underline{G}$ in period 1 was progressive or regressive from the parents' perspective. We therefore consider how the intervention affects parents' utility in the final period (as given in Eq. (4), and imposing functional form assumptions for utilities only):[36]

$$\underbrace{\frac{\partial U}{\partial \underline{G}}}_{\substack{\text{Effect of}\\ \text{intervention}\\ \text{on parents'}\\ \text{utility}}} = \underbrace{\beta \frac{1}{\theta_2}\frac{\partial \theta_2}{\partial \theta_1}\frac{\partial \theta_1}{\partial \underline{G}}}_{\substack{\text{Utility gain}\\ \text{from intervention's}\\ \text{effect on skills}}} + \Big(\underbrace{\frac{\partial x_2}{\partial \underline{G}} + \frac{\partial e_2}{\partial \underline{G}}}_{\substack{\text{Parents'}\\ \text{adjustment}\\ \text{of inputs}}}\Big)\Big[\underbrace{\beta \frac{\partial \theta_2}{\partial I_2}\frac{\partial I_2}{\partial P_2}\frac{\partial P_2}{\partial x_2}}_{\substack{\text{Marginal}\\ \text{productivity}\\ \text{of parents'}\\ \text{adjustments}}} - \underbrace{(1-\alpha)\frac{1}{l_2}}_{\substack{\text{Marginal}\\ \text{utility of}\\ \text{leisure from}\\ \text{adjustments}}}\Big] \tag{15}$$

Eq. (15) shows that parents' utility is affected through several sources: i) the direct effect that higher public inputs have on children's skills and thus parental utility, all else equal, ii) the change to parents' inputs in children's skill formation, iii) the productivity of this change in inputs, and iv) how the changing inputs affect parents' leisure.

For the intervention to be progressive, that is increasing redistribution, it must benefit or increase the utility of low-skilled parents more than of high-skilled parents. $\partial U/\partial \underline{G}$ should be decreasing in parental quality θ_P. The first term of Eq. (15) is likely decreasing in parents' skills, as $1/\theta_2$ is highest for children with low skilled parents. The sum in the brackets is also decreasing in parents' skills assuming that production functions are concave and because low skilled parents have higher levels of leisure. However, as we also showed when

[36] Derivations in Section B.5.

we discussed whether the intervention leveled the playing field, progressiveness is not given if home and institutional investments are complements. In that case, the term $\frac{\partial x_2}{\partial \underline{G}} + \frac{\partial e_2}{\partial \underline{G}}$ would be increasing in parents' skills. In other words, only if home and institutional investments are substitutes is it certain that the intervention will be progressive.

Of course, public investments do not appear out of the blue but are often combined with progressive taxation as funding. The key relationship in this paper arises as a result of parents' responses and the opportunity costs of their time, which determines who benefit from the intervention. A natural next question is then whether a progressive tax $\tau(\theta_P)$ on parents' income that increased in parents' skills would ensure that the intervention is progressive irrespective of whether home and institutional investments are complements or substitutes.

An income tax will alter parents' utility from leisure, but it does not affect the essence of parents' trade-off: whether to devote time as input in home or institutional investments. The term $\frac{\partial x_2}{\partial \underline{G}} + \frac{\partial e_2}{\partial \underline{G}}$ remains as a determinant of whether the intervention is progressive of regressive from the parents' perspective. Whether to use one hour to invest in children is determined by the opportunity costs of time and thereby by an income tax. But whether this additional hour improves children's skills is determined by the relative productivity of home and institutional investments.[37]

Thus, the elasticity of substitution between home and institutional investments results in a complex set of trade-offs. On the one hand, we showed earlier that the *investment multiplier* in the baseline would favor children with high skilled parents most if home and institutional investments are substitutes (as high skilled parents could then focus on labor supply and invest in children through institutional sorting). On the other hand, increasing public investments would not necessarily be progressive from children's and their parents' perspective unless home and institutional investments are substitutes.

[37] In our specific case we get that $\frac{\partial U(c_2)}{\partial l_2} w(1-\tau) = \frac{\partial U(l_2)}{\partial l_2}$ from the additive separability and $\frac{\alpha}{1-\alpha} w(1-\tau) l_2 = c_2$ from the log-specification in the utility function, which cancels out. More generally, however, τ will only change the relative price of consumption/leisure, and not whether parents should devote time of x or e.

5.4 Implication of Heterogeneous Treatment Effects for Substitution Parameter

What can we say about the elasticity of substitution between home and institutional investments from the intervention? The treatment effects persist for children from low-skilled parents because the improved preschool quality improved their own skills (skills beget skills) and because parents increased their inputs after observing the higher public quality. The treatment effects for children with high-skilled parents, however, fade out as parents become less selective in their school choices. This finding is compatible only with parental and institutional investments being *substitutes* (i.e. $\sigma > 0$) in the specific model we derived. The model assumptions to allow this conclusion are a CES production function for the two types of investments (home investments that are given by parents' time spent with their child, and institutional investments that are affected both by public inputs and parental efforts to sort into higher quality neighborhoods) and early residential choice.

Concluding that the types of investments are substitutes also relates to inequality in total investments. Greater substitutability between home and institutional investments implies greater inequality in total investments between children of highly and less educated parents due to the investment multiplier, which captured that parents' investments become more effective as their skills increase. Hence, equalization of total investments through universal childcare is hampered by parents' ability to easily substitute between investing via private investments (at home and through sorting) and public channels in the skill production function.

The more general model without functional form assumptions does not allow us to draw conclusions about the elasticity of substitution, apart from it being a function of parents' joint response on home inputs and institutional sorting when institutional quality changes. The general model can, however, bridge the gap in previous studies, which have found seemingly conflicting results on the question of substitution vs. complementarity. Gelber and Isen (2013) find that randomization into the higher-quality Head Start *increases* parental involvement. However, parents can also affect institutional quality. Fredriksson et al. (2016) study students in grades 4-6 and conclude that lower quality of public schools leads parents to change schools – a conclusion similar to Pop-Eleches and Urquiola (2013), who find that parents lower investments in response to better high school quality. But it is not sufficient to observe whether parents increase or decrease one type of input.

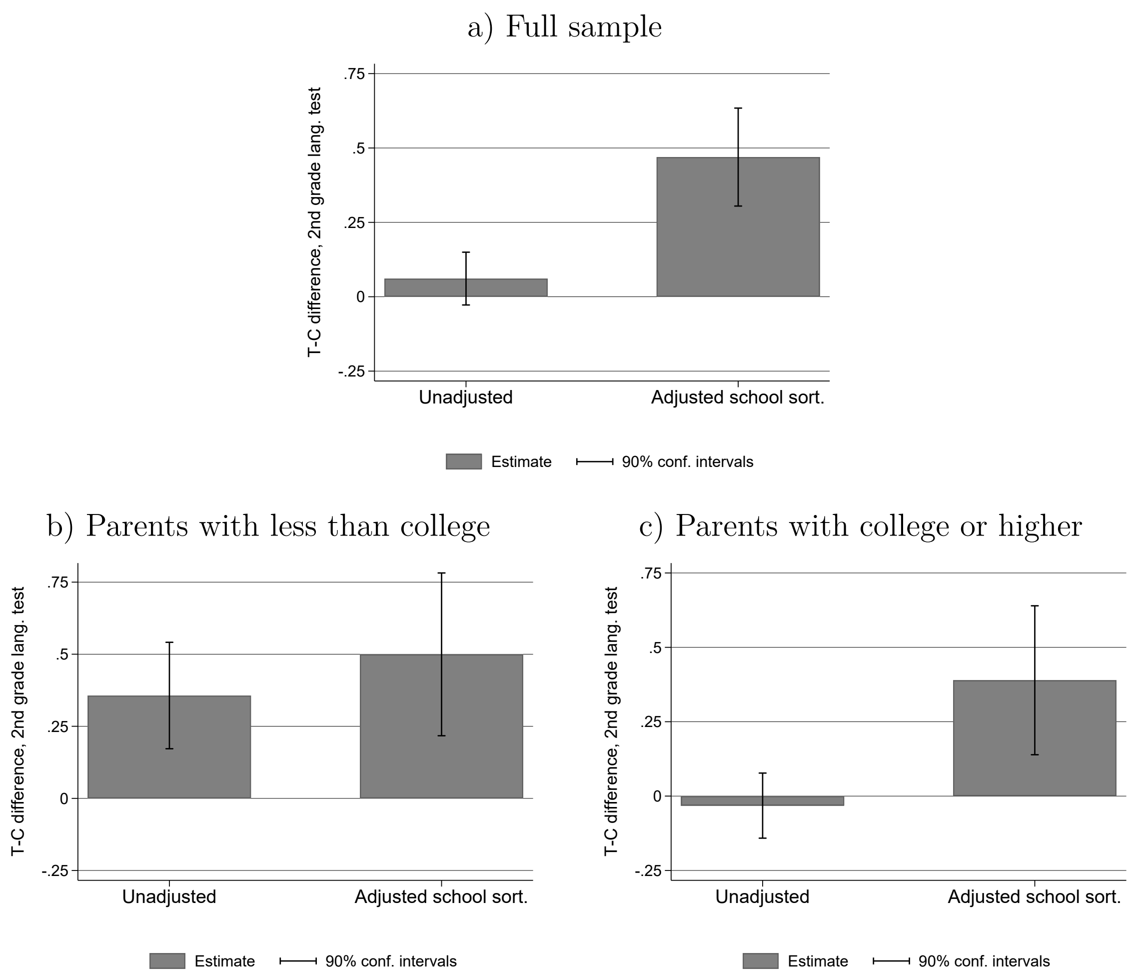
Moreover, the complete fade-out for children from high-skilled parents is remarkable and comparable to Currie and Thomas 2000, who also find full crowd-out as they use school sorting as a margin of adjustment. This finding raises the natural question of whether the treatment effect fade-out can be explained by these differences in school choice (or expressed in terms of the model what the treatment effects would be if $\frac{\partial e_2}{\partial \underline{G}} = 0$). We may obtain a proxy of the intervention's effects on language test scores, *net of any school selection*, by conditioning on school quality in a regression of language test scores on the treatment. Formally, we estimate the two equations

$$y_i = \alpha + \beta T_i + \varepsilon_i \tag{16}$$

$$y_i = \alpha + \tilde{\beta} T_i + \gamma_1 * SQ_i + \gamma_2 * SQ_i * T_i + \tilde{\varepsilon}_i \tag{17}$$

where y_i captures child i's test scores, T_i denotes their treatment assignment and SQ_i their school quality. β corresponds to the treatment-control differences presented in Fig. 5 and $\tilde{\beta}$ to the treatment-control differences net of the changed school selection (at $SQ_i = 0$). We are aware that this conditions on an outcome variable (school quality), and that the estimates can not be interpreted causally. However, if unobservables guiding school choice and affecting child test scores are positively correlated, we will, if anything, underestimate $\tilde{\beta}$. Figure 8 presents the results, first for all children (a) and then by parental education (b-c). Once we control for school quality, there are large and significant treatment effects for in-school language tests in the same order of magnitude as found for the short run post-trial tests. Breaking this down by parents' education, we see that the estimate changes a little for children with low educated parents (as there is a small change in school choice here), whereas they re-emerge for children with higher educated parents. Figure A.9 extends this finding and shows that it is mainly the middle and lower part of the test score distribution that is shifted by the treatment, once we control for school selection.

Figure 8: Long-term Treatment Effects, Controlling for School Sorting, by Parents' Education



Note: The figure plots estimates of Equation (16) by parents' education. The baseline treatment-control differences presented in the bars "Unadjusted" present estimates of β, while the treatment-control differences net of the changed school selection $\tilde{\beta}$ are presented in the bars labeled "Adjusted for school sorting." The estimates should be interpreted with caution, as we condition on an outcome variable (school quality) which may bias estimates. However, if unobservables guiding school choice and affecting child test scores are positively correlated, we will underestimate $\tilde{\beta}$.

6 Discussion and Conclusion

This paper studies how parental and public investments in children's skill formation interact. We do so by first formulating a general model of child skill formation, which includes two types of investments; home investments that are given by parents' time spent with their child, and institutional investments that are affected both by public inputs and parental efforts to sort into higher quality neighborhoods and institutions.

The model's main implications can be stated as follows: the degree to which public investments actually boosts overall investments (and thus child skill outcomes) and level the playing field depends on whether the inputs from home and from preschools and schools are substitutes or complements. Without any functional forms imposed on skill formation or production functions, we show that this elasticity of substitution is given by the relative marginal productivities of parents' time spent either investing at home or influencing institutional quality via sorting, which in turn depend on the specific home and education production functions. We then gradually impose functional form assumptions and constraints to finally arrive at a technology of skills formation with closed form solutions.

We use a randomized controlled trial in Danish preschools, which exogenously increased the quality of preschools, to assess the model's main predictions. We link children from the RCT to full population register data with information on later school choice, school quality, and child test scores. Our empirical analysis shows that increasing the quality of universal childcare reduces skill gaps between children from advantaged and disadvantaged backgrounds. The intervention had large initial positive effects on language skills at age 4-5 across all backgrounds. For children with low SES parents, at ages 8-9 (3-5 years after the intervention), test scores remain 0.26 standard deviations higher in the treatment group than in the control group. The treatment effects are persistent for children from low-skilled parents, partly because the improved preschool quality improved their own later skills (skills beget skills), and partly because parents increased their inputs after observing the higher public quality. There is, however, a fade-out for children from high SES parents who use school sorting as a margin of adjustment thereby offsetting the initial treatment effect. Linking these heterogenous responses to our model (where we assume a CES production technology) shows that they are only compatible with home and institutional investments being substitutes.

While our findings after imposing specific functional forms may apply with a local range of investment choices, they may not apply globally. Our general version of the model shows that it cannot be determined whether the elasticity of substitution is constant or even has the same sign across the full range of home and institutional quality without specific knowledge about the underlying home and educational production functions. Similarly, while the vast majority of children in OECD countries attend preschool and thus face the intensive margin problem relating to the quality of institutions conditional on enrollment (which we study), the results and elasticity of substitution between home and institutional investments may be different for the extensive margin problem of whether to send a child to preschool. In addition, our empirical setting focuses on children from preschool age onwards. Issues such as substitution between different types of inputs when it comes to infants and toddlers may be different than for preschoolers.

Yet, our finding that at preschool age, home and institutional investments are likely substitutes highlight several challenges. We show that the productivity of investments in the technology of skill formation depends on parents' skills through what we label an *investment multiplier*. This multiplier is increasing in parental skill level, and we illustrate that the inequality in investments is largest when home and institutional investments are substitutes, because the opportunity costs of reducing labor supply relative to home investments are largest for high skilled parents. We also show that Danish public schools – a system different from, for example, the U.S. school system because funds are equated through a strong redistribution – is still characterized by sorting both at the family level and teacher level. Hence, the most able teachers work at schools which children with affluent background attend, while the least able teachers work at schools which children from disadvantaged background attend. Thus, the joint sorting by families and teachers generate a Matthew-effect.

Furthermore, while low-skilled parents tend to increase own investments (from the lower base level) to complement the public investments, high-skilled parents instead tend to "consume" some of the public investments. Our findings thus distill an innate trade-off when designing policies; whether to target those with most needs or to target all with the caveat that some children would have been just as well off without. The finding that home and institutional investments are substitutes therefore comes at a cost because some of public investments indirectly feed into parents' consumption or leisure. However, if high skilled parents reduce the efforts put into institutional sorting when baseline institutional quality increases, public investments may lead to less segregation across schools and less inequality in child skills. Our results thereby underscore the potential of providing investments during childhood as a lever to promote equality of opportunity.

