

THREE ESSAYS ON EARLY CHILDHOOD DEVELOPMENT IN CHILE

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To my baby boy, who without knowing, has push me through the final steps of this work.

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ABSTRACT

THREE ESSAYS ON EARLY CHILDHOOD DEVELOPMENT IN CHILE

Alejandra Abufhele Milad

Jere R. Behrman

Early childhood development literature has emphasized the role that parental investment and early life conditions play on human capital formation. Still, there is little evidence on the mechanisms driving such dependence. This dissertation examines potential mechanisms explaining the relationship between parental investments, early life conditions and children's outcomes. The first chapter exploits a plausibly exogenous variation on the timing at which a maternity leave extension reform was implemented to estimate the causal effect of additional weeks of maternity leave on breastfeeding duration in Chile. By using data from the Chilean Longitudinal Survey of Early Childhood (ELPI), I find that additional weeks of maternity leave increases significantly breastfeeding duration; however, the effects show substantial heterogeneity by socioeconomic status in favor of low-educated mothers, suggesting that the reform has equalizing effects. The second chapter examines how parental investments respond to differences in the initial endowment between siblings within families, and how parental preference tradeoffs vary between families with different maternal education. Using ELPI twins data, I find that preferences are not at the extreme of pure compensatory investments to offset endowment inequalities among siblings nor at the extreme of pure reinforcement favoring the better-endowed child with no concern about inequality, but that parental investment preferences are neutral, so that they do not change the inequality on endowment differentials, a result that is consistent across families with low- and high-educated mothers. The third chapter provides empirical evidence on the effects of birth weight on cognitive and non-cognitive development. Results from singletons births show a positive association. The first-difference models for identical twins, show that birth weight does not have a significant effect on the developmental test scores. However, twins estimates stratified by age of the children show that birth weight effects

are positive and significant but only for children between 3 and 7 years old. Overall, I conclude that endowments at birth, parental investments and policy interventions are all key determinants to unravel children's outcomes, and exploring the role that age and socioeconomic heterogeneity play in the production of these outcomes seems to be key for a thorough understanding of early childhood inequalities.

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INTRODUCTION

Early childhood development literature has stressed the significant role that early-life environment has on later-life development and well-being. Cross-disciplinary work from the last decade has shown that the pregnancy period, along with the maternal and parental investment decisions once the child is born are key determinants for the process of human capital formation. While this work has been especially influential for countries like Chile, where important governmental efforts have been made towards improving the quality of children's life¹, there is still little evidence on the mechanisms driving such relationships as well as its heterogeneity across individual's age and socioeconomic status.

In the present dissertation, I attempt to help to fill this gap by providing empirical evidence on potential mechanisms that explain the relationship between early life conditions, parental investments and children's outcomes. The dissertation comprises three papers, all of which use data from the Chilean Longitudinal Survey of Early Childhood, a Chilean nationwide representative survey of infants and young children. This face-to-face survey gathered two types of information: a socio-demographic survey applied to all mothers; and a battery of tests for evaluating cognitive, socio-emotional and anthropometric development in children and their mothers. The 2010 wave sample consists of 15,000 children born between January 2006 and August 2009, while the 2012 wave includes the children interviewed in 2010, an additional 3,000 children who were born between September 2009 and December 2011, and a cross-sectional sample of around 1,000 twin pairs.

Chapter 1, explores one of the first investments that a mother can make after her child's birth: breastfeeding. Given all the very well-known beneficial effects of breastfeeding, public health authorities have been promoting and incentivizing breastfeeding as the main source of food for children during the first year of life, with emphasis on exclusive breastfeeding for the first six months. By using the singleton sample, I exploit an exogenous variation on the timing at which a maternity leave reform was implemented to estimate the causal effect of extra weeks of maternity leave on breastfeeding duration. I find that one more week of maternity leave causes an increase of 0.194 months of breastfeeding (around 6 days), on average. However, the effects show substantial heterogeneity between high- and low-educated mothers. One additional week of maternity leave increases the months of breastfeeding by around 10 days for low-educated

¹ The maternity leave extension, the significant increase in the quantity of child day care facilities, and the comprehensive *Chile Crece Contigo* program, are some examples of this important efforts made during the last 10 years.

mothers, while for high-educated mothers the effect is weakly negative and statistically insignificant.

Moreover, an additional week of maternity leaves increases breastfeeding duration for low-income mothers (quintiles 1 to 3 in the income scale) by around 15 days, while high-income mothers (quintiles 4 and 5) do not increase breastfeeding duration at all. Interestingly, the overall sample result is not robust to the use of a binary indicator on whether the mother breastfeed exclusively at least 6 months. Nonetheless, the results are still robust across the high and low socioeconomic groups. One more week of maternity leave generates a significant increase in the proportion of low-educated and low-income mothers that breastfeed their children at least 6 months (9% and 16% increase with respect to mothers that were not exposed to the policy, respectively), but the effects are null for richer mothers.

The latter results suggest that the maternity leave extensions had important redistributive effects in favor of children of disadvantaged mothers. This paper adds two main contributions to this literature. First, this is one of the first papers to estimate the causal effects of weeks of maternity leave on breastfeeding in a developing country. Second, the policy-based identification strategy makes use of the exogeneity of the change in the law to control for several potential confounders that previous studies have missed, including unobserved maternal and child characteristics.

Chapter 2, focuses on the relationship between endowments, parental preferences and children's outcomes. Parental investments are typically argued to be influenced by parental preferences as well as by external factors like prices, production technology linking investments to outcomes, and resource constraints. A less explored factor is parents' perceptions about the endowments of their children. Parents learn about the endowment of a child at birth (or soon after), and this influences their decisions about postnatal investments (Del Bono, Ermisch, & Francesconi, 2012). Using the 2012 twins sample, this chapter seeks to unravel the mechanisms underlying heterogeneity in human capital formation (and thereby in children's outcomes) by looking at parental preferences with respect to allocation of investments *across* children *within* the same family and the factors driving differences in parental preferences *between* families. Specifically, I examine how parental investments affecting child education and health respond to initial endowment differences on birth weight across twins within families, and how parental preference tradeoffs vary between families with different maternal education.

Using the separable earnings-transfers model (Behrman, Pollak, & Taubman, 1982), I first illustrate that preference differences may make a considerable difference in the ratios of health

and learning differentials between siblings – up 30% in the simulations that I provide. I find that preferences are not at the extreme of pure compensatory investments to offset endowment inequalities among siblings nor at the extreme of pure reinforcement to favor the better-endowed child with no concern about inequality. Instead, I find that they are neutral, so that parental investments do not change the inequality among children due to endowment differentials. I also find no significant differences between families with low- and high-educated mothers.

The last chapter, examines the effects of birth weight on children's development. Empirical evidence has shown positive associations of birth weight with health, educational attainment, earnings, and cognitive development. However, most of the studies are based on later life outcomes and use cross-section or siblings' study designs that have limited ability to control for unobserved variables that affect both birth weight and outcomes of interest. This research aims to provide new empirical evidence as to the effects of birth weight on cognitive and non-cognitive development using both singletons and the twins sample from the 2012 ELPI round.

In particular, the chapter attempts to disentangle the confounding effects in the relationship between birth weight and cognitive and non-cognitive development in children by comparing the association between birth weight and cognitive, motor, language and socio-emotional skills for singletons and twins' births samples between 6 months and 7 years old. The comparison between cross-sectional data of single births with the twins sample allows me to examine the effect of controlling for unobserved heterogeneity between children coming from the same family. While fraternal twins share approximately half of genetic composition (or more if there is positive assortative mating), identical twins share all the genetic composition as well as the same age, pregnancy-related variables and family background. Also, we know that differences in birth outcomes, specifically birth weight, between twins are not the result of parental decisions to invest more in one twin than in the other but are due to differential locations in the womb or umbilical cord insertion in the placenta (Torche & Conley, 2016).

I find that for singletons births the association is positive. However, the first-difference models show that birth weight does not have a significant effect on the developmental test scores for identical twins. Twins effects stratified by age of the children show that the birth weight effect is positive and significant only for children between 3 and 7 years old. The contribution of this chapter is twofold. First, it provides new evidence about the effects of birth weight on early childhood cognitive and non-cognitive development for a developing country. Second, I contribute to the literature by using twins data that account for unobserved factors in this relationship.

Each of the chapters of this dissertation examines different aspects of children's well-being. Birth weight, breastfeeding, parental preferences are all crucial factors determining health and educational child development. Understanding the importance of the effects of these early-on investments on child development as well as the mechanisms underlying the differences in children's outcomes, within and between families, is crucial for policy makers especially in developing countries like Chile. However much more research is required for a comprehensive understanding of the determinants underlying early child development and its potential consequences on later-life outcomes.

Chapter 1: Effects of Maternity Leave on Breastfeeding: Evidence from Chile

Abstract

In this paper, I exploit a plausibly exogenous variation on the timing at which a maternity leave extension reform was implemented to estimate the causal effect of an additional week of maternity leave on breastfeeding duration in Chile. I find that one additional week of maternity leave increases breastfeeding duration by 0.19 months (around 6 days), on average. While the effects are about one third of a month and almost half a month for low-educated and low-income mothers, respectively, no effects at all are found for high-educated and high-income mothers. Universal reforms oriented to extend maternity leave to all women can have significant equalizing effects on breastfeeding duration.

Introduction

Breastfeeding is one of the first investments that a mother can make after her child's birth; in most cases, it is the best possible way to feed the baby. Existing literature provides abundant evidence of the short and long term health benefits of breastfeeding for the mother and the children, the most important being protection against morbidity and mortality due to infectious diseases (Horta, Bahl, Martines, & Victora, 2011; World Health Organization, 2013). Furthermore, some empirical work from high and middle income countries has shown that there is a positive association of breastfeeding with children's cognitive and non-cognitive outcomes (Belfield & Kelly, 2012; Borra, Iacovou, & Sevilla, 2012; Del Bono & Rabe, 2012; Fitzsimons & Vera-Hernández, 2013; Victora et al., 2015). Accordingly, public health authorities have been promoting and incentivizing breastfeeding and specifically, exclusive breastfeeding for the first six months of the child's life. An interesting case study is Chile. Until 2011, the maternity leave legislation in Chile consisted of 6 weeks before and 12 weeks after the baby was born. Permission for this leave was mandatory and un-waivable. In 2011, a law was enacted that allowed women to take an additional 12 full-time weeks (for a total of 24 full-time weeks) or an additional 18 half-time weeks of maternity leave. One of the main policy goals of this reform was to promote mother-child bonding, but most importantly exclusive breastfeeding during the first six months of the child's life.

In this paper, I exploit a plausibly exogenous variation on the timing at which the policy was implemented to estimate the causal effect of the maternity leave extension on breastfeeding

duration. Using data from the Chilean Longitudinal Survey of Early Childhood (ELPI), a nationwide representative survey of mothers of children born between January 2006 and December 2011, I argue that mothers did not decide to have their children on a certain date because of the extension of the maternity leave, and thus use the time at which the mother had the baby (before or after the policy) as an instrument for the number of weeks that mothers took for maternity leave, and examine whether the increasing number of weeks of maternity leave generated any effect on the number of weeks that mothers breastfeed.

The findings are conclusive. One more week of maternity leave causes an increase of 0.194 months of breastfeeding (around 6 days), on average. However, the effects show substantial heterogeneity between high- and low-educated mothers. One additional week of maternity leave increases the months of breastfeeding by 0.351 (around 10 days) for low-educated mothers, while for high-educated mothers the effect is weakly negative and statistically insignificant. Moreover, an additional week of maternity leaves increases the months of breastfeeding for low-income mothers (quintiles 1 to 3 in the income scale) by 0.468 (around 15 days), while high-income mothers (quintiles 4 and 5) do not increase breastfeeding duration at all. Interestingly, the overall sample result is not robust to the use of a binary indicator on whether the mother breastfeed at least 6 months, which was the policy goal. Nonetheless, the results are still robust across the high and low socioeconomic groups. One more week of maternity leave generates a significant increase in the proportion of low-educated and low-income mothers that breastfeed their children at least 6 months (9% and 16% increase with respect to mothers that were not exposed to the policy, respectively), but the effects are null for richer mothers. The latter suggests that the maternity leave extensions had important redistributive effects in favor of children of disadvantaged mothers.

Previous evidence on maternity leave and its effects on breastfeeding and other outcomes is mixed. Albagli and Rau (2016) evaluate the 2011 Chilean reform and find positive and significant effects in terms of children's development and mother's outcomes. However, the specific question about the effect of the maternity leave extension on breastfeeding duration is not examined in depth, although the authors argue that breastfeeding is one of the potential channels driving the results. Baker and Milligan (2008) used a Canadian family leave expansion and found significant increases in the duration of breastfeeding in the first year and in the proportion of mothers attaining 6 months of exclusive breastfeeding. However, their study does not find a consistent positive effect on health measures. Dahl, Løken, Mogstad, and Salvanes (2013) also show evidence that, in Norway, an increase in the maternity leave has little effect on children's schooling, parental earnings and labor force participation, completed fertility, marriage or divorce.

Huang and Yang (2015) looked at the implementation of a paid family leave program in California, and show evidence of an increase of 3-5 percentage points for exclusive breastfeeding through the first three and six months, and an increase of 10-20 percentage points for breastfeeding for the three, six and nine months. Finally, Carneiro, Løken, and Salvanes (2015) show that a 1977 reform that increased the maternity leave in Norway did not increase the average months of breastfeeding -- if anything, there was a small decline.

This paper adds two main contributions to this literature. First, this is one of the first papers to estimate the causal effects of weeks of maternity leave on breastfeeding in a developing country. Second, the policy-based identification strategy makes use of the exogeneity of the change in the law to control for a number of potential confounders that previous studies have missed, including unobserved maternal and child characteristics.

Chilean Maternity Leave Extension

On October 17, 2011, a Chilean law that extended the weeks of maternity leave was enacted. The previous law consisted of 12 full-time weeks of paid maternity leave to mothers who were working at the time of the conception. The new law provided two options for the extension of the maternity leave: 12 additional full-time weeks (paid fully) or 18 additional half-time weeks (half-paid); and mothers could choose to transfer a fraction of their extended leave to the father. The maternity leave covers formal workers who have an employment contract and are contributors to the social security system or independent workers that have affiliation with the social security system for at least one year and six or more contributions during the six months prior to the maternity leave. As in the previous law, this reform included full income replacement (with a maximum benefit) funded by the government and job protection of one year after completion of the leave. The population subject for the extension for the maternity leave included all mothers whose children were born after October 17, 2011 and all mothers who had children less than 24 weeks old at the time of passage, i.e. mothers whose children were born after May 2, 2011. I will argue that the date of the reform was not correlated with breastfeeding decisions through any mechanism other than the duration of the maternity leave; more on this in the next section.

Empirical Strategy

The objective is to identify the effect of the maternity leave extension on the duration of breastfeeding. A simple way to proceed is by estimating the following linear regression model:

$$y_{it} = \alpha_0 + \alpha_1 ML_{it} + \alpha_2 x_{it} + \alpha_3 w_{it} + \alpha_4 y_{it} + \varepsilon_{it} \quad (1)$$

where y_{it} is the number of months that the mother breastfed the child. ML_{it} is the actual number of weeks of maternity leave that the mother took. x_{it} is a vector of controls of mother characteristics that include: schooling attainment in grades, a cognitive test score called Wechsler Adult Intelligence Scale (WAIS), which is a test designed to measure intelligence in older adolescents and adults, age of the mother at the time of delivery, if the father lives in the household, number of people that live in the household, income quintile, and if the zone of residence is urban or rural. w_{it} is a vector of controls of child characteristics that includes: if the baby was born premature, gender, age in months and birth weight of the child. Finally, in order to control for potential seasonality effects, we include y^b_t , a vector of dummy variables for the month the child was born.

There are a number of selection issues that may bias the estimation of the causal effect of maternity leave on breastfeeding duration. Mothers who took a longer maternity leave may be systematically different from those who took shorter periods of time. The differences may be related to observable characteristics or to unobservable characteristics such as the mother's motivation or ability. If these characteristics also affect the duration of breastfeeding, it may appear that the maternity leave itself has beneficial consequences, when in fact it is due to characteristics of the mothers and their children. The effect of these unobserved variables is captured in the error term ε_{it} , and the endogeneity arises because these unobserved characteristics could be correlated with the outcome and with the number of weeks of leave the mother decided to take. If this happens, estimating Eq. (1) by Ordinary Least Squares (OLS) will give biased estimates.

A common solution for the endogeneity problem is to use an instrumental variable approach. The critical assumptions when using this strategy are (i) that the instrument is relevant for (affects significantly) the behavior of the endogenous variable, and (ii) that the instrument affects the outcome of interest only through the endogenous variable, i.e, it is exogenous and uncorrelated to other potential channels. Hence, the instrument should be correlated with the number of weeks of maternity leave (the endogenous variable) but should not directly affect the duration of breastfeeding (variable of interest). In other words, unbiased estimators can only be obtained if the instruments (z_i) are sufficiently highly correlated with ML_{it} (relevance condition) and if the instruments are truly exogenous; z_i does not directly impact y_{it} , it affects y_{it} only via its correlation with ML_{it} (exclusion restriction).

An instrumental variable that plausibly meets these two requirements is the implementation of an extension of the maternity leave. The date of the implementation of the extension is the one used as the instrument: a dummy variable that equals one if the child was born after May 2, 2011 and equals zero if the child was born before May 2, 2011. The instrument is considered exogenous because the number of weeks that the mothers took is positively and highly correlated with being exposed to the extension of the maternity leave and it is unlikely that mothers decided to have their children on a certain date because of the extension of the maternity leave. I argue that it is unlikely that the implementation of the extension of the maternity leave had a direct effect on breastfeeding duration; and that the main channel through which the extension of the maternity leave affected the outcome is through the number of weeks that the mother actually took. Thus, I use the time at which the mother had the baby (before or after the policy) as an instrument for the number of weeks that mothers took for maternity leave, and examine whether increasing the number of weeks of maternity leave generated any effect on the number of weeks that mothers breastfed.

In particular, using two-stage least squares (2SLS), I estimate the following equations:

$$\text{First Stage:} \quad ML_{it} = \beta_0 + \beta_1 z_i + \beta_2 x_{it} + \beta_3 w_{it} + \beta_4 y_{it} + v_{it} \quad (2)$$

$$\text{Second Stage:} \quad y_{it} = \alpha_0 + \alpha_1 \widehat{ML}_{it} + \alpha_2 x_{it} + \alpha_3 w_{it} + \alpha_4 y_{it} + \mu_{it} \quad (3)$$

where z_i is the excluded and identifying instrument: a dummy variable that identifies children whose mothers were exposed to the extension of the maternity leave from those who were not exposed (x_{it} , w_{it} , and y_{it} follow the same definitions used above).

Data and Descriptive Statistics

The data used in this paper come from the Chilean Longitudinal Survey of Early Childhood (ELPI), a nationwide representative survey. This face-to-face survey gathers two types of information: a socio-demographic survey applied to all mothers; and a battery of tests for evaluating cognitive, socio-emotional and anthropometric development in children and their mothers. The sample for the 2010 wave was randomly drawn from official administrative birth records of children born between January 2006 and August 2009. The sample size was approximately 15,000. The second wave was conducted in 2012. The target population for 2012 was the same sample interviewed in 2010 and an additional (refresher) sample of 3,000 children who were born between September 2009 and December 2011. The sample includes different

cohorts of children, differentiated by year of birth (Behrman, Bravo, & Urzúa, 2010). For this paper, I restricted the sample to mothers for whom the maternity leave was applicable and that breastfeed one year or less.

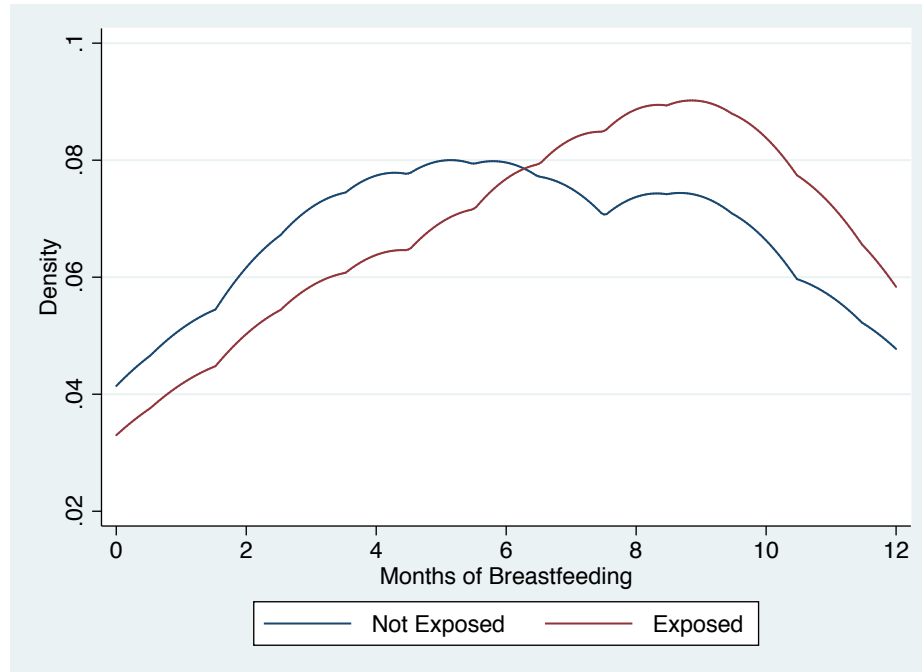
Table 1.1 presents the descriptive statistics for the analytical sample, comparing the samples exposed and not-exposed to the maternity leave extension. The table shows the mean, standard deviation, minimum and maximum for each variable, and the p -value of the t -test of the difference between the two samples. The proportion of the overall sample of mothers that were exposed to the extension of the maternity leave is 7%. The mothers exposed to the maternity leave extension took on average 17 weeks of maternity leave, almost 4 more weeks than the unexposed mothers. In terms of breastfeeding, considering the whole sample, only 4.5% of the mothers did not breastfeed their child, and the average number of months of breastfeeding of the exposed mothers is statistically different from the not exposed mothers. This is not the case for six months exclusive breastfeeding. Figure 1.1 shows the distribution of months of breastfeeding for the mothers exposed and not exposed to the reform, showing that mothers exposed give more months of breastfeeding. The peak of the curve is at 5 months for mothers not exposed, while for mothers exposed it is at around 9 months.