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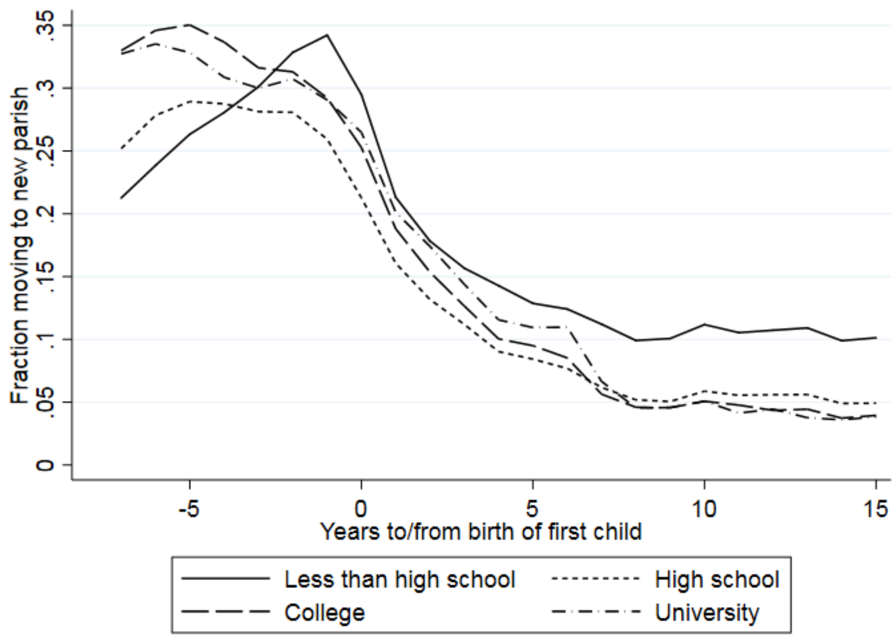
A Additional Figures and Tables

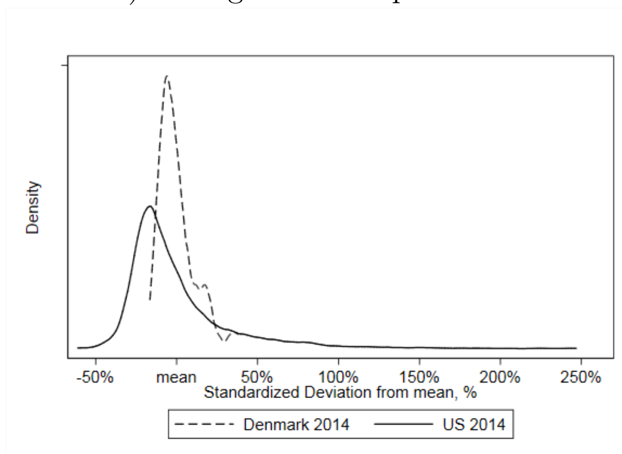
Figure A.1: Stability of Residential Choice: Fraction moving each year by time to/from birth of first child and mother's education



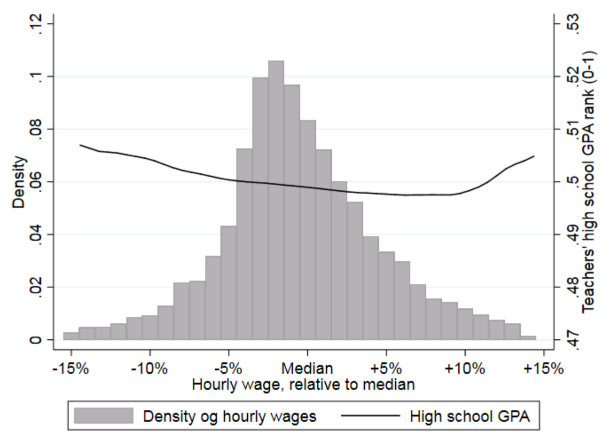
Note: Reprint of from Cholli et al. (2020). The figure shows the fraction of mothers moving to a new parish (regions around half the size of the average census-tract), by mothers' education and time to/from the birth of her first child. Full population register data form cohorts born 1991-1995. Note that school start is at age 7 for the cohorts in question (i.e. the year after the downward kink in the middle of the figure).

Figure A.2: Average School Expenditures in Denmark and the U.S.

a) Average school expenditure



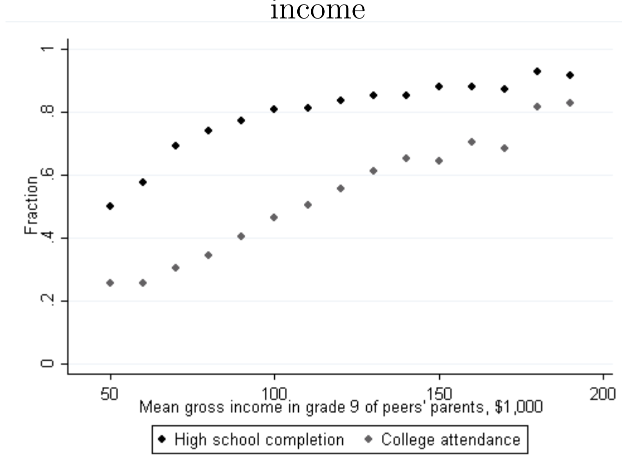
b) Teachers' hourly wages



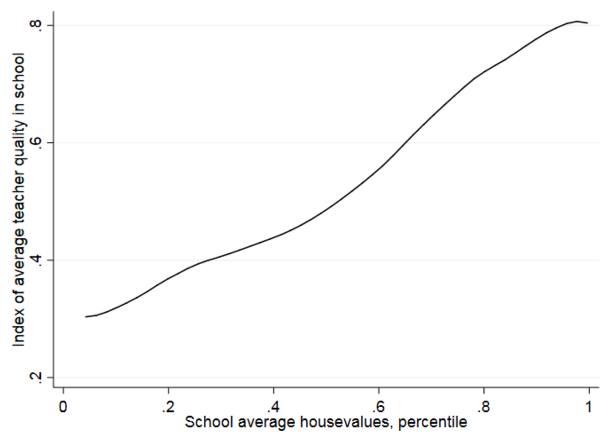
Note: Figure a) shows average per pupil school expenditures in public schools in 2014 relative the to the country average. Source: Denmark: www.statistikbanken.dk (Statistics Denmark); U.S.: . Figure b) shows the distribution of teachers' hourly wage rates in 2014 as a percentage deviation from the median wage rate. The figure also presents the association between teachers' rank of high school GPA and hourly wages (note that the y-axis only span from 0.47–0.53; $corr(wage, testscore) = -0.03$, with $p = 0.73$ for H_0 that $corr = 0$ and H_A that $corr \neq 0$). Hourly wage rates are adjusted for years of experience to remove the variation stemming from the wage-progression at different levels of experience set by collective bargaining. This adjustment involves some measurement error, as it uses *years since graduation* and not *years of employment as a teacher in a Danish municipality.* Also, the hourly wage rates are not adjusted for the roughly 5% wage differences across regions (a PPP adjustment).

Figure A.3: Evidence of Sorting at School-level in Denmark

a) Average child high school completion and college attendance across school-peers' family income



b) Average estimated school quality across property values in catchment area



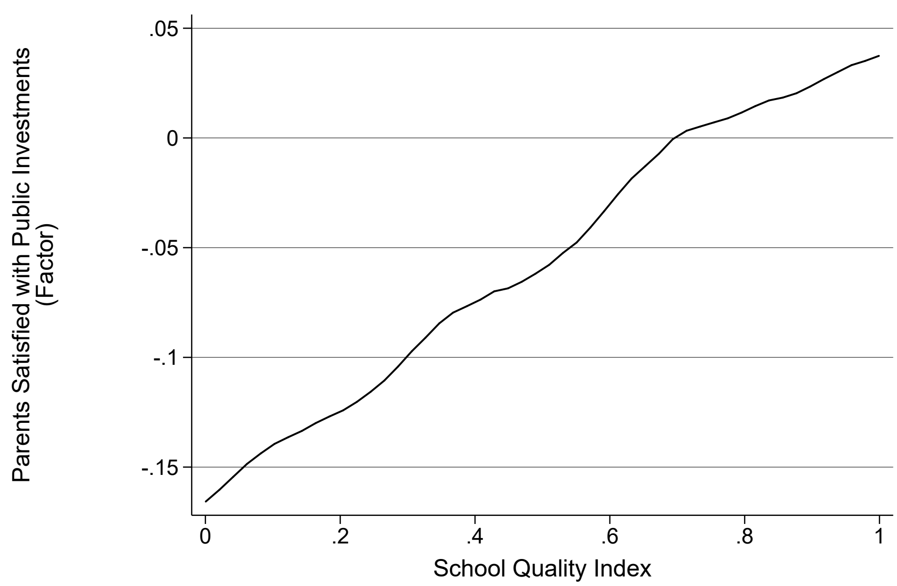
Note: Figure a) reprints Figure 12 from Landersø and Heckman (2016) showing average high school completion and college attendance rates across the average of school peers' family income. Figure b) shows the average estimated teacher quality percentile in schools across the average property value in the school catchment area ranked from lowest average values to highest. To proxy average teacher quality in a given school, we use a unique link between all school teachers in Denmark, the schools they work in, and the children that attend those schools. The multiple dimensions of teacher characteristics are condensed to an index ranging from 0 (the lowest quality teacher by observable characteristics) to 1 (the highest quality teacher). Sections 4 and C.3 introduce this measure in more detail.

Table A.1: Children's test scores by estimated school quality deciles

Decile	10th percentile	Average	90th percentile
1	-1.38	-0.55	0.34
2	-1.28	-0.35	0.53
3	-1.13	-0.24	0.58
4	-1.00	-0.16	0.64
5	-0.88	-0.09	0.68
6	-0.89	-0.06	0.72
7	-0.73	0.04	0.81
8	-0.66	0.15	0.87
9	-0.59	0.29	1.13
10	-0.41	0.47	1.29

Note: Table the 10th percentile, average, and 90th percentile of school average test scores by deciles of estimated school quality measure from teacher's observable characteristics. Test scores have been standardized to mean 0 and standard deviation 1 at year and grade level. The table is based on 5,557 school by year observations and 1,526,234 observations of children's standardized test scores.

Figure A.4: Parents' Satisfaction with Teaching by School Quality



Note: Showing the association between parents' satisfaction with public investments (see details on the factor analysis in Section C.4) with school quality (described in Section 4). Fit estimated with kernel-weighted local polynomial smoothing.

Table A.2: Joint Test of Balance by Treatment

	(1) All	(2) Less than college	(3) College or higher
Pre-Trial Test Score	0.024	0.025	0.026
	(0.020)	(0.025)	(0.023)
Age	0.027	-0.015	0.059
	(0.040)	(0.050)	(0.052)
Born in 2007	-0.058	0.216	-0.224^{+}
	(0.092)	(0.138)	(0.126)
Born in 2008	-0.007	0.159^{+}	-0.115
	(0.060)	(0.093)	(0.078)
Born in 2009	0.041	0.148*	-0.030
	(0.042)	(0.068)	(0.059)
Born in 2010	0.000	0.000	0.000
	(.)	(.)	(.)
Boy	-0.026	-0.050	-0.011
	(0.026)	(0.034)	(0.034)
Child's birth weight, kg	-0.055*	-0.093*	-0.027
	(0.027)	(0.040)	(0.037)
Gestation length, weeks	0.000	-0.012	0.004
	(0.009)	(0.012)	(0.012)
Apgar score	0.018	-0.002	0.026
	(0.021)	(0.033)	(0.024)
Number of siblings	-0.019	-0.028	-0.020
	(0.020)	(0.028)	(0.022)
Mother's weight, kg.	0.001	-0.000	0.002^{+}
	(0.001)	(0.001)	(0.001)
Mother's age, 2015	0.003	0.008	-0.002
	(0.004)	(0.006)	(0.005)
Mother's years of schooling	-0.005	-0.004	-0.002
	(0.008)	(0.015)	(0.009)
Mother employed in 2012	0.036	0.054	-0.003
	(0.037)	(0.051)	(0.047)
Father's years of schooling	-0.002	-0.006	0.004
	(0.009)	(0.012)	(0.011)
Father's age, 2015	-0.005	-0.002	-0.006
	(0.003)	(0.005)	(0.004)
Father employed in 2012	-0.012	-0.021	0.025
	(0.052)	(0.063)	(0.061)
Household Income	0.000	-0.000	0.000
	(0.000)	(0.001)	(0.000)
Constant	0.396	1.313	-0.135
	(0.656)	(0.800)	(0.872)
Observations	2300	838	1462

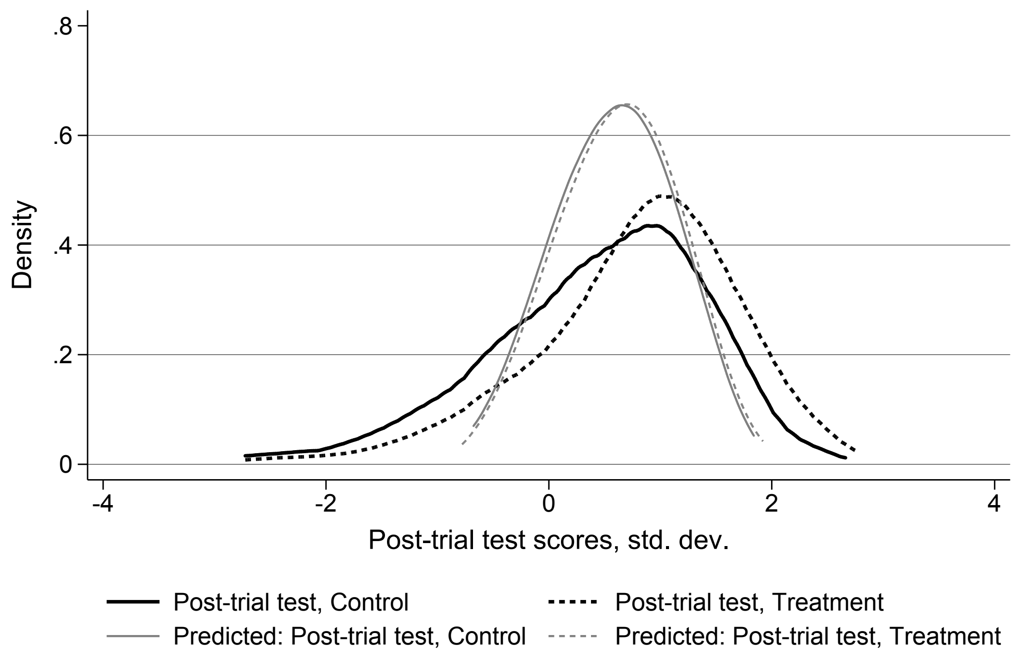
Note: The table shows regression results from outcomes y_i regressed on covariates. The pre-trial test score is standardized to

Table A.3: Test of Balance by Treatment for Outcomes Predicted from Covariates

	(1) All	(2) Less than college	(3) College or higher
Post-trial test	0.039	0.048	0.047
	(0.047)	(0.047)	(0.045)
Long run language test	0.024	0.078^{+}	0.014
	(0.057)	(0.047)	(0.051)
Parental investment factor	0.022	0.024	0.030
	(0.028)	(0.034)	(0.027)
School quality index	-0.002	0.029^{+}	-0.012
	(0.028)	(0.016)	(0.025)
Child's daily hours away from home	0.017	-0.006	0.032
	(0.027)	(0.033)	(0.029)
Parents' daily hours on work	-0.006	0.008	0.020
	(0.083)	(0.085)	(0.064)
N	2,300	838	1,462

Note: The table shows regression results from outcomes y_i predicted from a regression on covariates: $y_i = X_i'\beta$ and test $X'\hat{\beta}$. See Table 2 for a full list of the included covariates. Standard errors in parentheses. $+(p < 0.1)$,* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$.

Figure A.5: Actual and Predicted Test Score Distributions



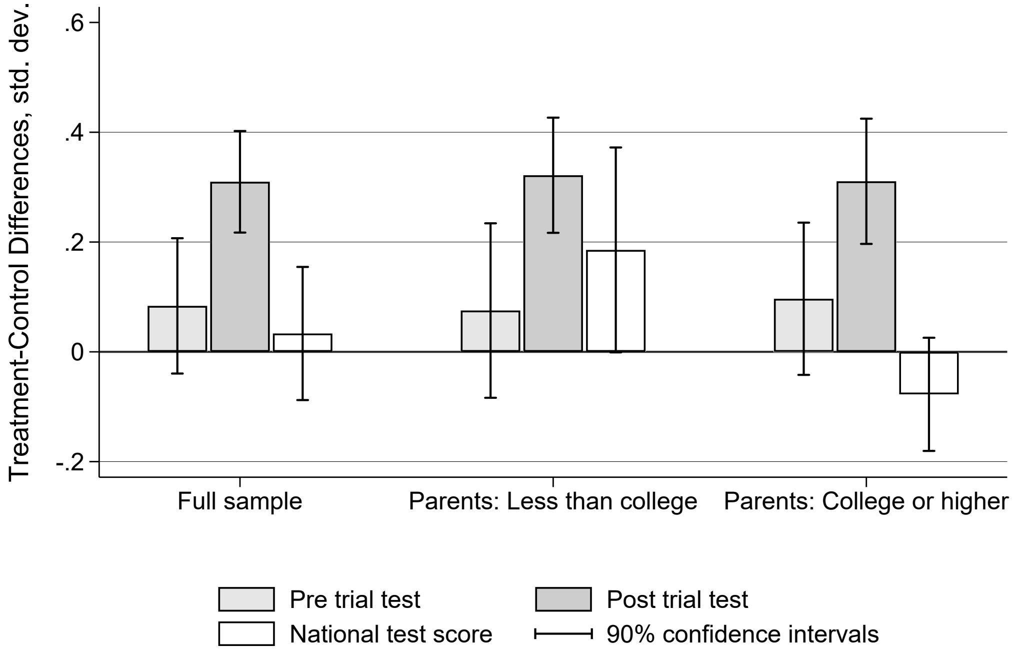
Note: The figure shows the actual post-trial test score distribution by treatment status (black lines) and predictions from regression results: $y_i = X_i'\beta$ (grey lines). See table 2 for a full list of the included covariates and Table A.2 for the mean differences in predicted test scores.

Table A.4: Correlation between Outcomes and Background Variables, Control Group

	(1) **Post-Trial Test**	(2) **National Test**	(3) **Parental Inv**	(4) **School Rank**	(5) Hrs School	(6) Hrs Work
Pre-Trial Test	0.507***	0.341***	0.115**	0.043***	0.066+	0.153+
	(0.024)	(0.034)	(0.041)	(0.013)	(0.038)	(0.085)
Year of birth	0.058*	0.022	0.171***	−0.081***	0.157***	−0.102
	(0.028)	(0.044)	(0.041)	(0.016)	(0.037)	(0.084)
Child's birth weight, kg	0.072	0.048	−0.166*	−0.035	−0.133+	0.094
	(0.059)	(0.072)	(0.083)	(0.026)	(0.076)	(0.169)
Gestation length, weeks	−0.014	0.016	−0.001	−0.009	−0.023	0.113*
	(0.018)	(0.022)	(0.027)	(0.008)	(0.024)	(0.054)
Apgar score	0.078	−0.022	−0.023	0.006	−0.045	0.000
	(0.048)	(0.062)	(0.090)	(0.022)	(0.083)	(0.184)
Child's age, 2018	−0.072*	−0.048	−0.170***	−0.010	−0.217***	0.087
	(0.033)	(0.047)	(0.049)	(0.016)	(0.045)	(0.101)
Mother's weight, kg.	−0.001	−0.001	−0.004	−0.005***	0.000	0.000
	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.005)
Mother's age, 2015	0.011*	0.036***	0.005	0.020***	−0.025**	−0.006
	(0.006)	(0.007)	(0.008)	(0.002)	(0.008)	(0.017)
Mother's years of schooling	0.069***	0.126***	0.048**	0.046***	−0.026	0.102**
	(0.011)	(0.014)	(0.018)	(0.005)	(0.016)	(0.036)
Mother employed in 2012	0.196*	0.302**	0.211+	0.125***	−0.144	1.326***
	(0.076)	(0.094)	(0.121)	(0.034)	(0.112)	(0.243)
Father's years of schooling	0.045***	0.120***	0.020	0.043***	−0.035*	0.106**
	(0.012)	(0.014)	(0.017)	(0.005)	(0.016)	(0.035)
Father's age, 2015	0.005	0.020***	0.007	0.015***	−0.015*	−0.003
	(0.005)	(0.006)	(0.007)	(0.002)	(0.007)	(0.015)
Father employed in 2012	0.078	0.268*	0.006	0.100*	−0.153	0.929**
	(0.095)	(0.120)	(0.154)	(0.043)	(0.142)	(0.314)
Household Income	0.001**	0.002***	−0.001	0.001***	0.000	0.006***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
N	1,150	770	648	692	659	659

Note: Standard errors in parentheses. $+(p < 0.1)$,* $(p < 0.05)$,** $(p < 0.01)$,*** $(p < 0.001)$. Shown are the coefficients of individual ordinary least squares regressions of one outcome (in columns) on one background variable (in rows). Not showing the constant that was also included in those regressions. Parental Education is the average of both biological parents measured in years, Household income is measured in 1,000 USD of the year 2010. The number of observations listed corresponds to the first row of regressions, and is lower for the variables from the parent survey, such as hours of school/work.

Figure A.6: Baseline Balancing, Short-Run, and Longer Run Treatment Effects - Conditional on Covariates



Note: The figure mimics Fig. 5, but is conditional on all covariates in Table 2, including pre-trial test scores for regressions of post-trial and 2nd grade language test scores. We plot Treatment-Control differences (β_t) in test scores y_{it} from $y_{it} = \alpha + \beta_t T_i + X'\delta_t + \varepsilon_{it}$ with 95% CIs on the treatment indicator. Standard errors are clustered at the institution level. Note that the sample can vary from the two pre-and post-trial tests to the 2nd grade language test score. See Table A.7 for detailed numerical results.

Table A.5: Treatment Effects, Heterogeneity by Parental Education

	Pre-Trial Test		Post-Trial Test		National Test Grade 2	
	(1)	(2)	(3)	(4)	(5)	(6)
	Low ed	High ed	Low ed	High ed	Low ed	High ed
Treatment	0.080	0.090	0.349^{***}	0.354^{***}	0.260^{**}	-0.051
	(0.093)	(0.093)	(0.088)	(0.091)	(0.109)	(0.064)
Observations	836	1462	836	1462	597	963
Pretest	No	No	No	No	No	No
Covariates	No	No	No	No	No	No
Mean Dep.var. Control	-0.305	0.110	0.242	0.539	-0.294	0.384

Note: Standard errors in parentheses. $^{*}(p < 0.10),^{**}(p < 0.05),^{***}(p < 0.01)$. Table corresponding to Fig. 5 in main text. "Low ed" is the subsample of parents who have less than 14 years of education, labeled "Less than college" in the main text, and "high ed" is given by parents with "College or more." The average of the dependent variable *among children in the control group*, by parental education, is given in "Mean Dep.var. Control."

Table A.6: Treatment Effects, Heterogeneity by Child's Pre-trial Test Scores

	Pre-trial language score		
	Q1	Q2	Q3
Treatment	0.003	-0.006	0.043
	(0.936)	(0.813)	(0.263)
Observations	830	711	759
	Post-trial language score		
	Q1	Q2	Q3
Treatment	0.379^{***}	0.348^{***}	0.222^{*}
	(0.000)	(0.000)	(0.033)
Observations	830	711	759
	2nd grade language score		
	Q1	Q2	Q3
Treatment	0.073	-0.001	-0.074
	(0.583)	(0.988)	(0.500)
Observations	559	530	454
Covariates	No	No	No

Note: p-values in parentheses. $^{*}(p < 0.10),^{**}(p < 0.05),^{***}(p < 0.01)$. Table corresponding to Table A.5 but by the child's own pre-trial test score terciles - referenced by "Q1" to "Q3".

Table A.7: Treatment Effects, Conditional Regressions by Parental Education

	Pre-Trial Test		Post-Trial Test		National Test Grade 2	
	(1)	(2)	(3)	(4)	(5)	(6)
	Low ed	High ed	Low ed	High ed	Low ed	High ed
Treatment	0.075	0.097	0.322***	0.311***	0.186	−0.077
	(0.440)	(0.257)	(0.000)	(0.000)	(0.107)	(0.222)
Child's age 1-9/17	−0.122	0.005	−0.085	−0.068	0.066	0.025
	(0.156)	(0.933)	(0.190)	(0.185)	(0.513)	(0.695)
Born in 2007	0.098	0.240	0.016	−0.270**	0.000	−0.209
	(0.748)	(0.444)	(0.944)	(0.035)	(.)	(0.152)
Born in 2008	−0.261	0.019	0.021	−0.256**	0.106	−0.115
	(0.456)	(0.954)	(0.939)	(0.036)	(0.400)	(0.225)
Born in 2009	−0.213	0.030	−0.106	−0.409**	0.134	0.000
	(0.577)	(0.920)	(0.735)	(0.014)	(0.496)	(.)
Born in 2010	−0.218	0.255	0.087	−0.567***	0.000	0.000
	(0.597)	(0.422)	(0.809)	(0.006)	(.)	(.)
Male	−0.049	−0.005	0.006	0.012	−0.282***	−0.129***
	(0.522)	(0.925)	(0.917)	(0.788)	(0.001)	(0.005)
Child's birth weight, kg	0.068	0.089	0.083	0.064	0.108	0.038
	(0.357)	(0.172)	(0.144)	(0.186)	(0.240)	(0.529)
Gestation length, weeks	0.016	0.009	−0.027	−0.017	−0.026	0.044**
	(0.546)	(0.690)	(0.241)	(0.323)	(0.308)	(0.038)
Apgar score	−0.016	−0.013	−0.027	0.047	−0.165***	−0.019
	(0.689)	(0.744)	(0.406)	(0.439)	(0.008)	(0.487)
Number of siblings	−0.078*	−0.093**	−0.067**	−0.042	0.042	−0.003
	(0.075)	(0.036)	(0.034)	(0.181)	(0.414)	(0.933)
Mother's weight, kg	−0.000	−0.002	0.001	−0.001	0.000	−0.000
	(0.999)	(0.454)	(0.721)	(0.635)	(0.976)	(0.973)
Mother Age	0.002	0.008	0.003	0.002	0.008	0.015
	(0.795)	(0.290)	(0.655)	(0.830)	(0.478)	(0.105)
Mother Educ	0.039	0.047***	−0.002	0.026**	0.042	0.031**
	(0.179)	(0.004)	(0.925)	(0.041)	(0.160)	(0.049)
Mother employed in 2012	−0.029	0.043	0.040	0.053	0.027	0.086
	(0.732)	(0.628)	(0.569)	(0.470)	(0.736)	(0.339)
Father Educ	0.014	0.041***	0.002	0.008	−0.001	0.039***
	(0.513)	(0.009)	(0.899)	(0.481)	(0.962)	(0.002)
Father Age	−0.003	−0.004	−0.004	−0.000	0.011	−0.010
	(0.655)	(0.476)	(0.572)	(0.988)	(0.237)	(0.158)
Father employed in 2012	0.064	−0.019	−0.086	−0.007	0.167	0.026
	(0.498)	(0.826)	(0.244)	(0.923)	(0.135)	(0.775)
Household Income	0.002	0.000	0.001*	−0.000	0.000	−0.000
	(0.115)	(0.703)	(0.059)	(0.832)	(0.705)	(0.873)
Pre-Trial Test			0.452***	0.449***	0.277***	0.240***
			(0.000)	(0.000)	(0.000)	(0.000)
Constant	−0.428	−1.850	2.168*	0.864	0.079	−2.701***
	(0.709)	(0.101)	(0.067)	(0.412)	(0.960)	(0.008)

Table A.8: Association of Child Skills with Parent Skills by Treatment

	(1) Pre-Trial Test	(2) Post-Trial Test	(3) National Test
Control × Parental years of schooling	0.100***	0.078***	0.165***
	(0.013)	(0.013)	(0.015)
Treated × Parental years of schooling	0.110***	0.087***	0.093***
	(0.013)	(0.013)	(0.015)
Treated	-0.076	0.220	1.129***
	(0.284)	(0.268)	(0.319)
Constant	-1.522***	-0.731***	-2.315***
	(0.201)	(0.189)	(0.229)
Observations	2300	2300	1543

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

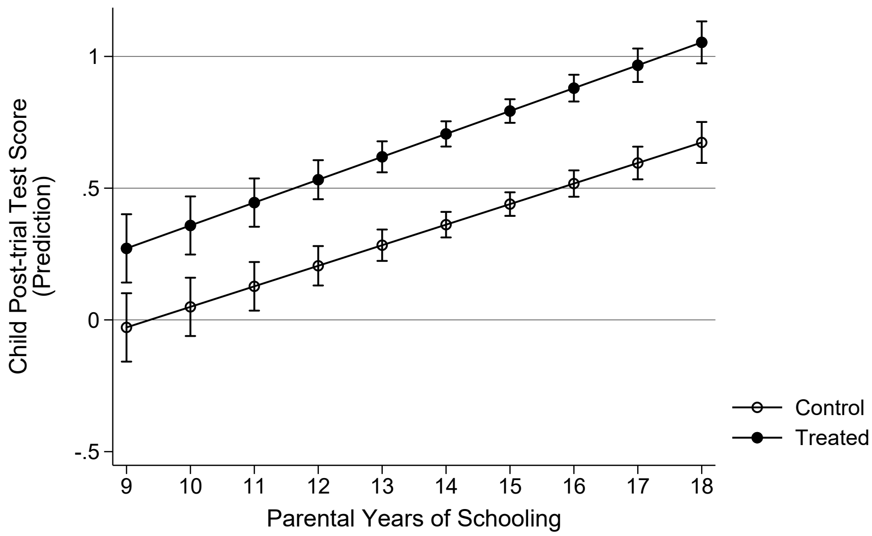
Table A.9: Treatment Effects on Parents' Behavior, Heterogeneity by Parental Education

	(1) Parental Investment Factor	(2) School Quality	(3) Hours worked/day
Treated × High school or less	0.188*	−0.013	−0.245
	(0.097)	(0.027)	(0.200)
Treated × College or more	0.125*	−0.073***	0.136
	(0.066)	(0.020)	(0.135)
High school or less	0.000	0.000	0.000
	(.)	(.)	(.)
College or more	0.277***	0.276***	0.502***
	(0.085)	(0.024)	(0.175)
Constant	−0.265***	0.355***	6.468***
	(0.071)	(0.020)	(0.146)
Observations	1336	1382	1360
Covariates	No	No	No
Mean Dep.var., High school or less	−.165	.348	6.34
Mean Dep.var., College or more	.076	.596	7.04

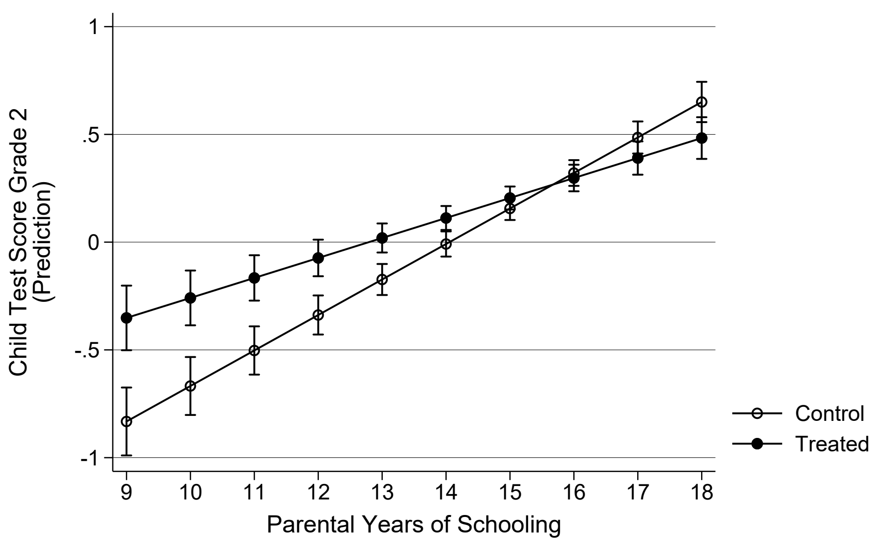
Note: Standard errors in parentheses. *($p < 0.10$),** ($p < 0.05$),*** ($p < 0.01$). Table corresponding to Fig. 6 in main text. The average of the dependent variable by parental education is given in "Mean Dep.var."
Note that the treatment effects are statistically significantly different in the treatment/control groups for school quality (p-value 0.07), but not parental investments and borderline for the work hours (p-value .11). The corresponding estimates by children's pre-trial test scores are presented in Table A.10.