Table 1. 1 Descriptive Statistics

Variable	Analytical Sample								
	Not Exposed to Maternity Leave				Exposed to Maternity Leave				P-value
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	
Weeks of maternity leave	13.61	7.94	0	52	16.94	7.90	0	48	0.000
Breastfeeding duration [months]	6.44	3.64	0	12	6.97	3.50	0	12	0.064
Six months exclusive breastfeeding [1=yes]	0.38	0.48	0	1	0.41	0.49	0	1	0.392
Mother characteristics									
Schooling attainment [grades]	13.04	2.87	0	25	12.93	2.51	4	23	0.642
WAIS vocabulary	39.79	17.59	0	80	31.49	17.51	0	70	0.000
WAIS numeric	9.33	2.02	0	17	9.40	1.92	4	15	0.621
Age mother delivery baby	29.14	5.93	14	47	29.16	5.94	19	44	0.975
Father in household	0.75	0.43	0	1	0.72	0.45	0	1	0.328
Number of people in the household	4.49	1.49	2	23	4.65	1.78	2	12	0.199
Rural	0.05	0.23	0	1	0.06	0.23	0	1	0.831
Child characteristics									
Premature [1=yes]	0.02	0.13	0	1	0.08	0.27	0	1	0.000
Sex child [1=boy]	0.51	0.50	0	1	0.48	0.50	0	1	0.505
Age child [months]	50.9	16.4	16	82	12.0	2.6	7	18	0.000
Birthweight [gr.]	3358.10	473.85	1152	4980	3328.45	533.14	1011	4962	0.432
Obs. 2223					Obs. 173				

In terms of mother's characteristics, exposed and not-exposed samples are generally balanced on schooling and human capital, age, whether the father is present at home or not, household size, and zone. Children characteristics are also well balanced, although mothers exposed to the policy show a higher proportion of children that were born premature. Mothers exposed to the policy have younger children, which is expected.

Figure 1. 1 Distribution of Months of Breastfeeding Exposed and Not Exposed Mothers



Results

Maternity Leave and Breastfeeding

Table 1.2 presents the OLS and 2SLS estimates for breastfeeding duration. The first column shows the OLS results without adjusting for any covariates to the regression and the second column shows the OLS results with maternal and child characteristics as controls. First, I find that there is a positive and statistically significant association between the number of maternity weeks and breastfeeding duration. An increase of one week of maternity leave is associated with 0.026 months of breastfeeding, which is actually not even one day. As discussed before, these results are potentially biased because of the endogeneity of maternity leave.

The instrumental variable estimations are presented in columns 3 (first stage) and 4 (second stage) for the unadjusted estimations and columns 5 (first stage) and 6 (second stage) for the estimations with maternal and child characteristics as controls. The exposure to the extension of the maternity leave is measured by a dummy variable that equals 1 if the mother of the child was eligible for extending the weeks of the maternity leave and 0 if not. As expected, the association between the exposure to the maternity leave extension and the actual duration of the leave is positive and statistically significant. The coefficient indicates that being exposed to the maternity leave extension increases the duration of the maternity leave by 3.2 weeks. As mentioned before, one of the assumptions in the IV-2SLS approach is that the instruments are strong enough in predicting the endogenous variable. Indeed, the F test is significant and above the threshold of 10 for testing weak instruments (Andrews & Stock, 2005; Angrist & Pischke, 2009). I strongly reject the null hypothesis that the first stage equation is weakly identified.

From the results of the second stage of the instrumental variable estimation, I confirm that the association between weeks of maternity leave and duration of breastfeeding is positive and statistically significant. However, when controlling for endogeneity the magnitude of the coefficient estimate is much higher than in the OLS estimations: one more week of maternity leave is associated with 0.194 months of breastfeeding (around 6 days). The large difference between the OLS and IV-2SLS estimates suggest at least three possibilities. One could be that there may be classical measurement error in the weeks of maternity leave. This variable is measured by using the mothers' reports of weeks she took leave; therefore, some recall bias could be present. In presence of this classical measurement error the result of the OLS estimate suffers from attenuation bias (Bleakley & Chin, 2004; Griliches & Hausman, 1986). A second possibility is that there is some unobserved determinant of breastfeeding that is negatively associated with weeks of maternity leave so the OLS estimate is biased downward. A third possibility is that the IV estimates uses only the variation in maternity leave induced by the instrument, whereas the OLS uses all the variation, so if the marginal return to maternity leave for mothers affected by the instrument differs systematically from that of the population, then the coefficient estimated using OLS will differ from that using IV (Angrist & Imbens, 1995).

Table 1. 2 Weeks of Maternity Leave and Breastfeeding Duration

	Breastfeeding Duration [months]					
	OLS (Unadjusted)	OLS	First Stage (Unadjusted)	2SLS (Unadjusted)	First Stage	2SLS
Maternity leave [weeks]	0.027*** (0.009)	0.026*** (0.009)		0.160* (0.090)		0.194* (0.113)
Maternity leave extension date [1=yes]			3.327*** (0.626)		3.222*** (0.754)	
Mother characteristics						
Schooling attainment [grades]		0.038 (0.030)			0.218** (0.066)	0.001 (0.040)
WAIS vocabulary		-0.008* (0.005)			-0.001 (0.010)	-0.008 (0.005)
WAIS numeric		0.008 (0.040)			0.059 (0.087)	-0.004 (0.043)
Age of mother when delivered baby		0.017 (0.013)			0.068* (0.028)	0.004 (0.016)
Father in household		0.539*** (0.178)			-0.156 (0.390)	0.564*** (0.189)
Number of people in the household		-0.085* (0.051)			0.112 (0.111)	-0.106* (0.055)
Quintile 2 [ref. quintile 1]		-0.430 (0.367)			0.194 (0.806)	-0.483 (0.390)
Quintile 3 [ref. quintile 1]		0.199 (0.340)			-0.084 (0.746)	0.203 (0.360)
Quintile 4 [ref. quintile 1]		-0.255 (0.327)			0.791 (0.718)	-0.400 (0.360)
Quintile 5 [ref. quintile 1]		-0.313 (0.331)			0.315 (0.726)	-0.374 (0.353)
Rural		0.203 (0.329)			-0.346 (0.721)	0.259 (0.350)
Child characteristics						
Premature [1=yes]		-1.416*** (0.541)			-2.976* (1.186)	-0.932 (0.659)
Sex child [1=boy]		-0.207 (0.149)			-0.007 (0.328)	-0.197 (0.158)
Age child [months]		-0.002 (0.004)			-0.007 (0.010)	0.003 (0.006)
Birthweight [gr.]		0.000*** (0.000)			-0.000 (0.000)	0.001*** (0.000)
Constant	6.107*** (0.148)	3.966*** (0.941)	13.61*** (0.168)	4.265*** (1.243)	10.50*** (2.062)	2.065 (1.620)
Month of birth dummy variables		Yes			Yes	Yes
Observations	2,396	2,396	2,396	2,396	2,396	2,396
F stat (excluded instruments)			28.21		18.27	

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The results for six months exclusive breastfeeding are different. The OLS estimations show a positive and significant association between the weeks of maternity leave and exclusive breastfeeding, however the estimations that control for the endogeneity are positive but not statistically significant. This suggests that while the maternity leave extension increased breastfeeding duration, the effects were not large enough to attain the policy goal. However,

concluding that the policy was ineffective could be an error as the effects could be heterogeneous across different socioeconomic groups.

Table 1. 3 Weeks of Maternity Leave and Six Months Exclusive Breastfeeding

	Six Months Exclusive Breastfeeding					
	OLS (Unadjusted)	OLS	First Stage (Unadjusted)	2SLS (Unadjusted)	First Stage	2SLS
Maternity leave [weeks]	0.004*** (0.001)	0.004*** (0.001)		0.010 (0.012)		0.010 (0.014)
Maternity leave extension date [1=yes]			3.331*** (0.626)		3.218*** (0.754)	
Mother characteristics						
Schooling attainment [grades]		-0.001 (0.004)			0.217** (0.066)	-0.002 (0.005)
WAIS vocabulary		0.001* (0.001)			-0.001 (0.010)	0.001* (0.001)
WAIS numeric		0.004 (0.005)			0.061 (0.087)	0.004 (0.005)
Age of mother when delivered baby		0.001 (0.002)			0.068* (0.028)	0.001 (0.002)
Father in household		0.066*** (0.024)			-0.158 (0.390)	0.067*** (0.024)
Number of people in the household		-0.003 (0.007)			0.113 (0.111)	-0.004 (0.007)
Quintile 2 [ref. quintile 1]		-0.078 (0.049)			0.193 (0.806)	-0.080 (0.049)
Quintile 3 [ref. quintile 1]		-0.037 (0.046)			-0.0826 (0.746)	-0.037 (0.046)
Quintile 4 [ref. quintile 1]		-0.051 (0.044)			0.794 (0.718)	-0.056 (0.046)
Quintile 5 [ref. quintile 1]		-0.069 (0.044)			0.313 (0.726)	-0.071 (0.045)
Rural		0.012 (0.044)			-0.345 (0.721)	0.014 (0.044)
Child characteristics						
Premature [1=yes]		-0.130* (0.073)			-2.987* (1.186)	-0.113 (0.084)
Sex child [1=boy]		-0.022 (0.020)			-0.013 (0.328)	-0.022 (0.020)
Age child [months]		-0.001 (0.001)			-0.007 (0.010)	-0.000 (0.001)
Birthweight [gr.]		0.000*** (0.000)			-0.000* (0.000)	0.000** (0.000)
Constant	0.329*** (0.020)	0.077 (0.126)	13.61*** (0.168)	0.244 (0.160)	10.57*** (2.063)	0.008 (0.206)
Month of birth dummy variables		Yes			Yes	Yes
Observations	2,396	2,396	2,396	2,396	2,396	2,396
F stat (excluded instruments)			28.28		18.23	

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 1.4 shows effects by using different socioeconomic group samples. First, I use an educational indicator: high-educated mothers defined as those who have more than 12 grades of schooling attainment, while low-educated mothers are defined as those with 12 or less grades of

schooling. Notice that the 12 grades schooling marker in Chile is a meaningful distinction since it is the end of high school. Interestingly, maternity leave effects for low-educated mothers are completely different compared to the case of high-educated mothers. One additional week of maternity leave increases the months of breastfeeding by 0.351 (around 10 days) for low-educated mothers, while for high-educated mothers the effect is close to zero and statistically insignificant.

The third and fourth columns in Table 1.4 replicate the exercise but now by income groups, with quantiles 1-3 considered as “low-income” group, while quantiles 4-5 as “high-income” group. An additional week of maternity leave increases the months of breastfeeding for low-income mothers by 0.468 (around 15 days), while for high-income mothers this coefficient is null and statistically insignificant.

Table 1. 4 Weeks of Maternity Leave and Breastfeeding Duration by SES

	2SLS Breastfeeding Duration [months]			
	Low-Educated Mothers	High-Educated Mothers	Quintiles 1, 2 and 3	Quintiles 4 and 5
Maternity leave [weeks]	0.351** (0.165)	-0.102 (0.209)	0.468** (0.234)	0.037 (0.152)
Observations	1,533	863	797	1,599

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, father in household, number of people in the household, income quintile, rural dummy variable, if the child was born premature, sex and age (in months) of the child, birth weight and dummies for month of birth of the child.

Note that the results are robust across subsamples when considering the six months exclusive breastfeeding dummy (see Table 1.5). One more week of maternity leave generates a significant increase in the proportion of low-educated and low-income mothers that breastfeed their children at least 6 months (9% and 16% increases with respect to mothers that were not exposed to the policy, respectively), but the effects are indistinguishable from zero for richer mothers. This suggests that the maternity leave extensions had important redistributive effects in favor of disadvantaged mothers. A potential explanation for these results could be that for high-educated and richer mothers the decision about how many months to breastfed is not directly related with additional weeks of maternity leave, but other factors are driving the decision. In the context of a

developing country, low-income women usually face substantial financial constraints, thus having a longer maternity leave becomes the best alternative way of feeding the child. As a result, it is expected that the maternity leave extension increases the breastfeeding duration for this group. This is not the case of richer women who are less credit constrained and can replace breastfeeding by alternative (and typically more expensive) ways of feeding the child.

Table 1. 5 Weeks of Maternity Leave and Six Months Exclusive Breastfeeding by SES

	2SLS Six Months Exclusive Breastfeeding			
	Low-Educated Mothers	High-Educated Mothers	Quintiles 1, 2 and 3	Quintiles 4 and 5
Maternity leave [weeks]	0.034* (0.020)	-0.042 (0.036)	0.059** (0.029)	-0.022 (0.023)
Observations	1,533	863	797	1,599

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, father in household, number of people in the household, income quintile, rural dummy variable, if the child was born premature, sex and age (in months) of the child, birth weight and dummies for month of birth of the child.