Figure A.7: Association of Child Skills with Parent Skills by Treatment

a) Post-trial Test Scores (Preschool)



b) Test Scores 2nd Grade (School)



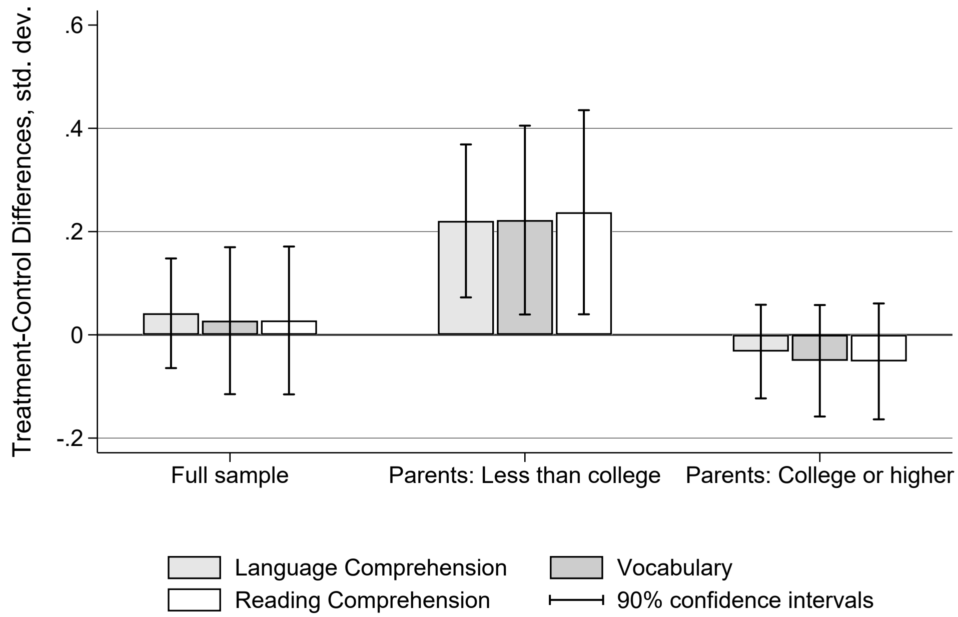
Note: Showing predicted values for a) post-trial test scores in preschool, and b) 2nd-grade language test scores, from the regression in Table A.8, which used a linear term for average parental highest years of education interacted with a treatment indicator.

Table A.10: Treatment Effects on Parents' Behavior, Heterogeneity by Child's Pre-trial Test Scores

	(1) Parental Investment Factor	(2) School Quality	(3) Hours worked/day
Treated × Pre-test Tercile=1	0.235**	−0.068**	0.007
	(0.095)	(0.030)	(0.198)
Treated × Pre-test Tercile=2	0.139	−0.041	0.155
	(0.097)	(0.029)	(0.202)
Treated × Pre-test Tercile=3	0.032	−0.109***	−0.165
	(0.091)	(0.030)	(0.190)
Pre-test Tercile=1	0.000	0.000	0.000
	(.)	(.)	(.)
Pre-test Tercile=2	0.123	0.043	0.252
	(0.096)	(0.029)	(0.199)
Pre-test Tercile=3	0.319***	0.101***	0.441**
	(0.095)	(0.030)	(0.198)
Constant	−0.220***	0.498***	6.588***
	(0.067)	(0.020)	(0.139)
Observations	1336	1383	1360
Covariates	No	No	No

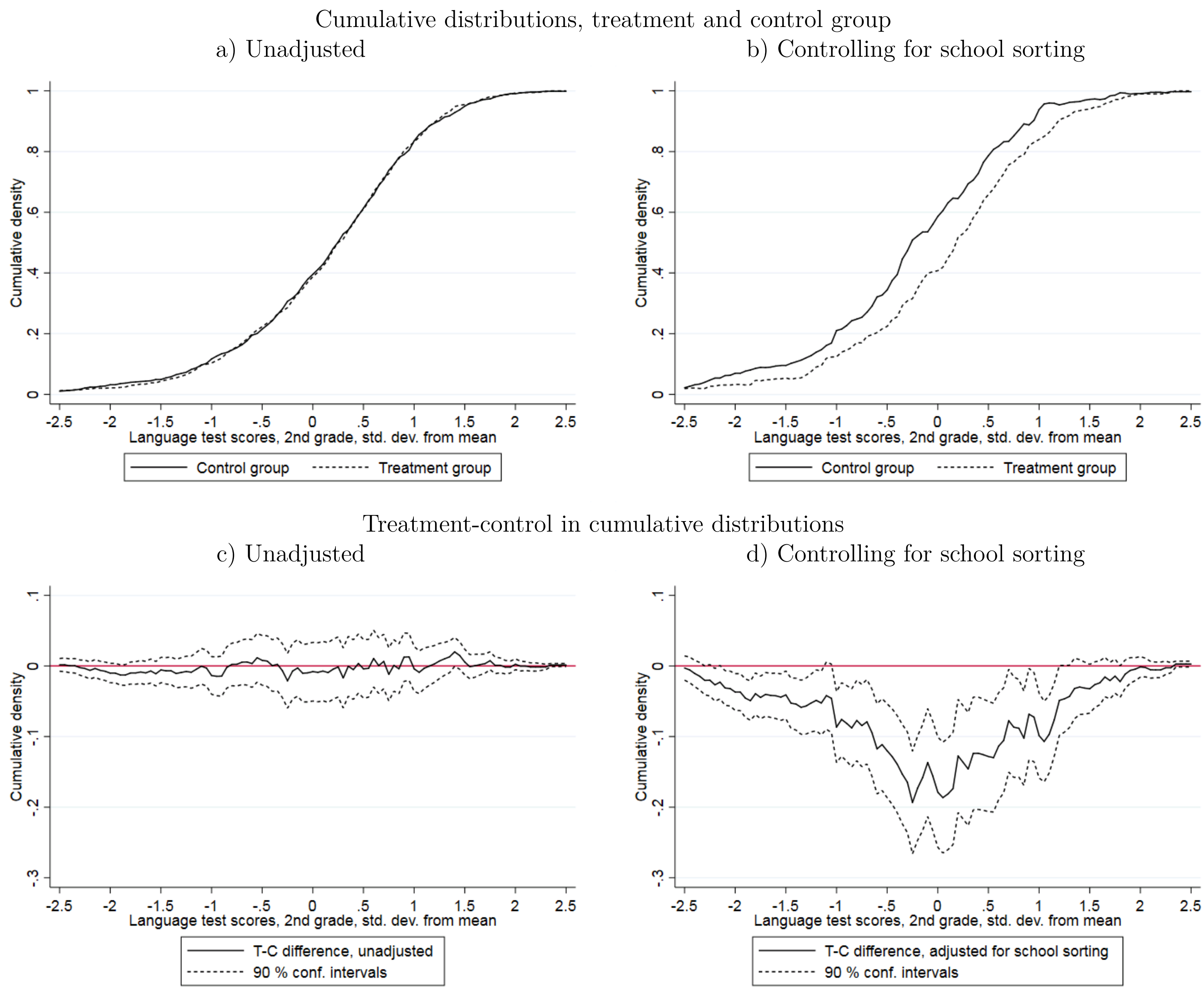
Note: Standard errors in parentheses. $^{*}(p < 0.10)$,** $(p < 0.05)$,*** $(p < 0.01)$. Table corresponding to Table A.9 but by the child's own pre-trial test score terciles - referenced by "Q1" to "Q3".

Figure A.8: Longer Run Treatment Effects by Language-Skill Dimension and Parental Education



Note: Showing coefficients with 95% CIs on the treatment indicator, from regressions of 2nd-grade sub-test-scores on the treatment indicator, clustering standard errors at the institute level.

Figure A.9: Cumulative distribution of language test scores, 2nd grade



B Technical Appendix

B.1 The General Model

This appendix formally derives the main results presented in Section 2.

The technology of skill formation we use begins with a standard production function for univariate end-of-period skills θ_t that includes self-productivity from θ_{t-1} and investments I_t:

$$\theta_t = j(\theta_{t-1}, I_t) \tag{A.1}$$

Investment is itself a function of parental direct investments P_t and skill investments via the institutional setting, or public G_t, where parents shape $P_t = p(x_t, \theta_P)$ through direct time investments x_t, of which the efficacy depends on their own skills θ_P:

$$I_t = m\left(p(x_t, \theta_P), g\left(\underline{G}, \kappa Y_t, et_t, \theta_P\right)\right), \tag{A.2}$$

Skill investments via the institutions G_t are a function $g()$ of parental quality and three levels of institutions: The average level of public institutions, $\underline{G}$, which parents take as given. Institutional investments depend also on 1) selection into neighborhoods, which is paid for by fraction κ of parents' income, and 2) differences in school quality within neighborhoods. Parents influence public investments G_t through the two last channels, where they select into neighborhoods through spending income, and they select into schools within neighborhoods through spending time on school choice e_t.

$$G_t = g(\underline{G}, \kappa Y_t, e_t, \theta_P), \qquad t \in \{1, 2\} \tag{A.3}$$

Before we continue with the model and the derivations, we briefly pause to motivate the use e_t. In the paper we provide evidence of and discuss how parents can sort even within a given neighborhood (that is in addition to the sorting the comes from income). This could for example be via exploring the quality of schools (with via public available records or from visiting schools), contacting administrative personnel in charge of slots in preschools or schools. We do not posit that e in absolute terms is as large as x or h, only that this effort also affects realized school quality.Furthermore, in essence e is simply an input into institutional sorting that has the same opportunity costs in terms of foregone leisure as time spent on home-investments (x). While labor supply h has the same effect in terms of increasing institutional investments at the expense of leisure, labor supply also enters utility through its effects on consumption. Hence, the intuition is clearer when we focus on e as it allows us to distill parents' tradeoff when balancing home and institutional investments.

Parents receive an hourly wage w for their labor h_t, where w is a function ω of their quality. Thus, income depends on $w = \omega(\theta_P)$, and time spent working h_t.

$$Y_t = h_t w, \qquad t \in \{1, 2\} \tag{A.4}$$

Parents thus spend all their available time of 1 on work, direct investments, school selection, or leisure l_t:

$$1 = h_t + x_t + e_t + l_t \quad \text{for} \quad t \in \{1, 2\} \tag{A.5}$$

If we consider a 2-period model, parental **utility** is the following function of own consumption and children's future skills:

$$U(c_1, c_2, l_1, l_2, \theta_2) = u_1(c_1, l_1) + \beta u_2(c_2, l_2) + \beta^2 V(\theta_2) \tag{A.6}$$

where β is the discount factor. **Without borrowing**, parents' budget constraints each period are:[38]

$$\begin{aligned} c_1 &= (1-\kappa)Y_1 \\ c_2 &= (1-\kappa)Y_2 \end{aligned} \tag{A.7}$$

Parents then maximize their utility, subject to time and budget constraints and the tech-

[38] Below we will also consider the case where parents can borrow freely at the same rate as implied by the discount factor β.

nology described in Eqs. (A.1) to (A.3). The Lagrangian for this problem (ignoring the non-negativity constraints on time use) is

$$\begin{aligned}
\mathcal{L}_{c_1,c_2,h_1,h_2,x_1,x_2,e_1,e_2} &= u_1(c_1,l_1) + \beta u_2(c_2,l_2) + \beta^2 V\left(\theta_2\left(\theta_1(\theta_0,I_1),I_2\right)\right) \\
&+ \lambda_1\left(h_1 w(1-\kappa) - c_1\right) \\
&+ \lambda_2\left(h_2 w(1-\kappa) - c_2\right) \\
&+ \lambda_3\left(1 - h_1 - x_1 - e_1 - l_1\right) \\
&+ \lambda_4\left(1 - h_2 - x_2 - e_2 - l_2\right)
\end{aligned}$$

B.1.1 General First-Order Conditions in Absence of Shock to Public Quality

The **First Order Conditions** are

$$\frac{\partial \mathcal{L}}{\partial c_1}: \quad \frac{\partial u_1}{\partial c_1} = \lambda_1 \tag{FOC.c_1}$$

$$\frac{\partial \mathcal{L}}{\partial c_2}: \quad \beta \frac{\partial u_2}{\partial c_2} = \lambda_2 \tag{FOC.c_2}$$

$$\frac{\partial \mathcal{L}}{\partial l_1}: \quad \frac{\partial u_1}{\partial l_1} = \lambda_3 \tag{FOC.l_1}$$

$$\frac{\partial \mathcal{L}}{\partial l_2}: \quad \beta \frac{\partial u_2}{\partial l_2} = \lambda_4 \tag{FOC.l_2}$$

$$\frac{\partial \mathcal{L}}{\partial x_1}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial P_1} \frac{\partial P_1}{\partial x_1} = \lambda_3 \tag{FOC.x_1}$$

$$\frac{\partial \mathcal{L}}{\partial x_2}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial P_2} \frac{\partial P_2}{\partial x_2} = \lambda_4 \tag{FOC.x_2}$$

$$\frac{\partial \mathcal{L}}{\partial e_1}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial G_1} \frac{\partial G_1}{\partial e_1} = \lambda_3 \tag{FOC.e_1}$$

$$\frac{\partial \mathcal{L}}{\partial e_2}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial e_2} = \lambda_4 \tag{FOC.e_2}$$

$$\frac{\partial \mathcal{L}}{\partial h_1}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial G_1} \frac{\partial G_1}{\partial h_1} + \lambda_1 w(1-\kappa) = \lambda_3 \tag{FOC.h_1}$$

$$\frac{\partial \mathcal{L}}{\partial h_2}: \quad \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial h_2} + \lambda_2 w(1-\kappa) = \lambda_4 \tag{FOC.h_2}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_1}: \quad h_1(1-\kappa)w = c_1 \tag{FOC.λ_1}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2}: \quad h_2(1-\kappa)w = c_2 \tag{FOC.λ_2}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_3}: \quad h_1 + x_1 + e_1 + l_1 = 1 \tag{FOC.λ_3}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_4}: \quad h_2 + x_2 + e_2 + l_2 = 1 \tag{FOC.λ_4}$$

It immediately follows from Eqs. (FOC.x_1) to (FOC.e_2) that

$$\frac{\partial V(\theta_2)}{\partial x_t} = \frac{\partial V(\theta_2)}{\partial e_t}$$

$$\leftrightarrow \frac{\partial V}{\partial \theta_2}\frac{\partial \theta_2}{\partial I_t}\frac{\partial I_t}{\partial P_t}\frac{\partial P_t}{\partial x_t} = \frac{\partial V}{\partial \theta_2}\frac{\partial \theta_2}{\partial I_t}\frac{\partial I_t}{\partial G_t}\frac{\partial G_t}{\partial e_t}$$

$$\leftrightarrow \frac{\partial I_t(P_t, G_t)}{\partial P_t}\frac{\partial P_t(x_t, \theta_P)}{\partial x_t} = \frac{\partial I_t(P_t, G_t)}{\partial G_t}\frac{\partial G_t(\underline{G}, \kappa Y_t, e_t, \theta_P)}{\partial e_t} \qquad \text{for} \quad t \in \{1, 2\} \tag{A.8}$$

Note that this equality between the productivities of parental investments via direct time spent with children (x_t) and via institutional selectivity (e_t) is a very general result that holds in both periods, and which does not depend on the possibility of borrowing or the budget constraints. It results simply from the condition that in optimality, parents must be indifferent between how to invest time in their children's skill formation.

In fact, Eq. (A.8) is a general result for any within-period (not just two as we consider here) optimization **only assuming that functions are twice differentiable and $I()$ is increasing in P and G, and $p()$ and $g()$ increasing in x_t and e_t, respectively.**

B.1.2 Marginal Rate of Technical Substitution

Rewriting Eq. (A.8), it becomes evident that in each period, the marginal rate of technical substitution in the "production" of I between home and institutional investments is given by:

$$\text{MRTS}(P_t, G_t) = \frac{\partial I(P_t, G_t)/\partial P_t}{\partial I(P_t, G_t)/\partial G_t} = \frac{\partial g(\underline{G}, \kappa Y_t, e_t, \theta_P)/\partial e_t}{\partial p(x_t, \theta_P)/\partial x}, \qquad t \in \{1, 2\} \tag{A.9}$$

This formulation highlights the close link between the "outer" production function for investments, $I(P, G)$, and the "inner" production functions for parental and institutional-specific investments as they depend on parental time investments in terms of direct investments x_t and school choice activities e_t. It becomes evident that assumptions about how P_t and G_t interact in producing overall investments I_t immediately have implications for the micro-foundations of these sub-types of investments by parental time e_t and x_t. The productivities of investments at home and in the institutional setting are inherently linked at the "outer" and "inner" parts of the production functions. For example, when assuming a Cobb-Douglas production technology for I_t, shaping the ratio of $\frac{\partial I_t}{\partial P_t} / \frac{\partial I_t}{\partial G_t}$ limits the possible production functions for how parental time uses shape P_t and G_t individually, influencing $\frac{\partial P_t}{\partial x_t} / \frac{\partial G_t}{\partial e_t}$.

Equation A.9 states that the marginal rate of technical substitution (MRTS) between home and institutional investments as inputs in total investments in human capital formation must equal the ratio between the marginal productivity of parents' time spent on investments at home and in an institutional setting.

As the opportunity costs of increasing x and e are identical, it must hold that if parents choose time inputs in home investments at a level where additional time spent at home would increase home investments P more than a similar change in e would increase institutional investments G, then it must be because the marginal return to home investments P in total investments I is lower than the marginal return to institutional investments G in total investments I.

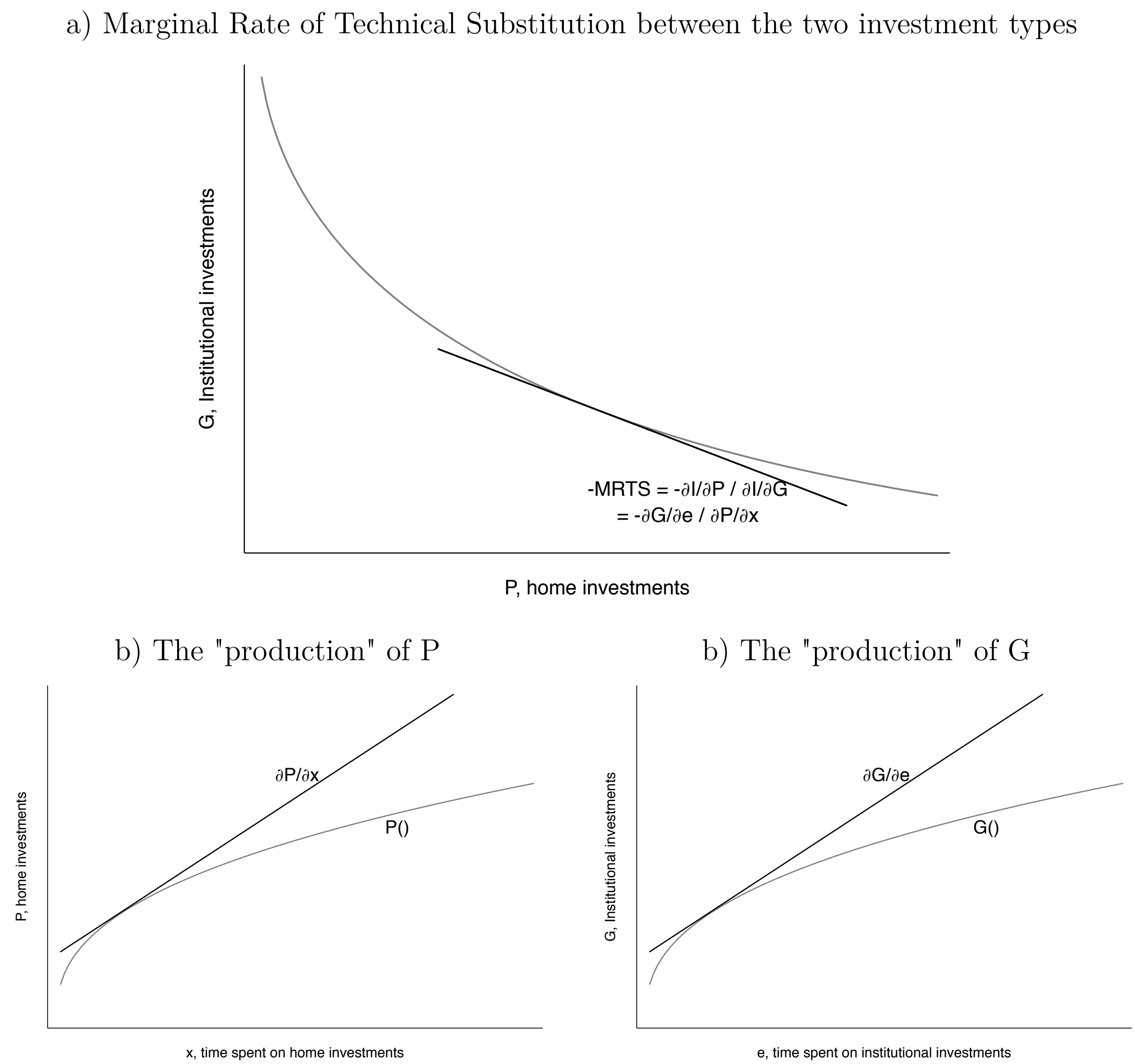
Figure A.10 presents a graphical illustration of the intuition. Figure A.10a shows the isoquant between home and institutional investments, and the associated MRTS (the tangent). The tangent in Figure A.10a must equal to ratio between the two marginal products of time spent at home and on institutional sorting, illustrated in Figures A.10b and A.10c.

The elasticity of substitution between P and G is then given by:

$$\varepsilon_{P,G} = \left[\frac{\partial \text{MRTS}(P,G)}{\partial (P/G)} \frac{P/G}{\text{MRTS}(P,G)} \right]^{-1} \tag{A.10}$$

The second term of the product in Eq. (A.10) will always be positive (because we have assumed that both e_t and x_t are always strictly productive in their respective investment functions). Therefore, whether P and G are substitutes or complements in the "production" of investments (whether $\varepsilon_{P,G}$ is positive or negative), depends on the sign of the first term, which relates a change in the MRTS to an underlying change in the ratio of parental to public investments (P/G). This is useful to analyze what happens when institutional invest-

Figure A.10: Optimal choices of G and P



Note: The figure illustrates the marginal rate of technical substitution (MRTS) between home and institutional investments, and how this relates to the marginal product of time spent on home investments and institutional investments (through e.g., sorting). For illustrative purposes, a) is constructed from a CES function with an elasticity of substitution of 0.5, while both home and institutional investments in b) and c) are drawn as having concave production functions.

ments increase because public quality ($\underline{G}$) increased. This would initially lower P/G. From Eq. (A.9), we have that $\text{MRTS}(P_t, G_t) = \frac{\partial g}{\partial e_t} \Big/ \frac{\partial p}{\partial x_t}$, which implies that the elasticity of substitution between home and institutional investments depends on the slopes of $g()$ and $p()$ as a function of e_t and x_t. Thus, if it is observed (at current levels of P and G) that home and institutional investments are *substitutes* ($\varepsilon_{P,G} > 0$), then $\partial\text{MRTS}(P_t, G_t)/\partial(P/G)$ must be positive. Note that this analysis has to factor in parental responses to both e_t and x_t, as they together produce the elasticity. If the increase in $\underline{G}$ even after parental adjustments leads to a decrease in P/G, the marginal productivity of $g()$ with respect to e_t must fall relative to the marginal productivity of $p()$ with respect to x_t. If home and institutional investments are complements,[39] the first term of Eq. (A.10) has to be negative. The joint changes of e_t and x_t, and how these changes investments in the home and institutional setting, will inform us of the sign of the elasticity of substitution. We will return to this key result below.

Another set of noteworthy equilibrium conditions are the following expressions that relate the marginal utilities of the available parental time uses:

$$\frac{\partial u_1}{\partial l_1} = \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial P_1} \frac{\partial P_1}{\partial x_1} \tag{A.11}$$

$$= \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial G_1} \frac{\partial G_1}{\partial e_1}$$

$$\frac{\partial u_1}{\partial l_1} = \beta^2 \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial I_1} \frac{\partial I_1}{\partial G_1} \frac{\partial G_1}{\partial h_1} + \frac{\partial u_1}{\partial c_1} w(1-\kappa) \tag{A.12}$$

$$\frac{\partial u_2}{\partial l_2} = \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial P_2} \frac{\partial P_2}{\partial x_2} \tag{A.13}$$

$$= \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial e_2}$$

$$\frac{\partial u_2}{\partial l_2} = \beta \frac{\partial V}{\partial \theta_2} \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial G_2} \frac{\partial G_2}{\partial h_2} + \frac{\partial u_2}{\partial c_2} w(1-\kappa) \tag{A.14}$$

In equilibrium, parents must be indifferent in allocating their time to additional leisure (giving direct utility), direct investments in children or via school choice (giving indirect utility through future child skills), or labor (allowing greater consumption for direct utility

[39]Naturally, the elasticity of substitution can vary along the production possibility frontier. We will consider the specific conclusions from a CES function below.

or improving neighborhood public goods that raise future child skills).

B.1.3 Allowing Borrowing in General Model

With free borrowing at an interest rate of $r = 1/\beta - 1$, the previous first-order conditions all remain except for Eq. (FOC.λ_1) and Eq. (FOC.λ_2), and there will be added one first-order condition for borrowing amount B. The latter one will imply $\lambda_1 = \frac{1}{\beta}\lambda_2$, which immediately yields an additional across-period equilibrium condition of

$$\frac{\partial u_1}{\partial c_1} = \frac{\partial u_2}{\partial c_2} \tag{A.15}$$

To arrive at more direct implications of the model, we will have to introduce further restrictions.

B.2 The Specific Model: Early Residential Choice and Borrowing

A central part of the model is how parents' can influence the institutional investments. One way to do so is through residential choices. However, this is not completely flexible in practice, and empirically it is observed that most families settle with their children before the child starts school (see Section 5 in the main text, Fig. A.1 in the appendix, and Cholli et al., 2020). We therefore introduce a change with respect to the above set-up that renders the parents' decision problem more realistic, such that parents do not move between the different schooling stages of their children.

B.2.1 Introducing Lock-in of Early Residential Choices

We let the neighborhood quality be determined by *initial* parental income in period 1, not re-optimized each period. This alters the budget constraint, where neighborhood expenditures are fixed at $\kappa w h_1$, and h_1 influences on θ_2 not only via G_1 and thus θ_1, but also via public quality G_2.

$$c_1 + \kappa Y_1 = Y_1 \qquad \Leftrightarrow c_1 = h_1(1-\kappa)w \tag{A.16}$$

$$c_2 + \kappa Y_1 = Y_2 \qquad \Leftrightarrow c_2 = h_2 w - h_1 \kappa w$$

The Lagrangian for the more realistic problem changes to

$$\begin{aligned}
\mathcal{L}_{c_1,c_2,h_1,h_2,x_1,x_2,e_1,e_2} &= u_1(c_1,l_1) + \beta u_2(c_2,l_2) \\
&+ \beta^2 V\left(\theta_2\left(\theta_1(\theta_0,I_1),I_2\right)\right) \\
&+ \lambda_1\left(h_1 w(1-\kappa) - c_1\right) \\
&+ \lambda_2\left(h_2 w - h_1\kappa w - c_2\right) \\
&+ \lambda_3\left(1 - h_1 - x_1 - e_1 - l_1\right) \\
&+ \lambda_4\left(1 - h_2 - x_2 - e_2 - l_2\right)
\end{aligned}$$

using the same technology as above, and as there not allowing borrowing across periods. The altered **First Order Conditions** (relative to the general model of Section B.1) are

$$\frac{\partial \mathcal{L}}{\partial h_1}: \quad \beta^2 \frac{\partial V}{\partial \theta_2}\left[\frac{\partial \theta_2}{\partial \theta_1}\frac{\partial \theta_1}{\partial I_1}\frac{\partial I_1}{\partial G_1}\frac{\partial G_1}{\partial h_1} + \frac{\partial \theta_2}{\partial I_2}\frac{\partial I_2}{\partial G_2}\frac{\partial G_2}{\partial h_1}\right] + \lambda_1 w(1-\kappa) - \lambda_2\kappa w - \lambda_3 = 0 \tag{A.17}$$

$$\frac{\partial \mathcal{L}}{\partial h_2}: \qquad \lambda_2 w = \lambda_4 \tag{A.18}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_2}: \qquad h_2 w - h_1\kappa w = c_2 \tag{A.19}$$

The equilibrium conditions of the previous section are maintained (Eq. (A.8), Eq. (A.11) and Eq. (A.13)), except for Eq. (A.12) and Eq. (A.14), where specifically the latter becomes

$$\frac{\partial u_2}{\partial l_2} = w\frac{\partial u_2}{\partial c_2}. \tag{A.20}$$

The first order conditions can be further combined **if we assume a specific restriction on** $g()$ of Eq. (A.2) (but without losing generality), that within the function for investments from the institutional setting, the marginal productivity of parental labor time is proportional to the marginal productivity of time spent on school sorting:

$$\frac{\partial g_1}{\partial h_1} = \frac{\partial g_1}{\partial e_1}\kappa w \tag{A.21}$$

$$\frac{\partial g_2}{\partial h_1} = \frac{\partial g_2}{\partial e_2}\kappa w \tag{A.22}$$

This allows us to rewrite Eq. (A.17) as follows, because $\beta^2 \frac{\partial V}{\partial \theta_2}\frac{\partial \theta_2}{\partial \theta_1}\frac{\partial \theta_1}{\partial I_1}\frac{\partial I_1}{\partial G_1}\frac{\partial G_1}{\partial h_1} = \kappa w \lambda_3$ in Eq. (FOC.e_1), and $\beta^2 \frac{\partial V}{\partial \theta_2}\frac{\partial \theta_2}{\partial I_2}\frac{\partial I_2}{\partial G_2}\frac{\partial G_2}{\partial h_1} = \kappa w \lambda_4$ in Eq. (FOC.e_2):

$$\kappa w \lambda_3 + \kappa w \lambda_4 + \lambda_1(1-\kappa)w = \lambda_2 \kappa w + \lambda_3$$

$$\lambda_2 \kappa w(w-1) + \lambda_1(1-\kappa)w = \lambda_3(1-\kappa w) \qquad \text{using Eq. (A.18)}$$

Adding to this last expression equations FOC.c_1, FOC.c_1, and FOC.l_1, we get that the marginal utility of labor in period 1 is a function of both marginal utility of consumption in period 1 and 2.

$$\frac{\partial u_1}{\partial c_1}(1-\kappa)w - \frac{\partial u_2}{\partial c_2}\kappa w(1-w) = \frac{\partial u_1}{\partial l_1}(1-\kappa w), \tag{A.23}$$

which reflects that residential choice today affects future residential choice and thereby also future expenses to housing and what fraction of income that is left for consumption. The consequence is that period 1 labor supply will be increased to a higher point than it would otherwise have been (i.e. parents are going to work more than they would otherwise have done when the child is young).