Placebo test

As a robustness check, in this section I examine the sensitivity of the previous findings by using a false instrument to test if the results change or not due to a different timing. I use the same day and month of the original instrument but I changed the year, so instead of using the date May 2, 2011 as the binary instrument, I use May 2, 2010. By doing this I expect to find null results, since the false instrument should not be statistically significant in explaining variation in breastfeeding duration and six months exclusive breastfeeding. Table 1.6 confirms this result.

Table 1. 6 Weeks of Maternity Leave and Breastfeeding 2SLS Estimates with False Instrument

	Breastfeeding Duration	Six Months Exclusive Breastfeeding
Maternity leave [weeks]	-0.023 (0.233)	-0.016 (0.033)
Observations	2,320	2,320

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, father in household, number of people in the household, income quintile, rural dummy variable, if the child was born premature, sex and age (in months) of the child, birth weight and dummies for month of birth of the child.

Breastfeeding Duration and Children's Development

One of the main goals of the maternity leave extension reform was to improve children's overall wellbeing. This could be achieved in several different ways, one of the most obvious and probably more direct way is promoting and increasing the amount of time that mothers breastfed their children². There are two biological-specific mechanisms that could be driving the relationship between breastfeeding and children's developmental outcomes. The first is a physiological theory that relates the properties of breast milk to neural development; breast milk contains two acids that have a positive influence on the neural development of the child, which build up in the brain during the third trimester and first months of life positively affecting cognitive abilities (Rothstein, 2013). The second is a psychosocial theory related to the act of breastfeeding itself; the effects of enhanced early mother-child contact and nurturance (Luby, Belden, Whalen, Harms, & Barch, 2016). The act of breastfeeding causes the release of hormones in the mother (prolactin and oxytocin), which may enhance positive mothering behaviors and thus directly influence the children's cognitive development.

Albagli and Rau (2016) provide evidence for a positive causal effect of the 2011 reform on children's outcomes. While it is out of the scope of this paper to estimate the causal effect of breastfeeding on children's outcomes, I examine how breastfeeding duration evolves with child development. Children's developmental outcomes are measured through the Test of Learning

² Other mechanism could be that mothers spend more time with their children, stimulating their development through activities, like talking, playing, reading, playing music to them, among others.

and Child Development (TADI), a test that was applied to all children in the 2012 round. This is a rating scale for children from three months to six years, which is designed and standardized in Chile. TADI evaluates four dimensions: cognitive, motor, language and socio-emotional, each of which is a separate scale, allowing evaluating the development and learning globally.

I first regress children's outcomes on breastfeeding duration, controlling for maternal and child characteristics. Although there are reasons to believe that these associations may be biased, it is important to note that, for every dimension of the test, increasing the months of breastfeeding is associated with increases in the test scores, as is shown in Fig.1.2. This is suggestive evidence that breastfeeding could be one of the mechanisms explaining the positive effects of maternity leave extension on child development.

Moreover, when I look at these same results by socioeconomic status, I only see a positive association for low-educated mothers, with the relationship between breastfeeding duration and child outcomes weakly negative (although statistically insignificant) for high-educated mothers. The result is consistent with the findings in the previous section.

Figure 1. 2 Months of Breastfeeding and TADI Test Scores

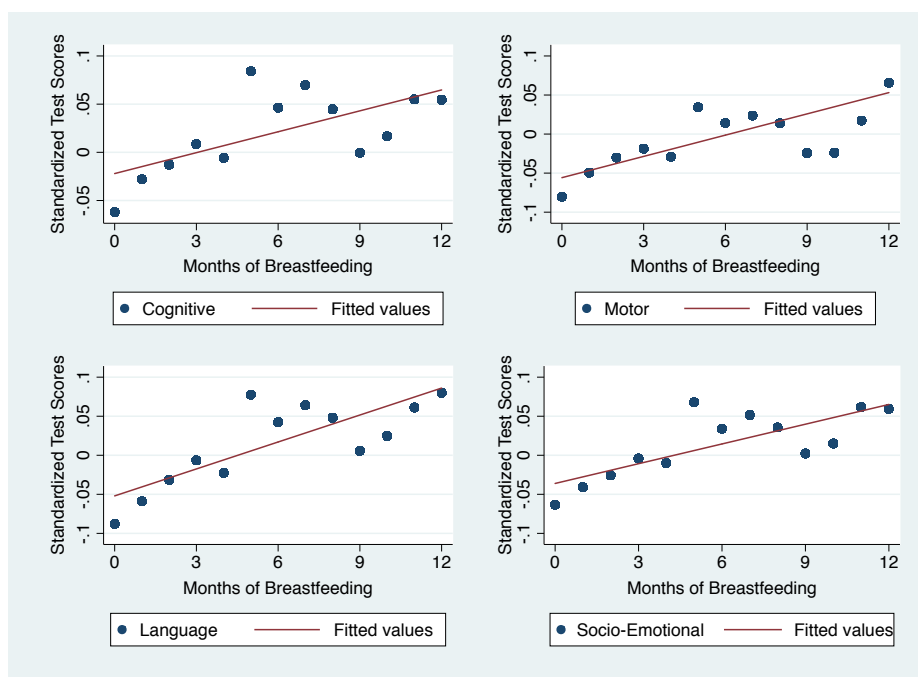
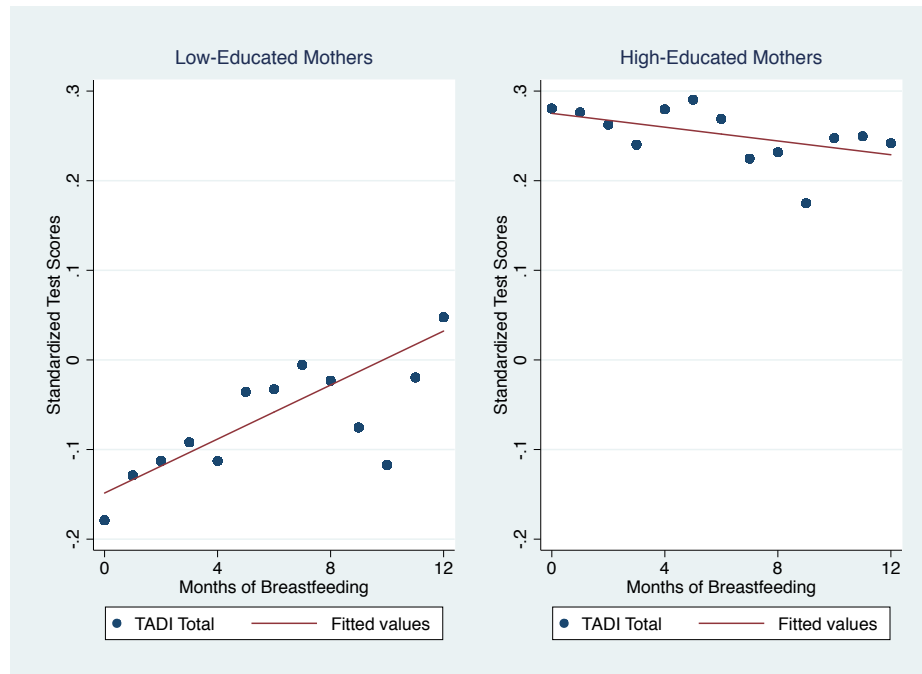


Figure 1. 3 Months of Breastfeeding and TADI Test Scores by Maternal Education



Conclusions

This paper provides empirical evidence that the number of weeks that mothers take for maternity leave has positive effects on the amount of time she breastfeeds her child. I have shown that not considering the endogeneity associated with the decision of the number of weeks of maternity leave would underestimate, in significance and size, the real associations between maternity leave and breastfeeding. Then, by exploiting a plausibly exogenous variation on the timing at which a maternity leave extension reform in Chile was implemented, I estimate the causal effect of the maternity leave extension on breastfeeding duration.

The findings are conclusive. One more week of maternity leave causes an increase of 0.194 months of breastfeeding (around 6 days), on average. This result is an important contribution to the literature because almost all the previous evidence in developing countries is associative due to the challenges in controlling for choices regarding the number of maternity leave weeks and measurement error. Therefore, in most studies weeks of maternity leave may be proxying in part for unobserved factors that may both affect the breastfeeding choices and the weeks of leave.

Importantly, the effects show substantial heterogeneity across high- and low-educated mothers. One additional week of maternity leave increases the months of breastfeeding by 0.351 (around 10 days) for low-educated mothers, while for high-educated mothers the effect is weakly negative and statistically insignificant. Moreover, an additional week of maternity leaves increases the months of breastfeeding for low-income mothers (quintiles 1 to 3 in the income scale) by 0.468 (around 15 days), while high-income mothers (quintiles 4 and 5) do not increase breastfeeding duration at all.

The heterogeneous effects across socioeconomic groups is a policy-relevant result in the context Chile, where there is evidence of significant income inequality. Breastfeeding is a very cost-effective investment that low-income mothers could make to compensate, at least partially, for lack of other resources. Nonetheless, other outcomes and the overall resource expenditure on the policy must be considered when doing a cost-benefit analysis of the policy. As the extension of the maternity leave is a universal and very expensive government funded policy, a natural policy implication of these results is that the policy should target the most disadvantaged groups, those for which the policy seems to be more cost-effective. However, this could be a rushed conclusion as there is not clear evidence on the mechanisms driving the heterogeneous effects. In particular, it is not obvious why did the policy had positive effects on poorer mother and null effects on richer ones, and thus more research should be done in this regard before throwing any definite policy conclusion.

Chapter 2: Parental Preferences and Allocations of Investments in Children's Learning and Health Within Families

Abstract

Empirical evidence suggests that parental preferences may be important in determining investment allocations among their children. However, there is mixed or no evidence on a number of important related questions. Do parents invest more in better-endowed children, thus reinforcing differentials among their children? Or do they invest more in less-endowed children to compensate for their smaller endowments and reduce inequalities among their children? Does higher maternal education, affect the preferences underlying parental decisions in investing among their children? What difference might such intrafamilial investments among children make? And what is the nature of these considerations in the very different context of developing countries?

This paper gives new empirical evidence related to these questions. I examine how parental investments affecting child education and health respond to initial endowment differences between twins within families, as represented by birth weight differences, and how parental preference tradeoffs and therefore parental investment strategies vary between families with different maternal education. Using the separable earnings-transfers model (Behrman et al., 1982), I first illustrate that preference differences may make a considerable difference in the ratios of health and learning differentials between siblings – up to 30% in the simulations that I provide. Using data from the Early Childhood Longitudinal Survey for Chile, I find that preferences are not at the extreme of pure compensatory investments to offset endowment inequalities among siblings nor at the extreme of pure reinforcement to favor the better-endowed child with no concern about inequality. Instead, they are neutral, so that parental investments do not change the inequality among children due to endowment differentials. I also find that there are not significant differences between families with low- and high-educated mothers.

Introduction

Empirical work from the last decade has emphasized the important role that early-life conditions and childhood development play in later life outcomes, especially in human capital formation. Cunha and Heckman (2007) developed a multistage process of skill formation whereby the existing stock of human capital of children complements parental investments in the process of

subsequent capital formation. Parental investments are influenced by parental preferences, prices, production technology that links investments to outcomes and resource constraints, but also by parents' perceptions about the endowments of their children. Parents learn about the endowment of a child at birth (or soon after), and this influences their decisions about postnatal investments (Del Bono et al., 2012).

Most of the empirical emphasis has been on differences *between* families in such investments. But there also may be important differences in investments *within* families that have been much less studied. Therefore, understanding parental preferences with respect to allocation of investments *among* children in the same family and the factors that drive the differences in these preferences *between* families is helpful for unraveling further the mechanisms underlying heterogeneity in human capital formation, and thereby in children's outcomes.