B.2.2 Introducing Free Borrowing

When we additionally **allow for free borrowing** at interest rate $r = 1/\beta - 1$ (but not allowing parents to leave positive or negative financial bequests), the new budget constraints in each period are

$$c_1 = (1-\kappa)Y_1 + B$$

$$c_2 = (1-\kappa)Y_2 - \frac{1}{\beta}B$$

and Eq. (A.23) changes to:

$$\lambda_1\left[(1-\kappa)w+\beta\kappa w(w-1)\right]=\lambda_3(1-\kappa w) \qquad \text{using that } \lambda_1=\lambda_2/\beta \text{ when allowing for borrowing}$$
$$\lambda_1 w d_w=\lambda_3 \qquad \text{defining } d_w\equiv\frac{1-\kappa-(1-w)\beta\kappa}{1-\kappa w} \tag{A.24}$$

The denotation of constant d_w is to serve as a reminder that it is a function of parental earnings w, which reflect parental quality θ_P. Adding the FOCs for consumption and leisure, it can be shown that

$$wd_w\frac{\partial u_1}{\partial c_1}=\frac{\partial u_1}{\partial l_1} \tag{A.25}$$

This corresponds to period 2, where the marginal utility of consumption must equal the marginal utility of leisure (combining Eqs. (A.18), (FOC.c_2) and (FOC.l_2)):

$$w\frac{\partial u_2}{\partial c_2}=\frac{\partial u_2}{\partial l_2} \tag{A.26}$$

Rewriting Eq. (A.24) further proves quite useful. Using the FOCs for B and h_2, which result in $\lambda_1=\frac{1}{\beta}\lambda_2=\frac{1}{\beta w}\lambda_4$, we obtain $\frac{d_w}{\beta}\lambda_4=\lambda_3$. This allows us to combine the FOCs for x_1 and x_2, and e_1 and e_2 as well as l_1 and l_2:

$$wd_w\frac{\partial u_1}{\partial c_1}=\frac{\partial u_1}{\partial l_1} \tag{A.27}$$
$$=\beta^2\frac{\partial V}{\partial\theta_2}\frac{\partial\theta_2}{\partial\theta_1}\frac{\partial\theta_1}{\partial I_1}\frac{\partial I_1}{\partial P_1}\frac{\partial P_1}{\partial x_1} \tag{A.28}$$
$$=\beta^2\frac{\partial V}{\partial\theta_2}\frac{\partial\theta_2}{\partial\theta_1}\frac{\partial\theta_1}{\partial I_1}\frac{\partial I_1}{\partial G_1}\frac{\partial G_1}{\partial e_1} \tag{A.29}$$

$$\leftrightarrow$$

$$d_w\frac{\partial u_2}{\partial l_2}=\frac{\partial u_1}{\partial l_1} \tag{A.30}$$
$$\frac{d_w}{\beta}\frac{\partial\theta_2}{\partial x_2}=\frac{\partial\theta_2}{\partial x_1} \tag{A.31}$$

$$\frac{d_w}{\beta}\frac{\partial\theta_2}{\partial e_2}=\frac{\partial\theta_2}{\partial e_1} \tag{A.32}$$

Across periods, parental investments must have equal discounted productivity, weighted with term d_w. These results depend on both the budget constraint with free borrowing for parents within periods 1 and 2, and the specific functional form with proportional productivities of investments via institutional quality through school or neighborhood sorting.

B.3 Inserting Functional Forms

Let us now specify all functional forms. Given that allowing for borrowing gives rise to interesting across-period equilibrium conditions that correspond to optimal investment paths over time, we now continue with the model of Section B.2, which allows borrowing (which nevertheless leaves the within-period results largely unchanged), and with the lock-in effect of residential choice in period 1. The standard functional form for skill formation can be used as a CES specification:

$$\theta_t = [\gamma\theta_{t-1}^{\phi} + (1-\gamma)I_t^{\phi}]^{1/\phi}, \qquad t \in \{1, 2\} \tag{A.33}$$

Note that this specification implies a separability of all investments from previous skills. Investment I_t can similarly be generated by a CES function:

$$I_t = [\pi P_t^{\sigma} + (1-\pi)G_t^{\sigma}]^{1/\sigma}, \qquad t \in \{1, 2\} \tag{A.34}$$

This formulation is agnostic about whether P_t and G_t are substitutes or complements, allowing $\sigma \in \{1, -\infty\}$. For g, f, and $u()$:

$$P_t = (x_t\theta_P)^a, \ 0 < a < 1 \tag{A.35}$$

$$G_t = (\underline{G} + \kappa w h_1 + e_t)^b, \ 0 < b < 1 \tag{A.36}$$

$$u(c_t, l_t) = \alpha ln(c_t) + (1-\alpha)ln(l_t) \tag{A.37}$$

$$V(\theta_2) = \nu ln(\theta_2) \tag{A.38}$$

The above optimality conditions in Eqs. (A.8), (A.13) and (A.20), which result from the general set-up, become

$$x_t = \left[\frac{a}{b}\frac{\pi}{1-\pi}\theta_P^{a\sigma}\left(\underline{G} + \kappa w h_1 + e_t\right)^{1-b\sigma}\right]^{\frac{1}{1-a\sigma}} \qquad \text{for } t \in \{1,2\} \tag{A.39}$$

$$\frac{1-\alpha}{l_2} = \beta\nu\pi a\theta_p \left[\gamma\theta_1^{\phi} + (1-\gamma)I_2^{\phi}\right]^{\frac{1}{\phi}-1-\phi}\left[\pi P_2^{\sigma} + (1-\pi)G_2^{\sigma}\right]^{\frac{1-\sigma}{\sigma}} P_2^{\sigma-1/a} \tag{A.40}$$

$$c_2 = w\frac{\alpha}{1-\alpha}l_2. \tag{A.41}$$

With borrowing across periods and the assumed functional forms, we also obtain the following equilibrium conditions (refer to Eqs. (A.30) to (A.32), and Eq. (A.25), respectively):

$$l_2 = d_w l_1 \tag{A.42}$$

$$\frac{x_1}{x_2} = \left[\frac{\beta\gamma}{d_w}\left(\frac{I_1}{I_2}\right)^{\phi-\sigma}\right]^{\frac{1}{1-a\sigma}} \tag{A.43}$$

$$\frac{G_1}{G_2} = \left[\frac{\beta\gamma}{d_w}\left(\frac{I_1}{I_2}\right)^{\phi-\sigma}\right]^{\frac{1}{1/b-\sigma}} \tag{A.44}$$

$$c_1 = w\frac{\alpha}{1-\alpha}d_w l_1 \tag{A.45}$$

Across periods Several equilibrium conditions are informative about how parental investments relate to each other over time. For example, Eq. (A.39) from the general setup can be used to show how the ratio of early to late direct investments depends on the ratio of investments x_t and e_t (dividing the expressions for both periods):

$$\frac{x_1}{x_2} = \left[\frac{\underline{G} + \kappa w h_1 + e_1}{\underline{G} + \kappa w h_1 + e_2}\right]^{\frac{1-b\sigma}{1-a\sigma}} \tag{A.46}$$

Equation (A.42) shows that while consumption is equal across the two periods for all parents, leisure is not necessarily equal. Parents consume the same amount of leisure in both periods only if $d_w = 1$, that is if $w = 1$. The derivative of d_w with respect to w is positive,[40] thus the ratio of l_2/l_1 is *increasing* in w, therefore it is increasing in parental quality. High earning parents have less leisure early relative to later than low-earning parents. That does not mean that they have lower *levels* than low-earning parents.

[40]Because if $\kappa < 1$, and unless $\kappa w = 1$, $\frac{\partial d_w}{\partial w} = \frac{(1-\kappa)(1+\beta\kappa w)}{(1-\kappa w)^2} = \frac{\pm}{+} > 0$.

Within periods Other conditions relate different choice variables within periods, such as Eqs. (A.41) and (A.45), but also Eq. (A.39).

A full expression of children's skills in period 2 can be obtained if we further align the functional forms of investments in private and public by setting $a = b$. Then, the full production function can be expressed as:

$$\theta_2 = \left\{ \gamma^2 \theta_0^{\phi} + \gamma(1-\gamma)\left[H(\theta_P)x_1^a\right]^{\phi} + (1-\gamma)\left[H(\theta_P)x_2^a\right]^{\phi} \right\}^{1/\phi} \tag{A.47}$$

where $H(\theta_P) = \theta_P^a \pi^{\frac{1}{\sigma}} \left[1 + \frac{\pi}{(1-\pi)}^{\frac{1}{a\sigma-1}} \theta_P^{\frac{a\sigma}{a\sigma-1}}\right]^{1/\sigma}$ is an *investment multiplier* capturing that parents' investments become more effective as their skills increase in the first term in the brackets and in the second term that parents' investment choices depend on whether investments at home or in an institutional setting are substitutes or complements.[41] Thus, $H(\theta_P)$ captures the inequality in total investments in a given period for a given level of parental home investments x_t.

B.4 Effects of a Shock to Institutional Investments (Increase in $\underline{G}$)

Our empirical setting changes $\underline{G}$ randomly in period 1, say by the amount s. Parents who were treated then expect that total G in period 2 becomes $G_2 = g\left((\underline{G} + s) + \kappa w h_1 + e_2\right)$. This change in the framework within which parents make decisions will cause treated parents to re-optimize their time allocation for the second period (they cannot re-allocate debt, which is repaid in period 2). The relevant equilibrium conditions involving first-order conditions for second-period time variables are Eqs. (A.39) and (A.41). Equation (A.41), together with the time and budget constraints for period 2, becomes the following:

$$h_2 = \alpha(1 - x_2 - e_2) + (1-\alpha)(h_1\kappa + \frac{1}{w\beta}B) \tag{A.48}$$

[41] $\frac{\partial H}{\partial \theta_P} > 0$ as long as $1 + \frac{a\sigma}{a\sigma-1}\theta_P^{\frac{a\sigma}{a\sigma-1}} > 0$ which it will be in all but a few special cases where θ_P close to 0 and $a\sigma$ is close to 1.

Equation (A.39) in a convenient format lets us look at comparative statics:

$$x_2^{1-a\sigma} = \theta_P \frac{a}{b} \frac{\pi}{1-\pi} \left((\underline{G} + s) + \kappa w h_1 + e_2 \right)^{1-b\sigma} \tag{A.49}$$

When the right hand side of Eq. (A.49) increases by s for the treated group, the adjustment back to optimality can happen through a *reduction* in e_2 and/or an *increase* in x_2 on the left hand side. At this point, the magnitudes of these changes cannot be determined yet, but we can study the ratio of possible changes that yield optimality.

$$\frac{\Delta x_2}{\Delta e_2 + s} = \frac{1-b\sigma}{1-a\sigma} \frac{a}{b} \frac{\pi}{1-\pi} \left(\underline{G} + \kappa w h_1 + e_2 \right)^{-b\sigma} x_2^{a\sigma} \tag{A.50}$$

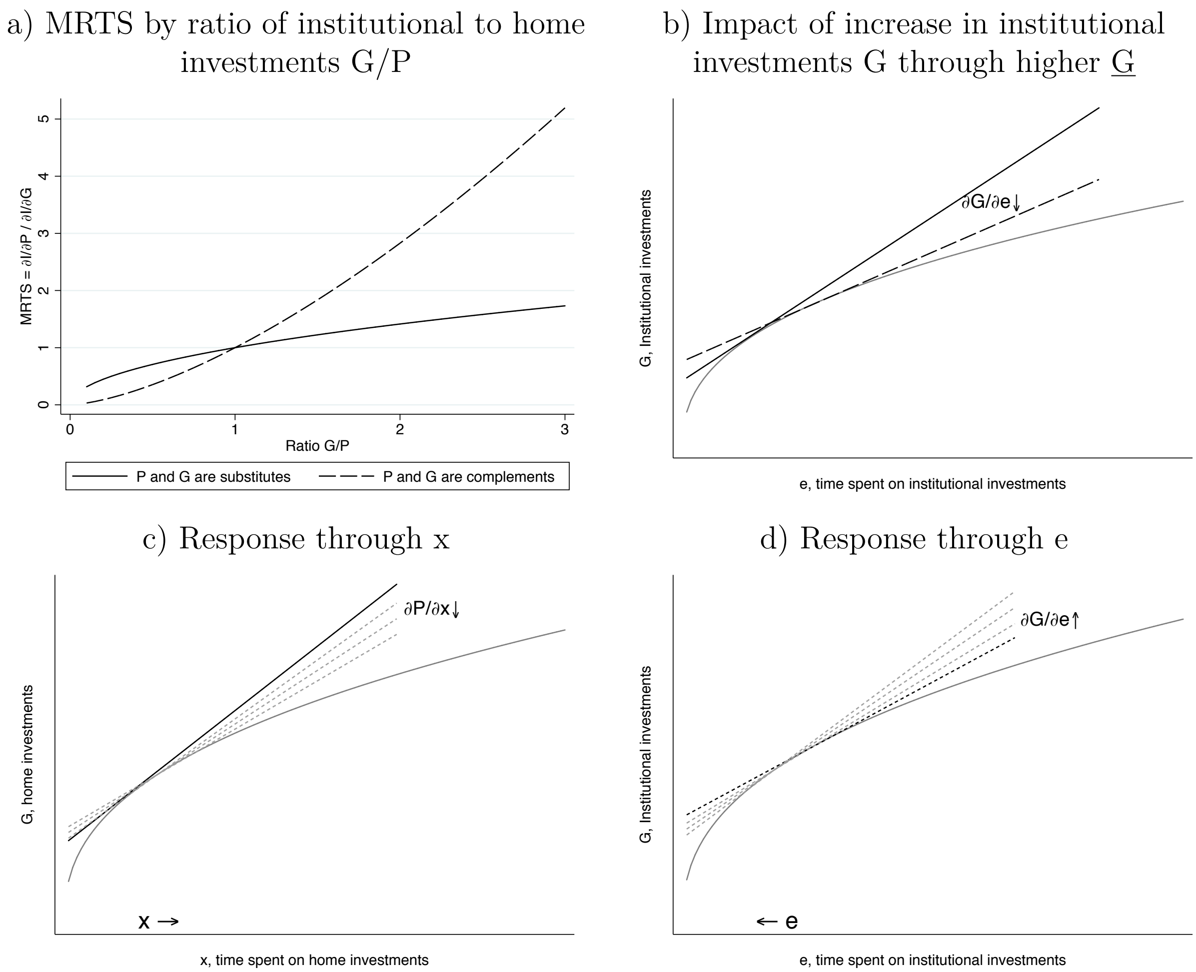
The ratio of the change in x_2 relative to the combined change in e_2 and the random shock s will be *large* when parents are already investing a lot directly (high level of x_2), when the level of e_2 is low, or when wh_1 is low. In those cases, any remaining increase in G (if parents do *not* offset the increased s by enough decreased e_2) would have to be compensated by large increases in x_2, because these parents are already at the part of the production function where the marginal productivity of additional increases in x_2 is relatively low. A large increase in x_2 risks being costly in terms of leisure or work time, which would risk reducing utility. Thus, for these parents it is likely more advantageous to have a high ratio on the left hand side of Eq. (A.50) through a small denominator - that is, offsetting the positive s through a greater reduction in e_2.

We now return to the more general model for a brief description of the intuition from a shock to public investments. Figure A.11 illustrates the impact of an increase in public investments $\underline{\text{G}}$ on parents' investment decision. Figure A.11a plots the MRTS across the ratio of institutional to home investments when the two are either complements (the dashed line) or substitutes (the solid line). As G increases through the intervention's increase in $\underline{\text{G}}$, it is clear from the figure that the change to the MRTS depends on the sign of the elasticity of substitution. Moreover, an increase of $\underline{\text{G}}$ will also affect the marginal product of all other inputs in institutional investments G, exemplified by the change in Figure A.11b (here assuming a concave production function for illustrative purposes).

The equilibrium condition Equation (A.9) is thereby possibly violated (as several terms change), begging adjustments to parents' investment decisions, which are illustrated in Figures A.11c and A.11d. Parents can, for example, respond to the decreasing marginal product of time input in institutional investments, by increasing time spent on home investments (A.11c), thereby decreasing the marginal product of time spent on home investments accordingly – or they can reduce time spent on institutional investments (A.11d).

The direct impact of the randomized increase in $\underline{\mathrm{G}}$ and the subsequent parental adjustments will, thus, depend i) on the (sign of the) elasticity of substitution between home and institutional investments, and ii) the production functions linking home and institutional investments to the time inputs. *This is the key insight we will use to identify the sign of the elasticity of substitution from an RCT increasing* $\underline{G}$.

Figure A.11: Impact of increasing G



Note: The figure illustrates the change following an increase in public investments G. a) plots the MRTS across levels of G/P (the ratio of institutional investments relative to home investments, which will increase following an increase in G). b) illustrates the direct impact of an increase in G on the marginal productivity of institutional investments. c) and d) illustrate how parents can adjust either time spent at home x (increase) or time spent on institutional sorting e (decrease) to satisfy the equilibrium condition from Equation (A.9).

B.5 Determining the Progressivity of an Increase in $\underline{\text{G}}$

The model informs us also about whether or not an increase in the public baseline investments $\underline{\text{G}}$ benefits highly educated parents more or less than less educated parents—in other words, whether the intervention is progressive or regressive. We perform this analysis using the version of the model with all functional form assumptions for utilities and residential choice in period 1 only, for convenience (refer to Section B.3).

Seen from the perspective of the 2nd period (with respect to discounting), the change in parents' utility from increasing $\underline{\text{G}}$ in period 1 is:[42]

$$\frac{dU(c_1, c_2, l_1, l_2, \theta_2)}{d\underline{\text{G}}} = \frac{\partial u(c_2)}{\partial \underline{\text{G}}} + \frac{\partial u(l_2)}{\partial \underline{\text{G}}} + \beta \frac{dV(\theta_2)}{d\underline{\text{G}}}$$

Observing Eq. (A.41), and by definition $\partial U/\partial l = (1-\alpha)/l$, this expands and then simplifies to

$$\begin{aligned} \frac{dU(c_1, c_2, l_1, l_2, \theta_2)}{d\underline{\text{G}}} &= 1/w \frac{\partial u_2}{\partial l_2} \frac{\partial \left(w \frac{\alpha}{1-\alpha} l_2 \right)}{\partial \underline{\text{G}}} + \frac{\partial u_2}{\partial l_2} \frac{\partial l_2}{\partial \underline{\text{G}}} + \beta \frac{dV(\theta_2)}{d\underline{\text{G}}} \\ &= \frac{1}{l_2} \frac{\partial l_2}{\partial \underline{\text{G}}} + \beta \frac{1}{\theta_2} \frac{d\theta_2}{d\underline{\text{G}}} \end{aligned} \tag{A.51}$$

Combining Eqs. (A.19) and (A.41) and the time budget constraint for period 2, we know that $l_2 = (1-\alpha)(1 - x_2 - e_2 - \kappa h_1)$, which can be further used to derive Eq. (A.52). Then, continue with Eq. (A.8) and expand the term $d\theta_2/d\underline{\text{G}}$:

$$\frac{dU(c_1, c_2, l_1, l_2, \theta_2)}{d\underline{\text{G}}} = -(1-\alpha) \frac{1}{l_2} \left(\frac{\partial x_2}{\partial \underline{\text{G}}} + \frac{\partial e_2}{\partial \underline{\text{G}}} \right) + \beta \frac{1}{\theta_2} \frac{d\theta_2}{d\underline{\text{G}}} \tag{A.52}$$

$$\begin{aligned} &= (1-\alpha) \frac{1}{l_2} (-1) \left(\frac{\partial x_2}{\partial \underline{\text{G}}} + \frac{\partial e_2}{\partial \underline{\text{G}}} \right) + \beta \frac{1}{\theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial \underline{\text{G}}} + \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial P_2} \frac{\partial P_2}{\partial x_2} \left(\frac{\partial x_2}{\partial \underline{\text{G}}} + \frac{\partial e_2}{\partial \underline{\text{G}}} \right) \\ &= \beta \frac{1}{\theta_2} \frac{\partial \theta_2}{\partial \theta_1} \frac{\partial \theta_1}{\partial \underline{\text{G}}} + \left(\frac{\partial x_2}{\partial \underline{\text{G}}} + \frac{\partial e_2}{\partial \underline{\text{G}}} \right) \left[\beta \frac{\partial \theta_2}{\partial I_2} \frac{\partial I_2}{\partial P_2} \frac{\partial P_2}{\partial x_2} - (1-\alpha) \frac{1}{l_2} \right] \end{aligned} \tag{A.53}$$

[42]Note that the notation of $\underline{\text{G}}$ can be confusing because it lacks a time subscript. In all following, however, it should be considered as happening *only* in period 1.

C Data appendix

C.1 The Survey

In late April 2017, an invitation to participate in a survey was sent to all parents with children who had participated in the intervention. The invitation was sent via the personalized secure email *e-Boks*[43] to minimize non-response and ensure that all parents received the invitation. **All** Danes have such an email inbox in *e-Boks* and use this to receive (and send) official communication, for example from employers or public sector officials, on everything from children's medical visits, preschool and school enrolment, own reception of public transfers, tax records, etc.

The letter is presented below.[44]

[43]See https://www.e-boks.com/danmark/en/what-is-e-boks/.

[44]In English:

Dear Parents to [Child]

We are a group of researchers who are studying the environments that help children flourish and provide them with the best possible beginning of their life.

Your child's daycare has been part of a project focussing on children's language development, and you were in this context asked to participate in a survey a couple of years ago.

The interplay between different activities in a child's day

We would like to request your assistance by filling our a similar questionnaire. The questionnaire ask questions relating to your everyday activities, habits, and how your view your child's everyday. We would like to ask you this to improve our understanding of how children's everyday activities in- and outside the home environment are linked.

The questionnaire can be found by following this link: LINK

It will at most take 15 minutes to respond to the questionnaire, and you will – upon completion – participate in a lottery with the possibility of winning an iPad. Lottery-participation is not conditional on having participated in the old survey.

The study has been approved by the Danish Data Authorities (National IRB board) and *all information is confidential and will be anonymized.*

We hope you will participate in the survey and thereby provide an important contribution to the understanding of the early childhood of all children. If you have any questions, please let us know by writing to: startpaalivet econ.au.dk.

Den 21. april 2017

Kære forældre til [*barns navn*]

Vi er en gruppe af forskere, der er i færd med at undersøge, hvordan børn får de bedste betingelser til at udvikle sig under opvæksten og den bedst mulige start på livet.

Jeres barns dagtilbud har tidligere været med i et projekt med fokus på børns sproglige udvikling, og i den forbindelse har I for ca. 2 [3, 4] år siden fået tilsendt et spørgeskema.

Samspillet mellem aktiviteter i børns hverdag

Vi vil nu bede jer om at hjælpe os igen ved at udfylde et lignende spørgeskema. Det handler om jeres hjem, vaner og opfattelse af jeres barns hverdag. Vi vil gerne spørge jer om dette for bedre at forstå samspillet mellem de aktiviteter, som børn laver i deres hverdag både ude og hjemme.

Spørgeskemaet findes på dette link: www.spørgeskema.dk.

Det tager kun ca. 15 minutter at besvare spørgeskemaet, og når I besvarer, deltager I samtidig i en lodtrækning om en iPad. I behøver ikke have besvaret det foregående spørgeskema for ca. 2 [3, 4] år siden for at besvare dette.

Undersøgelsen er godkendt af Datatilsynet, og *alle oplysninger behandles anonymt og fortroligt*.

Vi håber, at I kan hjælpe os, og derved give et vigtigt bidrag til at øge forståelsen af, hvordan samfundet bedst muligt kan hjælpe alle børn på vej i deres tidlige år. Hvis I har spørgsmål til projektet, kan I kontakte os på startpaalivet@econ.au.dk.

Venlig hilsen

Dorthe Bleses (Professor, TrygFondens Børneforskningscenter på Aarhus Universitet)
Rasmus Landersø (Seniorforsker, ROCKWOOL Fonden)

Following the letter, two reminders were sent to non-respondents and finally non-respondents were contacted by phone.

The survey items are listed below. Some questions were given with different phrasing for pre-school and school students - notably when it is directly using the word (such as "When do you pick up your child from school/pre-school.") Here, we only give one version for brevity,

Sincerely,
Dorthe Bleses (Professor, TrygFonden's Centre for Child Research)
Rasmus Landersø (Rasmus Landersø, Senior Research, The Rockwool Foundation Research Unit)

and note in parentheses the school version when it differs.

In these first questions we will ask about your thoughts and concerns about your child's day, and what your child is doing in kindergarten. If you are unsure of the answer to a question, please share your best judgment.

1. How many times a week are you informed by the staff/teachers about what your child has done during the day?
2. How satisfied are you with the language support your child receives in preschool (school)?

How much do you agree with the following statements?

3. I know how often my child is being read with in preschool (school).
4. I would like to know more about how often my child is being read to in preschool (school).
5. One of the reasons I read to my child is to support my child's language.
6. I think the amount my child is being read to in preschool (school) is not sufficient.
7. If they read less in preschool (school), I would read more with my child.
8. I think it is boring or difficult to read for my child.
9. I enjoy reading for my child.
10. I am often too busy or too tired to read to my child.
11. I do a lot to teach my child to focus, concentrate, and complete a task.
12. One of the reasons I support my child's ability to focus, concentrate, and complete a task, is because there is not enough focus on it in preschool (school).
13. When I play or read with my child, it is important we finish before we stop or start new things.
14. I would like my child to receive more help to develop his ability to concentrate on a task.
    - If strongly/mildly agree:
        (a) I would like my child to receive more help in order to develop as much as possible his/her ability to concentrate on a task.
        (b) I would like my child to receive more help in order to not lose ground relative to his/her peers' ability to concentrate on a task.
    - If strongly/mildly disagree:
        (c) My child does not need more help because my child is already good at concentrating on a task.
        (d) My child does not need more help because my child's ability to concentrate is age-appropriate.
15. I feel that my child's language skills are better than the majority of his/her peers.
16. I feel that my child's language skills are weaker than the majority of his/her peers.
17. I would like my child to receive more help to develop his/her language.

- If strongly/mildly agree:
  (a) I would like my child to receive more help in order to develop his/her language as much as possible.
  (b) I would like my child to receive more help in order not to lose ground relative to his/her peers' language skills.
- If strongly/mildly disagree:
  (c) My child does not need more help because his/her language skills are already good.
  (d) My child does not need more help because my child's language skills are age-appropriate.

Now we ask you about your life and what you are doing with your child.

18. At what time does your child begin his day in preschool (school) on a typical day?
19. At what time is your child typically picked up from preschool (school)?
20. How many hours do you typically work per week?
21. How much time do you typically spend in commute to/from work?
22. How many books do you have in your home (including fiction, non-fiction, cookbooks, religious books, etc. but excluding children's books)?
23. How many children's books do you have in your home?
24. In the last week, how many times did you read books, newspapers, e-books, magazines, religious texts, texts on the tablet (eg iPad) or computer at your leisure?
25. During the last week, how often did you and your child do everyday activities together, such as cooking?
26. How often did you talk with your child about what they have done in preschool (school) in the last week?
27. How many times during the last month have you talked to your child about how he/she is doing generally?
28. How many times during the last month have you talked to your child about how it is going academically?
29. How many of your child's friends from preschool do you know by name?
30. In the last week, how often did you encourage or help your child to talk about letters (words and spelling)?
31. In the last week, how often did you encourage or help your child to talk about numbers, shapes, patterns (numbers, magnitudes, nature)?
32. How many times last week has your child been read to (or read with) at home?
33. (If your child can read, how often in the past week have you sat with your child while it read to you?)

34. (How many times last week have you or your child read, not counting schoolwork?)

35. How often did you sing or rhyme with your child last week?

In the next questions we will ask about your views about your child's development. There are no 'right' or 'wrong' answers. How much do you agree with the following statements?

36. As a parent, I have a big influence on how my child is going to learn to read, write and count.

37. My child is not old enough to acquire skills that are linked to read and write. (only preschool)

38. My child's ability to learn to read, count and calculate the intrinsic and will never change.

39. My child can always improve its ability to learn to read and count, no matter how old he / she is.

40. After a certain time my child will no longer be able to improve its ability to learn to read, count and calculate.

41. I can affect my child's ability to focus on completing a task.

42. There is not much I as a parent can change if my child has a harder time concentrating than other children.

In the next questions we ask about your assessment of how important it was that your child participated in the daycare intervention. (Only given to parents whose children took part in the intervention in any of the three programs)

43. My child's development was strengthened by the day-care participation in the intervention.

44. The participation of my day-care center in this intervention became important for the activities I do with my child at home.