This study gives new empirical evidence on how parental intrafamilial investment strategies respond to initial endowment differences between siblings within a family and how the underlying parental preferences vary across families with different maternal educational levels. Specifically, this paper addresses the questions: How are parental investments in child education and health allocated among siblings within the same family? Do parents reinforce or compensate for initial endowment differences, as measured by birth weights, among their children? Does this reinforcement/compensation behavior vary across families with different maternal educational levels? Is inequality in learning and health outcomes between siblings affected much by the nature of parental preferences?

Scholars tend to agree that parents may not make equal investments among children in the family. They disagree, however, on the type of child who receives additional resources. Parents who adopt a *reinforcing strategy* invest more in high-endowment children, hence leading to increased inequality in outcomes that depend on human capital (e.g., health, earnings) among children in the family. In contrast, parents who use a *compensating strategy* invest more in more-disadvantaged children; consequently, potential outcomes that depend on human capital among children are equalized to a degree. Parents may also adopt a *neutral strategy* in which they neither compensate or reinforce, hence disregarding initial endowments. Empirical studies have found that parental investments generally reinforce to a degree initial endowment differences (Aizer & Cunha, 2012; Behrman, Rosenzweig, & Taubman, 1994; Datar, Kilburn, & Loughran, 2010; Frijters, Johnston, Shah, & Shields, 2013); however, some studies also find evidence that parents adopt compensating behavior (Del Bono et al., 2012; Halla & Zweimüller, 2014). For an excellent review see Almond and Mazumder (2013).

Most of the previous studies on intrafamilial parental investments in early childhood have focused on siblings. However, even though siblings fixed-effects models control for common stable family characteristics, this strategy does not control for the possibility that children within the family differ in unobservable ways because singleton siblings are born at different times and parental characteristics at birth therefore are likely to differ and because there may be birth-order effects (Almond & Currie, 2011). Twins provide a better way to deal with the problem of unobservables including those that may vary as parents age. Twins fixed-effects estimates control for age-specific unobserved heterogeneity between children coming from the same family and for birth order.

Also, most of the previous research looks at developed countries. But realities in developing countries may be critically different. The lack of support that mothers receive in terms of maternity leave and postpartum care, combined with the huge quality gap between public and private schooling systems, can shape parental investment decisions and children's outcomes differently as compared to developed countries. Evidence looking at parental investment in early childhood from developing countries is scarce. Behrman (1988a) studied the intrahousehold allocation of nutrients between sons and daughters in rural India, with results suggesting a pro-male bias. This male preference is associated with caste rank; lower-ranked castes exhibit more male preference. Parents do consider equity and productivity, but the combination of limited inequality aversion and pro-male preferences, particularly for the lowest castes, may leave those children who are less-well endowed, close to the margin of survival. In Behrman (1988b) the focus was on birth order and seasonality. The evidence shown is that nutrients are allocated to children independent of their relative endowments, however, parents favor the older children and in the lean season inequality aversion is much less, and perhaps insignificant. Therefore, when food is scarcest, parents follow closer to a pure investment strategy, thereby exposing their more vulnerable children to greater malnutrition risk. Ayalew (2005) studied parental investment decisions in the face of differences in endowments among siblings in rural Ethiopia, finding that parents reinforce for learning inequalities and compensate for health inequalities. These findings provide useful evidence that parents in a developing context may behave differently when considering different outcomes, suggesting that maybe when parents are confronted with limited resources, they care about equality in terms of some outcomes, but they reinforce in others. However, these papers approach the within-family lens by looking at siblings, and not twins. Bharadwaj, Løken, and Neilson (2013) use a model of human capital accumulation in which parental investments respond to initial endowments. An interesting feature of this paper is that the authors compare the behavior of parents with singleton siblings versus parents with twins. They find that investments are compensatory regarding initial health endowments with siblings, but with

twins, parents do not invest differentially. Except for using sibling data, the methodological perspective of this paper resembles the one that I adopt in this study. However, Bharadwaj et al. (2013) look at parental investments and outcomes of the children later in life -- specifically they look at investments of parents in the schooling context and outcomes in standardized school tests.

Some authors have hypothesized that parental intrafamilial investment varies due to cultural parenting practices and family socioeconomic status rather than intentionally reinforcing or compensating for endowments (Lynch & Brooks, 2013). This narrative suggests that parental intrafamilial investment strategies are not tied to cost-benefit calculations on the part of parents, but are instead a product of socio-demographic characteristics and structural constraints (Lynch & Brooks, 2013). However, until recently, most of the empirical evidence has not given much consideration to this approach. But some recent evidence suggests that parental intrafamilial investment responses may vary with family socioeconomic status. Restrepo (2016) analyzed how parental investments respond to low birth weight, and found important differences in investment responses by maternal education; high school dropouts reinforce and high-educated mothers compensate. Hsin (2012) used a sibling fixed-effect model and also looked at differential investment by mother's education, specifically looking at maternal time investments. The author concluded that less-educated mothers devote more total time and more educationally-oriented time to the children with higher birth weight, whereas better-educated mothers devote more total and more educationally-oriented time to lower birth weight children. Grätz and Torche (2016) found a different result. Using as an endowment measure early cognitive ability, they found that advantaged parents provide more cognitive stimulation to higher-ability children, while less disadvantaged parents do not respond to ability differences. An interesting result of this paper is that there is no differential response between advantaged and disadvantaged parents to birth weight. This evidence of differential parental investment responses for different outcomes highlights the value of further research on such possibilities in other contexts.

Therefore, exploring heterogeneity in parental preferences underlying different intrafamilial investments affecting diverse children's outcomes and comparing between different levels of maternal education within a developing country context is an important contribution to the literature on preferences underlying intra-household allocations for several reasons. First, families from developing countries face different constraints than those from the developed world, that could end up shaping preferences for the type of investments they prioritize. Second, the knowledge and importance that public opinion gives to different child outcomes could also be different between contexts, determining how parents define their preferences in terms of

investments. Both of these aspects could have important implications on inequality in children's later-life outcomes. Also, given the large inequality in many developing countries, the childrearing process could be very different for children from upper-class families than for children from low-class families. There is a huge gap in such families' access to private and public health and schooling systems that, since conception, can determine the future of the child. Furthermore, families with lower maternal education could be willing to implement a strategy to reduce risk, and invest more in more-endowed children to make sure at least one child will be successful, or, alternatively, reinforcing behavior could occur because there is less effort in investing in highly-endowed children.

In sum, the mixed evidence, the lack of studies using twins data particularly for developing contexts, and the limited concern for the relation between maternal education and preferences all point to the need for further research on preferences underlying differential parental intrafamilial investment strategies within families from developing countries. In this paper I contribute to the literature on early childhood health and learning, adding new evidence on intra-household preference models of parental intrafamilial investments using twins data from Chile and examining how parental preferences underlying parental investment strategies vary between families with different maternal education.

Theoretical Framework

The paper uses an adaptation of the general preference model developed in Behrman et al. (1982). The original model is a constrained welfare (or utility) maximization model, where parental preferences play a central role in determining the distribution of educational attainments and earnings among children. Earnings are assumed to be the sole determinant of an adult's economic well-being. Expected lifetime earnings are determined by an individual's genetic endowments and education, and parental expenditures on education increase a child's expected lifetime earnings but at a diminishing rate. In the adapted version of the model used here, parents maximize the learning and health developmental outcomes of their children O_i (instead of earnings), subject to a logarithmic production function that depends on endowments G_i and parental investments S_i and subject to a budget constraint associated with the cost of these investments.

In the separable earnings-bequest model developed in Behrman et al. (1982) the parameters that determine whether parents adopt a compensating, reinforcing, or neutral intrafamilial investment strategy depend on parents' aversion to inequality and on the properties of the earnings function

(in our case cognitive, language, motor, socio-emotional, height, weight and BMI functions). In this paper I use a Constant Elasticity of Substitution (CES) welfare function as it provides a convenient functional specification that allows the full range of inequality aversion regarding the distribution of outcomes among the family's children; from the case of linear indifference curves (zero inequality aversion or extreme reinforcement), through the Cobb-Douglas case (unitary inequality aversion or neutrality), to the fixed-coefficient case (pure inequality aversion or extreme compensation). Also, I treat parental investments and genetic endowments as the only inputs in the production functions, which, given the young ages of the children, is a credible assumption.

I first estimate the parameters of the parental welfare function for learning and health developmental outcomes assuming that all families in our sample have the same welfare function. However, since I want to look at possible differences in preferences between families as they relate to maternal education, I subsequently relax this assumption and investigate parental welfare preferences differentiating families between low and high education of the mother. Maternal education is a particular important indicator of possible family differences given the dominant roles of most mothers in raising children and the perceived role of education in affecting preferences (Oreopoulos & Salvanes, 2009). Maternal education also is the indicator most commonly used in the previous literature (see introduction).

In our model parents maximize a CES welfare function of the form:

$$W^o(O_1, \dots, O_n) = \sum_{i=1}^n a(O_i)^c \quad (1)$$

subject to a double logarithmic learning/health production function

$$\log O_i = \alpha_g \log G_i + \sum_{s=1}^m \alpha_{ms} \log S_{mi} = \alpha_g \log G_i + \alpha_s \log S_i \quad (2)$$

and the budget constraint

$$P_s \sum_{i=1}^n S_i = R^o \quad (3)$$

where O_i is the expected test score or health measure of the i th child, G_i is the child's endowment at birth, S_i is the aggregate parental investments in the i th child (the weighted sum of the m individual investments S_{mi} in that child), and n is the number of children in the family. In the budget constraint, P_s is the price per unit of aggregate investment in children in the family and R^o

is the total value of resources devoted to children. Solving for the equilibrium ratios of aggregate investments and outcomes from the first-order conditions yields:

$$\log \frac{S_i}{S_j} = \frac{\alpha_g c}{1 - \alpha_s c} \log \frac{G_i}{G_j} \quad (4)$$

$$\log \frac{O_i}{O_j} = \frac{\alpha_g}{1 - \alpha_s c} \log \frac{G_i}{G_j} \quad (5)$$

The sign and significance of the coefficient c gives the curvature of parental preferences, and, thus, whether they are reinforcing, compensatory or neutral. If $c=1$, parents have no aversion to inequality and do not care about the distribution of test scores or health outcomes among their children. If $1>c$, parents have some concern about inequality but if $1>c>0$ they still invest so as to reinforce endowment differences among their children. If $c = 0$ (the log-linear or Cobb-Douglas case) parents are neutral and balance their preferences for equality against the trade-off the developmental outcome production functions and budget constraint offer them. If $0>c$ parents compensate by investing more in the less-endowed child. Table 2.1 summarizes the different cases.

Table 2. 1 Relation of c to parental concern about inequality and parental investment strategies

Value	Interpretation
$c = -\infty$	Parents have extreme compensatory preferences with only concern about inequality.
$c < 0$	Parents have compensating preferences and invest more in the less-endowed child.
$c = 0$	Parents have neutral preferences and invest equally in the children, regardless of the different endowments.
$1 > c > 0$	Parents have reinforcing preferences and invest more in the more-endowed child.
$c = 1$	Parents have extreme reinforcement preferences with no concern about inequality.

I use relation (4) to estimate the parameter c , related to the curvature of parental preferences that reflects their concern about equity versus productivity of their investments in their children. In this relation, the left- side is the logarithm of the ratio between the two children for the aggregate parental investments in each child. To get these aggregate parental investments in each child, I first estimated the production function in relation (2) using three (=m) different measures of

parental investments in each child. Using the weights estimated in this procedure (α_{ms}), I combined the three parental investments into one aggregate investment, which I then used to estimate relation (4). For more details, see Methodological Appendix. The next step was to get the value of the parameter c from the coefficient of the ratio of endowments obtained in the estimation of relation (4). For this step, I used the additional assumption of constant returns to scale in the production function so that $\alpha_g + \alpha_s = 1$. Hence, I used the estimation of α_g that I obtained from the production function (2), which allows us to estimate c . I do this for eight different learning and health developmental outcomes. The estimations that explore different preferences by maternal educational level also include an interactive dummy term between maternal educational level and the logarithm of each investment. Given the positive production function parameters, α_g and α_s , the compound coefficient from relation (4) will be significantly different than $-\infty$ (or a very big negative number such as negative 0.1^{12}) if there is not pure compensation but some concern about productivity in addition to strong concern about inequality, negative if the parameter c is negative, not significantly different from zero if the parameter c is not significantly different from zero, significantly positive if the parameter c is significantly positive, and not significantly different from 1.0 if there is extreme reinforcement and no concern about inequality. Therefore, I use the estimates of relation (4) to establish whether the parameter c is significantly different from $-\infty$, significantly negative, not significantly different from zero, significantly positive or not significantly different from 1.0.

Relation (5) is useful to provide a sense of how much the ratio of the outcomes between the twins might vary with changes in the values of the parameter c and in the production function parameter α_g . In Table 2.2 I show that, given the ratio of endowments (in this table 1.3, which is at the 90th percentile for the birth weight data in our sample) and given values of c and α_g , the ratios of outcomes between the twins may vary considerably. For $c = 1$ (extreme reinforcement), the outcome for the better endowed twin is 130% of the outcome of the less well-endowed twin. For $c = -\infty$ (extreme compensation), the ratio of outcomes is equal to 1 so that there is no difference between twins in the outcomes. For values of $c=0$ (neutrality), the ratio in the outcomes varies according to parameters of the production function, ranging from 105.4% to 123.4% for the three examples in Table 2.2.

Table 2. 2 Ratio of the outcomes for different values of parameters c and α_g

Outcome Ratio (for Endowment Ratio = 1.3)					
c values	$-\infty$	-0.5	0	0.5	1
α_g values					
0.20	1.000	1.038	1.054	1.091	1.300
0.50	1.000	1.111	1.140	1.191	1.300
0.80	1.000	1.210	1.234	1.263	1.300

Note that maternal education may have effects on parental investment through shifting the budget constraint through R^0 or by altering the production function parameters in relation (2), both of which may affect interfamilial differences in investments in children. But those possibilities are not what I am investigating in our estimates of the direct effect of maternal education on parental preferences through the within-family allocations. Or, to put it differently, I am examining the effects of maternal education on preferences related to *within*-family allocations controlling for (with the within-twins estimates) all family characteristics including family resources.

For this study, I used birth weight as the measure of endowment. Birth weight is of relevance, not only because it is a measure of prenatal exposures and proxies for health status at birth, but also has been used in other studies as a measure of endowments at birth that can be observed readily by parents (Torche & Conley, 2016). Birth weight is an important marker of individual health and human capital endowments at the beginning of life, which is predictive of later development. Birth weight has two proximate determinants: gestational age and intrauterine fetal growth. Twins do not vary in gestational age, so the only source of variation in birth weight in twin comparisons is differences in fetal growth. Within-twin pair comparison is based on the assumption that the birth weight discrepancy between twins emerges basically from random differences in access to nutritional intakes resulting, for example, from position in the uterus or umbilical cord attachment to the placenta (Torche & Conley, 2016).

Data

The data used in this paper comes from the *Encuesta Longitudinal de la Primera Infancia* (ELPI), a Chilean nationwide representative survey of infants and young children. This face-to-face survey gathered two types of information: a socio-demographic survey applied to all mothers; and a battery of tests for evaluating cognitive, socio-emotional and anthropometric development in children and their mothers.

The sample for the 2010 wave was randomly drawn from official administrative birth records of children born between January 2006 and August 2009. The sample size was 15,000. The second wave was conducted in 2012. The target population in 2012 was the children interviewed in 2010 and an additional 3,000 children who were born between September 2009 and December 2011. In the 2012 wave, a sampling of twins was added. I use this part of the sample for this paper. The cross-sectional sample of twins, that was only taken in the 2012 wave, includes 2,046 observations.

For the measurement of children's outcomes, I considered different dimensions: *learning and developmental outcomes*, namely, cognitive, language, motor and socio-emotional skills and *health and nutritional outcomes*, namely weight, height and body mass index (BMI). This decision was made based on previous research that has shown that parents could behave differently in terms of health and learning investments, therefore generating different results for their children (Ayalew 2005). To measure cognitive, language, motor and socio-emotional skills, I use a developmental test score called the Test of Learning and Child Development (TADI). This is a rating scale for children from 3 months to 6 years, designed and standardized in Chile. TADI evaluates four dimensions: cognitive, language, motor and socio-emotional, each of which is a separate scale, allowing the evaluation of development and learning globally. I use test scores, since they are reliable measures of children's development and also important predictors of future academic outcomes. The three health outcome variables that I explore are weight, height and body mass index (BMI). Weight has been considered as an indicator of the short-run health status of children mainly because it is highly sensitive to short-term changes in nutrients intakes and morbidity, providing a good measure in this framework of parental investments affecting outcomes. Height is an important indicator of chronic early-life health and nutritional status, with substantial associations with outcomes over the life cycle (Hoddinott et al., 2013; Victora et al., 2008). The body mass index is a measure of body weight for a specified height and it has been used in multiple studies as a measure of health because it provides a measure of body fatness, which is a function of a wide variety of dietary and non-dietary inputs controlled by parents. Also, it is correlated with diseases later in life. These three outcomes provide us with a fairly full picture of children's health status.

Weight was measured using digital floor weight scales and height was measured using tape measures. The interviewers were trained with a strict protocol on how to use the scales and tapes to get accurate measures of the mothers and children's weight and height. Interviewers were provided with a field-work manual with the instructions and corresponding pictures. The protocols

for weight and height measures were different depending on the age of the children. For the weight measure, children between 2 and 5 years old were asked to stand on the scales, without shoes, and using light clothes (removing jackets or big sweaters). For children aged less than 2 years, the protocol was done in two steps. First the mother was asked to stand on the scales, without shoes and using light clothes. Once the interviewer had a weight measure for the mother, she had to take the child in her arms, and stand on the scale again. The measure of the child weight was obtained by subtracting from the last measure the mother's weight. For the height measure, children between 2 and 5 years old were measured standing next to a wall and for children under 2 years old, the measurement was made on the floor or on the top of a table, with the help of the mother. The BMI was calculated using these measures, with the WHO standards.

For parental investments I use three different measures. The first measures the time that mothers spend with their children doing different activities like reading books, singing, going to the park, teaching names of animals or colors, etc. Maternal time investments are important components of the investments parents make towards their children's human capital development (Hsin, 2012). Also this measure reflects early stimulation that parents can do to improve early child development. The variable used was constructed using the set of questions in Appendix A1 and I build a continuous variable using the average of time spent in each activity with each child. The second parental investment variable came from a selection of questions from the Home Observation for the Measurement of the Environment (HOME). This instrument enables reporting on the educational quality of the home environment and emotional and verbal responses from the mother towards the child. The questionnaire is answered two times (one for each twin) by the interviewer while he/she is in the household doing the other evaluations. Since the home environment is the same for both twins, I build the scale only using the emotional and verbal responses that vary between twins. There is evidence of the importance of these kinds of variables in the development of pre-academic skills. The scale developed represents the percentage of positive answers out of the total answers. Appendix A2 shows the questions selected from each scale to build the indicators used in the analyses. I choose investments from mothers rather than fathers for two reasons. First, the HOME observation scale was applied during the interview with the mother, so in order to be consistent with our other investment variables I choose mothers. Second, the missing values from the paternal investments are considerably greater than for maternal investments. The third parental investment is related to children's food consumption and it is a simple count of the weekly healthy food consumption of the children (water, milk, fruits and vegetables). Table 2.3 shows means and percentage distributions for our sample of twins.

Table 2. 3 Means and percentage distributions of the sample

		Twins			
	Obs.	Mean	SD	Min	Max
Parental Investments					
Maternal Time (Activities)	2166	44.3	20.0	0	98
Home (Adapted version)	2163	0.9	0.2	0	1
Healthy food	2166	23.8	3.8	0	35
Outcomes					
TADI Cognitive Test Score	2126	33.0	13.4	2	52
TADI Language Test Score	2138	33.0	11.2	1	47
TADI Motor Test Score	2130	34.3	13.5	4	55
TADI Socio-Emotional Test Score	2138	37.8	12.2	8	56
Weight (kg)	2094	16.7	4.7	6.9	38.9
Height (cm)	2087	98.7	13.8	66	135
Body Mass Index	1983	16.9	1.7	12.0	22.2
Mother characteristics					
Schooling attainment [grades]	2148	11.7	3.1	0	25
Age	2152	32.0	6.8	16	49
Child characteristics					
Sex child [1=boy] %	2184	51.1	-		
Age child [months]	2184	45.2	20.4	8	84
Birth weight [gr.]	2017	2397.2	545.7	688	4850

An important requirement for estimating equation (4) is that there is sufficient within twins-pair variation in the child outcomes, parental investments and in the endowments to identify their effects. Table 2.4 shows the degree of variation within twinship-pairs in all the variables used in the estimates. The fourth column of Table 2.4 shows the number of twin-pairs that have variation, and columns 5 and 6 show the mean and standard deviation of these within twin-pairs differences. In terms of variation within twinship-pairs, the smallest percentage is for the measure of average consumption of healthy food, with 11.8%. In terms of the developmental and health measures approximately 80% of the pairs have differences. These within twinship-pair variations are sufficient to allow us to estimate the models. I also present in Appendix A3 four graphs to illustrate the patterns of outcome differences between twins as related to birth weight differences and average birth weight between twins, in the underlying data; basically, these graphs suggest that the outcome differences do not vary systematically with the birth weight differences and average birth weights.

Table 2. 4 Variation within Twin-Pair Parental Investments and Outcomes

	Pair Obs.	Mean	Std. Dev	Pairs with Variation	Mean Abs. Variation	Std. Dev Abs. Variation
Parental Investments						
Maternal time (Activities)	1083	1.62	5.24	248	7.11	9.01
Home (Adapted version)	1074	0.09	0.13	529	0.18	0.15
Healthy food	1083	0.60	2.18	128	5.10	4.15
Outcomes						
TADI Cognitive Test Score	1049	2.58	2.96	852	3.17	2.99
TADI Language Test Score	1054	2.61	3.03	847	3.24	3.06
TADI Motor Test Score	1061	2.21	2.54	809	2.90	2.55
TADI Socio-Emotional Test Score	1061	2.75	3.30	861	3.38	3.36
Weight [kg]	1018	1.19	1.41	960	1.26	1.42
Height [cm]	1014	1.93	2.30	792	2.47	2.33
Body Mass Index	940	0.98	0.93	915	1.01	0.93
Endowment						
Birth weight [gr.]	1004	261.9	251.0	969	271.4	250.4

Finally, I characterize, in Appendix A4, the completeness of coverage of the data. For the twins pairs with birth weight data, the percentages of missing data range from 0% to 1.6% for the parental investments and from 2.9% to 16.2% for the child outcomes, higher than 8% only for BMI. Logit estimates for being missing as a function of birth weight, twins' sex and maternal education indicate that there is no systematic correlation between these characteristics and the probability of missing data. Thus, the percentages of missing data are fairly small and are weakly related to observed family characteristics, which are controlled in the within-family estimates, so biases due to missing observations are not a major concern.