C.2 Survey Response

The survey-response rate was 60%, and in the main results we do not condition on response. The tables below compare characteristics of respondents and non-respondents.

Table A.11 presents estimation results from regressions of survey-response (0/1) on baseline characteristics for the control group and treatment group in columns 1 and 2, respectively. The two columns show that survey response cannot be considered being random. As would be expected, respondents are on average older, have completed more years of schooling, have a higher family income, and have children that score higher in language tests. However, when testing for treatment-control differences in the estimates, Column 3 shows that only father's age is significant. Moreover, there are no significant differences in response rates between the two groups.

Next, Table A.12 compares treatment effects across different sample restrictions. The columns labeled "unrestricted" present the estimates for the full sample considered in the main analysis. The columns labeled "panel DNT" show estimates for those who have reached 2nd grade, and the columns labeled "panel + survey" show the results for those who have reached 2nd grade and whose parents have responded to the survey. The table shows that treatment-control differences are almost identical across the different specifications. Thus, the only difference across the specifications and sampling is the power of our results.

Table A.11: Determinants of Response to Follow-Up Survey

	(1) Nonresp.	(2) Respondents	(3) Diff Resp.-Nonresp.
Treatment	0.481	0.513	0.032
	(0.500)	(0.500)	(0.021)
Pre-trial Test	-0.122	0.081	0.202
	(0.994)	(1.003)	(0.043)
Post-trial Test	0.496	0.677	0.181
	(0.963)	(0.940)	(0.041)
Age 1-9/17	8.255	8.274	0.019
	(1.036)	(1.026)	(0.044)
Father's age, 1/9-17	41.870	42.407	0.538
	(5.792)	(5.852)	(0.249)
Father's age at child's birth	33.192	33.679	0.487
	(5.754)	(5.805)	(0.251)
Father years of schooling	13.570	14.124	0.554
	(2.399)	(2.410)	(0.103)
Mother's age, 1/9-17	39.408	40.134	0.726
	(5.202)	(4.916)	(0.215)
Mother's age at child's birth	30.657	31.375	0.718
	(5.083)	(4.802)	(0.210)
Mother years of schooling	13.708	14.431	0.723
	(2.571)	(2.365)	(0.105)
Household wage income 2017, $1,000	94.675	102.973	8.298
	(65.100)	(67.916)	(2.853)
N	903	1,397	2,300

Note: Columns 1 and 2 show descriptive characteristics by who responded to the follow-up survey (mean and standard deviation). Column 3 tests the difference between the two, with standard errors in parentheses. $+(p < 0.1),^{*}\ (p < 0.05),^{**}\ (p < 0.01),^{***}\ (p < 0.001)$.

Table A.12: Treatment Effects by Outcome and Sample

	Gain Test			Post-Trial Test			National Test		
	unrestricted	panel DNT	panel+survey	unrestricted	panel DNT	panel+survey	unrestricted	panel DNT	panel+su
Treated	0.265***	0.283***	0.266***	0.342***	0.386***	0.399***	0.040	0.040	0
	(0.061)	(0.063)	(0.074)	(0.083)	(0.101)	(0.105)	(0.085)	(0.085)	(0
Constant	0.264	0.460+	0.260	0.279	0.228	0.136	0.472*	0.472*	0
	(0.214)	(0.254)	(0.295)	(0.175)	(0.210)	(0.296)	(0.199)	(0.199)	(0
Observations	2300	1562	951	2300	1562	951	1562	1562	951

Note: Results of the same ordinary least squares regressions in different samples, on 3 outcome measures: "Gain Test" corresponds to the improvement in test scores from just prior to the intervention to just after. "Post-Trial Test" simply regresses the test score just after the intervention on the treatment indicator. The "National Test" corresponds to the Danish reading scores in 2nd grade from the objective computer-scored national tests. The "unrestricted" sample uses all available students. The "panel DNT" restricts the sample to only those student for whom national test scores are available. "panel+survey" restricts the sample to all for whom the national tests are available, as well as the parent responses for the follow-up survey. All regressions are clustered at the institute level and also control for month of birth and age at the test (not shown). Standard errors in parenthesis, $+(p < 0.1),^{*} (p < 0.05),^{**} (p < 0.01),^{***} (p < 0.001)$. The controls are largely insignificant.

C.3 Data Construction

This section describes the data construction. The first step in the data construction was to collect the data from the intervention (see Section 3.1) and transfer this to Statistics Denmark. Here, the data was anonymized (i.e. all social security numbers were changed to anonymized unique *pnr*-numbers) with a code facilitating the link between the intervention data and the register data using the anonymized pnr-numbers. A similar procedure was conducted once the survey data had been collected.

The register data spans the entire population of Denmark from 1980-present with family identifiers (parent identifiers *pnrm, pnrf* and household identifiers *familie-id*) allowing us to link the children from the intervention to their parents. From the demographic register we also identify the children's country of origin (we limit the sample to those with at least one native parent), date of birth, and home addresses (again anonymized). We also link the children to the daycare register (DAGI) and educational register (UDDA). These data also include unique preschool and school identifiers (institution-numbers) allowing us to identify the institutions the children attend along with the peers whom they have attended the institutions with.

C.4 Background Characteristics and Outcomes

The pnr-numbers allow us to link the children to the National Birth Register and obtain information on their birth weight, the gestation length, their Apgar score, and their mothers' weight at the time of pregnancy. Using the parental identifiers, we also include information in parents completed education from the educational register, their employment status from the labor market register (RAS), and their household income from the income register (based on tax authorities' information).

Child outcomes We study two child-outcomes: post-trial language test scores and 2nd grade language test scores. The pre- and post-trial tests are constructed from 50 items relating to sound discrimination, rhymes, word-segmentation, and letter identification. We standardize the tests (mean zero, std. dev. 1) relative to the control group.

The 2nd grade test scores are part of the compulsory national tests from 2nd through 8th grade (with language tests in grades 2, 4, 6, 8). The tests focus on three underlying constructs: Reading comprehension, decoding, and language comprehension, and they take place near the end of the school year. The tests are performed on computers using an adaptive system in which questions are determined by the student's performance earlier in the test. The test is scored electronically without teacher input. Following Sievertsen et al. (2016) and Beuchert and Nandrup (2018), we standardize these three individual scores, take the simple average, and re-standardize them within year.

Parent outcomes We construct *parental investments* from a factor analysis with 26 items that describe parental activities and opinions. After extensive exploratory factor analysis, we perform a principal-component analysis with the number of factors limited to five, adding an oblique promax rotation with power 3. The estimates are reported in Table A.13. From these estimates, we predict five factor scores with Bartlett scores. The six statements/questions that load on the parental investment factor have six potential answers ranging from, for example, highly disagree to highly agree. We assign these answers values 1-6 in the factor analysis. Note that if we predict a parental investment factor score from a factor analysis that uses exclusively the parental investment items (instead of the full list of 26 as in Table A.13, the results are very similar. These two versions of a parental investment factor are correlated at .97.

Items for Parental Investment Factor

- How many times last week has your child been read to (or read with) at home?
- If your child can read, how often in the past week have you sat with your child while it read to you?
- How many times last week have you or your child read, not counting schoolwork?

- I think it is boring or difficult to read for my child.
- I enjoy reading for my child.
- I am often too busy or too tired to read to my child.

Table A.13: Factor Loading Matrix of Parental Activities and Opinions

	Neg.Pub Eval	Parental Inv.	Growth Mindset	Home Capital	Noncog Im
How many times last week has your child been read to (or read with) at home?	0.075	0.709	-0.094	0.055	0.24
If your child can read, how often in the past week have you sat with your child ...	0.080	0.528	-0.108	-0.160	0.39
How many times last week have you or your child read, not counting schoolwork?	0.055	0.585	-0.084	0.190	0.15
I think it is boring or difficult to read for my child.	0.063	-0.620	-0.154	-0.020	0.15
I enjoy reading for my child.	-0.004	0.643	0.146	0.033	-0.06
I am often too busy or too tired to read to my child.	0.074	-0.696	0.037	0.044	-0.05
As a parent, I have a big influence on how my child is going to learn to read, ...	-0.003	0.092	0.566	-0.030	0.16
My child's ability to learn to read, count and calculate are intrinsic ...	-0.063	0.059	-0.568	-0.020	0.05
My child can always improve its ability to learn to read and count, no matter ...	0.055	-0.081	0.670	-0.030	0.16
After a certain time my child will no longer be able to improve its ability to ...	-0.010	0.110	-0.615	-0.057	0.04
I can affect my child's ability to focus on completing a task.	-0.005	0.026	0.727	-0.003	0.09
There is not much I can change if my child has a harder time concentrating.	0.048	-0.046	-0.672	-0.025	0.03
I do a lot to teach my child to focus, concentrate, and complete a task.	-0.056	0.086	0.166	-0.169	0.54
When I play or read with my child, it is important to finish before we stop ...	0.152	0.049	0.090	-0.195	0.37
During the last week, how often did you and your child do everyday activities ...	-0.077	0.039	-0.009	0.293	0.49
How often did you talk with your child about what they have done in preschool ...	-0.100	0.113	0.047	0.001	0.62
How many times during the last month have you talked to your child ...	-0.028	0.035	0.121	0.079	0.49
I think the amount my child is being read to in preschool(school) is not sufficient.	0.678	-0.066	0.008	0.069	0.01
I would like my child to receive more help to develop his/her language.	0.679	-0.084	-0.032	-0.009	0.12
How satisfied are you with the quantity of language support your child receives?	-0.787	-0.152	-0.038	0.010	0.29
How satisfied are you with the quality of language support your child receives?	-0.822	-0.149	-0.075	-0.029	0.27
One of the reasons I support my child's ability to focus, concentrate, ...	0.667	-0.098	-0.005	0.020	0.17
I would like my child to receive more help to develop his ability to concentrate	0.610	-0.109	-0.094	-0.017	0.18
How many books do you have in your home?	0.048	0.000	0.023	0.845	-0.07
How many children's books do you have in your home?	0.025	0.117	-0.025	0.757	-0.01
In the last week, how many times did you read books, newspapers, e-books, ...?	-0.034	-0.050	0.039	0.612	0.22

Note: Factor loadings after PCA on all 26 items listed here, limited to 5 factors, with oblique promax rotation (power 3). $N = 1,336$. "Neg.Pub.Eval." stands for a negative evaluation of the public investments by parents. "Parental Inv." is the parental direct time investment factor used in the main analyses. "Growth Mindset" relates to how parents view their child's potential to change, and their own potential to influence their child's growth in both the cognitive and non-cognitive domains. "Home Capital" relates to the capital present in the home that could foster reading and language. "Noncog. Important" describes how important it is for parents to foster their child's socio-emotional skills, in addition to reading and language.

Table A.14: Treatment/Control Differences in Parental Answers to Investment Items

	(1) Control mean/sd	(2) Treatment mean/sd	(3) Treatment-Control coeff/std.err
How many times last week has your child been read to (...)?	3.772	3.954	
	(1.250)	(1.130)	
			0.169**
			(0.066)
If your child can read, how often in the past week have you sat (...)?	3.023	3.178	
	(1.338)	(1.308)	
			0.129+
			(0.072)
How many times last week have you or your child read (...)?	3.357	3.341	
	(1.305)	(1.327)	
			-0.0460
			(0.073)
I think it is boring or difficult to read for my child., reverse coded	5.304	5.394	
	(1.022)	(0.961)	
			0.109*
			(0.054)
I enjoy reading for my child.	5.279	5.333	
	(0.915)	(0.855)	
			0.034
			(0.048)
I am often too busy or too tired to read to my child., reverse coded	3.867	4.046	
	(1.374)	(1.346)	
			0.142*
			(0.074)
Observations	750	828	

Note: Columns 1 and 2 show descriptive statistics of the individual items by whether or not parents were in the treatment or control groups of the intervention (mean and standard deviation). Column 3 shows the difference between the treatment and control groups (with standard errors in parentheses), indicating p-values of the null hypothesis of no differences Standard errors in parentheses. $+(p < 0.1),^{*}(p < 0.05),^{**}(p < 0.01),^{***}(p < 0.001)$.

Table A.14 shows how the overall treatment effect of the intervention on increasing parental investments originates in the different items.

Finally, we construct the variable on *hours worked* from survey responses to the questions *At what time do you usually go to work?* and *At what time do you usually leave work?*.

School quality Our measure of school quality is based on the average characteristics of the teachers employed in each school in Denmark. We use a unique link developed by Statistics Denmark between all teachers (their pnr-numbers) and schools (institution-numbers) using employment records from the employer-employee match data to identify the full set of teachers employed at each school by January 1st from 2010-2016.

We link this data with the educational register, labor market register, and GPA from high school and teachers' college (UDG) to construct variables with each teacher's years of experience, tenure at a given school, unemployment spells and periods with sick leave, and GPA from high school and teachers' college.

The institution identifiers let us to merge the aforementioned data to test score information from the national test scores (see earlier paragraph). We obtain the predicted test scores from teacher characteristics by regression the children's test scores on the school-by-year average teacher information. Finally, we rank schools from lowest to highest (0-1) by their predicted test score level.

Figure A.12 show school-average teacher characteristics by average property values in catchment areas. Figure A.12a corresponds to A.3b and Figure A.12b exemplifies how the various underlying teacher characteristics vary across schools by plotting teacher high school GPAs against property values in school catchment areas.

Figure A.13 extends these associations by plotting parents' average years of schooling and gross (post-transfer) family income across the school quality index. Both Figure A.12 and A.12 confirm the earlier findings of strong associations between school quality proxied by teacher characteristics and parental resources.

Figure A.12: Teacher Characteristics by Property Values

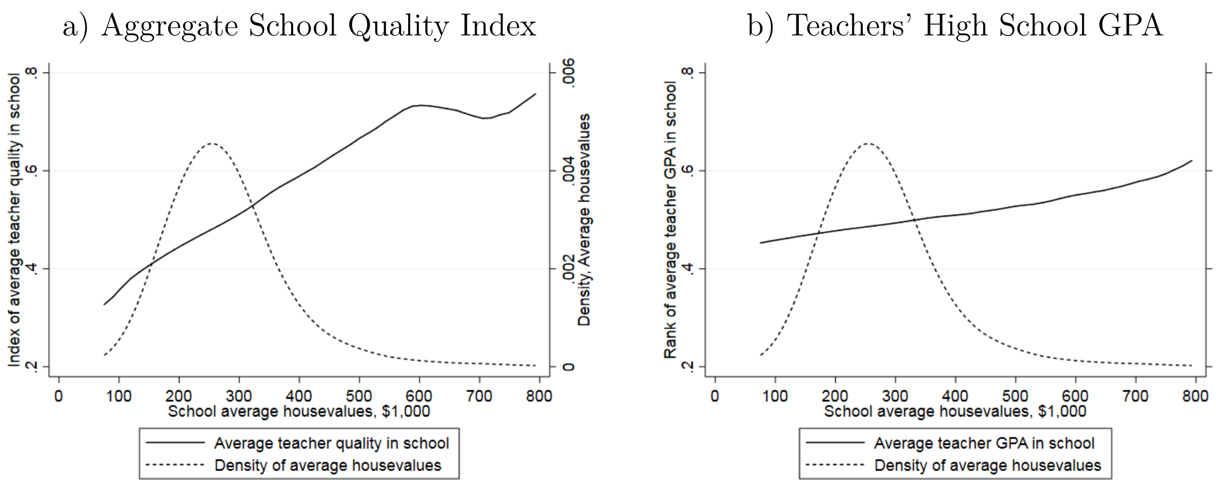


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Figure A.13: Teacher Characteristics by Parental Quality

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