Results

In this section I explore the within-family parental preferences for the whole sample of families with twins and subdivided by maternal education differences. I define high-educated mothers as those who have more than 12 grades of schooling attainment, while low-educated mothers are defined as those with 12 or less grades of schooling. I chose this division because the 12 grades schooling marker in Chile is a meaningful distinction since it is the end of high school. Dividing the sample this way, I have about 75% of the observations in the low-educated group and the remaining 25% in the high-educated group.

The first set of results show the estimates of the production function in relation (2), from which I estimated the proportional weights for the aggregate parental investment. Table 2.5 shows for each of the outcomes, the estimation of the production function with inputs including birth weight and the three measures of parental investments. Table 2.6 shows similar estimates, but adds interactions of the investments with the high/low maternal education variable. The estimation of the production function shows that, for all outcomes, birth weight, as the measure of endowment, significantly explains some of the variation of the test score and health measures. Also, for almost all outcomes, the time that mothers spend with the children is a significant predictor of the children's outcomes. Finally, mothers having high education changed some of the production function parameters significantly, in all but one case by increasing them so that for a given production input the outcome was greater. The coefficients from the parental investments, Activities, Home and Healthy Food, were combined and used to compute the aggregate parental investment.

Table 2. 5 Production Function Estimates

	TADI Total	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Birthweight	0.075*** (0.012)	0.082*** (0.019)	0.069*** (0.015)	0.096*** (0.018)	0.067*** (0.013)	0.127*** (0.012)	0.033*** (0.005)	0.058*** (0.009)
Activities	0.057*** (0.006)	0.070*** (0.009)	0.063*** (0.007)	0.072*** (0.009)	0.035*** (0.006)	0.015*** (0.006)	0.010*** (0.002)	-0.005 (0.004)
HOME	0.022** (0.010)	0.032** (0.015)	0.032*** (0.012)	0.007 (0.014)	0.015 (0.010)	0.003 (0.009)	-0.002 (0.004)	0.005 (0.007)
Healthy Food	0.036** (0.017)	0.033 (0.027)	0.035 (0.021)	0.033 (0.025)	0.045** (0.018)	0.022 (0.017)	0.011* (0.006)	0.005 (0.012)
Constant	1.733*** (0.111)	1.443*** (0.171)	1.669*** (0.136)	1.506*** (0.162)	2.084*** (0.116)	1.107*** (0.106)	3.944*** (0.041)	2.418*** (0.081)
Observations	1,938	1,926	1,932	1,938	1,938	1,906	1,901	1,807
R-squared	0.888	0.820	0.866	0.781	0.839	0.790	0.884	0.069

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Other controls not shown are: child age and gender.

Table 2. 6 Production Function Estimates by Maternal Education

	TADI Total	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Birth weight	0.075*** (0.012)	0.081*** (0.019)	0.068*** (0.015)	0.095*** (0.018)	0.066*** (0.013)	0.128*** (0.012)	0.033*** (0.005)	0.058*** (0.009)
Activities	0.052*** (0.006)	0.060*** (0.010)	0.055*** (0.008)	0.067*** (0.009)	0.036*** (0.007)	0.013** (0.006)	0.009*** (0.002)	-0.004 (0.005)
HOME	0.013 (0.010)	0.025 (0.016)	0.021* (0.013)	-0.001 (0.015)	0.003 (0.011)	0.006 (0.010)	-0.002 (0.004)	0.008 (0.007)
Healthy Food	0.039** (0.018)	0.041 (0.028)	0.042** (0.021)	0.037 (0.026)	0.040** (0.018)	0.023 (0.017)	0.011* (0.006)	0.004 (0.013)
Activities * High Educ.	0.030* (0.016)	0.052** (0.024)	0.053*** (0.019)	0.030 (0.023)	-0.004 (0.016)	0.005 (0.015)	0.001 (0.006)	-0.011 (0.011)
Home * High Educ.	0.054** (0.027)	0.037 (0.041)	0.072** (0.032)	0.049 (0.039)	0.071** (0.028)	-0.029 (0.026)	-0.002 (0.011)	-0.027 (0.022)
Healthy Food * High. Educ.	-0.027 (0.019)	-0.050* (0.029)	-0.056** (0.023)	-0.028 (0.027)	0.014 (0.019)	-0.002 (0.018)	-0.000 (0.007)	0.013 (0.014)
Constant	1.741*** (0.111)	1.442*** (0.171)	1.674*** (0.136)	1.513*** (0.162)	2.100*** (0.116)	1.102*** (0.106)	3.944*** (0.041)	2.417*** (0.081)
Observations	1,938	1,926	1,932	1,938	1,938	1,906	1,901	1,807

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All the variables shown in the Table are in logarithms. Other controls not shown are: child age and gender.

Table 2.7 shows the estimations of relation (4). Tables 2.8 and 2.9 also show estimates of relation (4), but considering high- and low-educated mothers separately. The dependent variable in these estimations is the ratio between twins of the aggregate investment obtained from the production function. As noted the coefficient estimate for this relation relates to the parental preference parameter for each sample.

Table 2. 7 First-Order Condition (Eq. 4)

	TADI Total	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Log ratio of Aggregate Parental Investments (twin i / twin j)								
Log ratio of birth weight (twin i / twin j)	0.006 (0.011)	0.008 (0.013)	0.007 (0.013)	0.006 (0.010)	0.004 (0.009)	0.001 (0.008)	0.002 (0.008)	0.089 (0.185)
Constant	-0.001 (0.002)	-0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)	0.000 (0.001)	0.001 (0.001)	0.001 (0.001)	0.015 (0.030)
Observations	948	936	943	948	948	917	914	789

Note: Standard errors in parentheses. Estimates are significantly different from - ∞ and from 1.0, but not significantly different from 0.0.

Table 2. 8 First-Order Condition (Eq. 4) for High-Educated Mothers

	TADI Total	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Log Ratio of Aggregate Parental Investments (twin i / twin j)								
Log ratio of birth weight (twin i / twin j)	0.032 (0.055)	0.028 (0.051)	0.103 (0.094)	0.015 (0.040)	0.038 (0.072)	-0.018 (0.029)	-0.011 (0.020)	-0.028 (0.566)
Constant	-0.004 (0.008)	-0.006 (0.008)	-0.010 (0.014)	-0.003 (0.006)	-0.000 (0.011)	0.002 (0.004)	0.002 (0.003)	0.082 (0.081)
Observations	206	203	206	206	206	199	199	156

Note: Standard errors in parentheses. Estimates are significantly different from $-\infty$ and from 1.0, but not significantly different from 0.0.

Table 2. 9 First-Order Condition (Eq. 4) for Low-Educated Mothers

	TADI Total	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Log Ratio of Aggregate Parental Investments (twin i / twin j)								
Log ratio of birth weight (twin i / twin j)	0.006 (0.010)	0.008 (0.012)	0.007 (0.011)	0.006 (0.010)	0.005 (0.008)	0.003 (0.010)	0.004 (0.008)	0.007 (0.224)
Constant	-0.000 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.000 (0.002)	0.000 (0.001)	0.001 (0.002)	0.001 (0.001)	0.022 (0.037)
Observations	741	732	736	741	741	718	714	635

Note: Standard errors in parentheses. Estimates are significantly different from $-\infty$ and from 1.0, but not significantly different from 0.0.

The estimated parental preferences in the developmental sub-dimensions of the TADI test score and the health outcomes, for the overall sample and differentiating between high- and low-educated mothers, was computed using the elements of the previous results (Appendix B1 shows the results). For the overall sample, all the parameters are between 0 and 1, but not statistically significantly different from zero (from the significance of the coefficient in estimations shown in Table 2.7), which means that parental preferences are neutral. The overall set of parental investments decisions is not made according to differential endowments between the children; they do not reinforce the better-endowed child or compensate the lower-endowed child. Also, there is no difference between low- and high-educated mothers, none of these coefficients are statistically significantly different from zero (from the significance of the coefficient in estimations shown in Tables 2.8 and 2.9), which means that parental preferences are neutral for both high- and low-educated mothers. However, all of them are significantly different from $-\infty$ -- which means that there is not extreme compensation with no concern about productivity and significantly

different from 1.0 --which means there is not extreme reinforcement with no concern about inequality.

Conclusions

Parental preferences about differential investments among their children are studied using four dimensions of children's development test scores (cognitive, language, motor and socio-emotional skills) and three health outcomes (weight, height and body mass index) for a Chilean twins sample. I demonstrate that the ratios of outcomes between children may vary considerably depending on the nature of parental preferences. The estimates indicate that parents have neutral preferences, whether the mothers are high- or low-educated. When parental preferences are neutral, the implication is that if endowments are unequal, then the resulting outcomes associated with those endowments are equally unequal, perpetuating the inequality between the children. Therefore, those inequalities that are present at birth will be maintained through childhood. This inequality is greater than that that would have occurred if parental preferences were of the extreme compensatory type, but much less than that that would have occurred if parental preferences were of the extreme reinforcing type.

Comparing the results with previous research, I conclude that our results are different from those from developed countries, which show that parental investments generally reinforce or compensate to a degree initial endowments differences (Almond & Mazumder, 2013) and different from some of the evidence from developing contexts that reports that in certain circumstances, for example scarcity, there is an investment strategy from the parents (Behrman, 1988b) or that in other contexts, like Ethiopia (Ayalew, 2005) parents reinforce for some inequalities and compensate for others. Our estimates are consistent with the empirical evidence from Chile Bharadwaj et al. (2013) that finds that parents do not invest differentially within twins. Also, this result is consistent with Grätz and Torche (2016) also for Chile, that finds that there is no differential response between advantaged and disadvantaged parents to birth weight. Thus, there are reasons to think that this parental behavior needs to be studied in each specific context, since the circumstances will affect the differential parental intrafamilial investments, therefore the consequences on inequalities in children's outcomes.

A few important caveats are worth mentioning. First, the model does not consider the role of child preferences; this means for example that, if parents are trying to invest equally in the children but one of them is rejecting the investment, then I could be interpreting the result as the parents investing more in one child than the other, when it is the child who is not responding to the

investment. To account for this kind of behavior I would need data that allowed us to understand children's responses, but this is out of the scope of the data available for this paper. Second, a key assumption of this model is that parents can completely differentiate some investments to different children. However, one alternative hypothesis is that parental investments have *public good* dimensions or have spillover effects. Since twins have the same age, many of the investments that parents undertake may affect both children. The implication of the public good dimension is that compensating (reinforcing) behavior will take longer to reduce (increase) the gap in the outcomes (Bharadwaj et al., 2013). These public good effects could be different for twins than siblings, but since I have only a sample of twins I cannot explore this possibility. Additionally, it is important to keep in mind that this research only focuses on families with two or more children, and, moreover, only on families with twins, though the estimation strategy controls for family characteristics including ways in which families with twins might be different from other families.

Despite these caveats, I have contributed to the literature on the nature of parental preferences that may affect substantially outcomes among children in the family and on how parental preferences determine investments among their children, investments that have important long-run implications for the children's learning and health over their lives. Although more research needs to be directed towards a comprehensive understanding of the consequences and heterogeneity of parental investments among their children; our estimates are an effort in this direction and this paper adds to the meager previous literature on this topic for developing countries.

Chapter 3: Birth weight effects on cognitive and non-cognitive development in early childhood: Evidence from twins data

Abstract

Empirical evidence has shown positive associations of birth weight with health, educational attainment, earnings, and cognitive development. However, most of the studies are based on later life outcomes and use cross-sectional or siblings' study designs that have limited ability to control for unobserved variables that affect both birth weight and the outcome of interest. This research aims to give new empirical evidence to the effects of birth weight on cognitive and non-cognitive development using single and twin births from a survey from Chile. I use children between 6 months and 7 years old and examine whether birth weight has any effect on children's developmental test scores early in life. Results from OLS models for singletons births show that the associations are positive. The first-difference models for identical twins, controlling for all genetic and family background characteristics that identical twins have in common, show that birth weight does not have a significant effect on the developmental test scores. However, twins estimates stratified by age of the children show that the birth weight effects are positive and significant but only for children between 3 and 7 years old.

Introduction

Academic research on the effects of birth weight on human capital accumulation is extensive. The positive associations of birth weight with health, educational attainment and earnings have been studied with different methodologies and in diverse contexts. However, most of the previous studies in this literature are based on later life outcomes and use cross-sectional or siblings' study designs that have limited ability to control for maternal, family, and genetic factors that are correlated with both birth weight and cognitive and non-cognitive development. Even though siblings fixed-effects models control for common family characteristics, this strategy does not control for the possibility that children within the family differ in unobservable ways. Since siblings are born at different times, parental characteristics at birth differ across them generating birth-order effects (Almond & Currie, 2011).

In this paper, I look at the effects of birth weight on children's development. Using data from the Chilean Longitudinal Survey of Early Childhood (ELPI), this study compares the association between birth weight and cognitive, motor, language and socio-emotional skills for singletons and

twins' births between 6 months and 7 years old. This paper disentangles the confounding effects in the relationship between birth weight and cognitive and non-cognitive development in children by using two different aspects of twins data. First, the comparison between cross-sectional data of single births with twins data allows us to control for unobserved heterogeneity between children coming from the same family. Twins share the same age, pregnancy-related variables and family background. Also, fraternal twins share approximately half of genetic composition (or more if there is positive assortative mating) and identical twins share all the genetic composition. Second, we know that differences in birth outcomes, specifically birth weight, between twins are not the result of parental decisions to invest more in one twin than the other but are due to differential location in the womb or umbilical cord insertion in the placenta (Torche & Conley, 2016).

Most of the previous literature has focused on the effects of birth weight on later-life outcomes such as educational attainment or labor market performance (Behrman & Rosenzweig, 2004; Behrman et al., 1994; Bharadwaj et al., 2013; Black, Devereux, & Salvanes, 2007; Boardman, Powers, Padilla, & Hummer, 2002; Figlio, Guryan, Karbownik, & Roth, 2014; Oreopoulos, Stabile, Walld, & Roos, 2008; Royer, 2009), while not much is known about the effect of birth weight on developmental outcomes early in life. Only recently researchers have shifted their attention to early childhood cognitive outcomes. Studies that address this specific question using twins data, have shown mixed results. Figlio et al. (2014) looked at birth weight effects on children's cognitive development using twins for the US. The main focus of that paper was to look at schooling (third to eight grade) outcomes, but they also included kindergarten children. They conclude that the effect of neonatal health on cognitive development is present by age 5 and remains roughly constant between kindergarten throughout the schooling period that they study (third to eight grade). Another study, looking at a 5 years old UK cohort of twin pairs examined the relationship between birth weight and IQ (Wechsler Intelligence Scale), showing a positive association; birth weight differences within MZ twins pairs predicted IQ differences within pairs (Newcombe, Milne, Caspi, Poulton, & Moffitt, 2007). Datar and Jacknowitz (2009) using the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) for the US show that very low birth weight and moderately low birth weight have large negative effects on mental and motor development in children between 9 months and 2 years of age. However fraternal twins showed much less effects of birth weight on these measures and with identical twins there are statistically insignificant effects. They concluded that after controlling for the influence of maternal, environmental and genetic factors, low birth weight has, at most, small negative effects on children's mental and motor development in their first 2 years of life. Specifically for Chile, Torche and Echevarría (2011) looked at the effect of intra-uterine growth on cognitive development and found that birth weight differences within twin parts have substantial effects on math and

language test scores (fourth graders), and the effects are larger among identical than fraternal twins. Also for Chile, Bharadwaj, Eberhard, and Neilson (2010) show that a 10% increase in birth weight improves performance in math by nearly 0.05 standard deviations in 1st grade. They conclude that this effect is persistent and does not decline as children advance through grade 8.

The contribution of this paper is to provide new evidence about the effects of birth weight on early childhood cognitive and non-cognitive development for a developing country using twins data to control for unobserved factors in this relationship. Given that some evidence points to the fact that in early childhood the effects could be smaller than later in life, my objective is to test when those effects start to show up for children less than seven years old.

Empirical Strategy

First, I begin by looking at Ordinary Least Squares (OLS) regressions between birth weight and the developmental outcome measures, controlling for observed characteristics of the child, the mother and the family:

$$Y_{ij} = \alpha + \beta bw_{ij} + \gamma x_{ij} + \varepsilon_{ij} \quad (1)$$

where Y_{ij} is the developmental test score for child j born to mother i , bw_{ij} is birth weight, x_{ij} is a vector of observed characteristics of the child, mother and family, and ε_{ij} is an error term. Cross-sectional estimates of this equation likely lead to biased estimates of the parameter of interest, β , because of the correlation between birth weight and unobserved determinants of Y_{ij} , like unobserved family or maternal characteristic i.e. maternal behavior and abilities, or genetic dispositions (represented by ε_{ij}).

Second, if we assume that unobserved family characteristics and genetic dispositions are the only confounders leading to an inconsistent estimate of β , I can use twins to get unbiased estimates of the parameter of interest. Twins share the same age, pregnancy-related variables and family background. Also, fraternal twins share approximately half or more of their genetic composition and identical twins share all the genetic composition. Under these assumptions, I can limit the bias of the estimate of the effect of birth weight by taking twin differences of equation (1):

$$Y_{i2} - Y_{i1} = \beta(bw_{i2} - bw_{i1}) + (\varepsilon_{i2} - \varepsilon_{i1}) \quad (2)$$

because the observed and the unobserved child, mother and family determinants generally are the same for two twins in each pair; so, I limit the bias to the genetic differences for fraternal twins and estimate an unbiased effect of birth weight when using identical twins since the genes at conception do not vary within identical twin pairs. I argue that the estimation from MZ twins are a much better proxy of the true effect of birth weight on developmental outcomes since differences between twins are not confounded by parental family life-cycle differences, difficult-to-observe family background or, for identical twins, genes at conception (Kohler, Behrman, & Schnittker, 2011).

The plausibility of these estimates depends on the size of the within-twin differences in both birth weight and the developmental outcomes; Figures 3.1 and 3.2 show a wide range of differences across twin pairs in birth weight and developmental outcomes respectively.

This model has at least two limitations. First, there could be a measurement error in birth weight, biasing the estimated effect towards zero. Second, I have to assume that the source of the within-twin difference in birth weight is unrelated to the within-twin difference in the developmental outcomes. However, despite these limitations, the within-twin regressions provide a robust approach for controlling for unobserved characteristics.

Figure 3. 1 Within-twins Differences in Birth weight

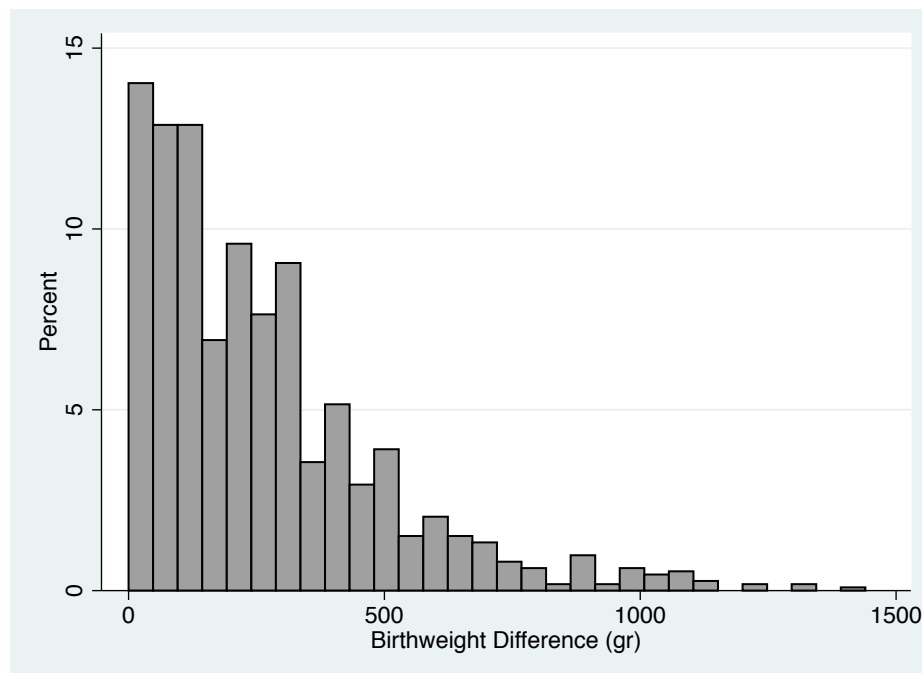
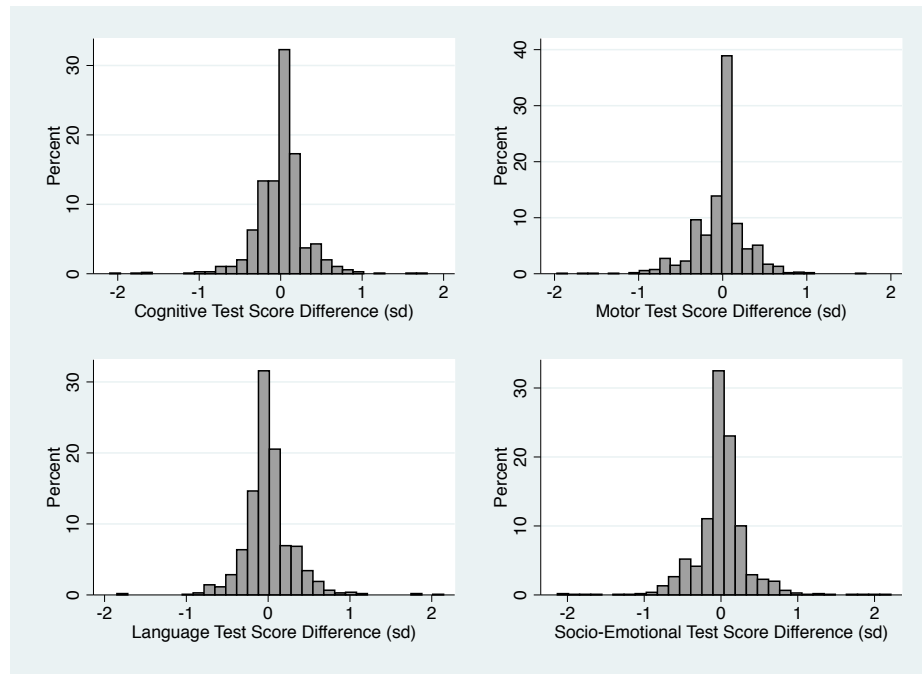


Figure 3. 2 Within-twins Differences in TADI Test Scores



Data and Descriptive Statistics

The data used in this paper comes from the *Encuesta Longitudinal de la Primera Infancia* (ELPI), a Chilean nationwide representative survey. This face-to-face survey gathers two types of information: a socio-demographic survey applied to all mothers; and a battery of tests for evaluating cognitive, socio-emotional and anthropometric development in children and their mothers. The sample for the 2010 wave was randomly drawn from official administrative birth records of children born between January 2006 and August 2009. The sample size was 15,000. The second wave was conducted in 2012. The target population was the same children interviewed in 2010 and an additional (refresher sample) 3,000 children who were born between September 2009 and December 2011. The sample includes different annual birth cohorts of children. In the 2012 wave, an oversampling of twins was added. The cross-sectional sample of twins includes 2,046 observations. 1,212 observations (606 pairs) are monozygotic twins (identical twins), while 834 observations (417 pairs) are dizygotic twins (fraternal twins).

Children's developmental outcomes are measured through the Test of Learning and Child Development (TADI), a test that was applied to all children in the 2012 round. This is a rating scale for children from 6 months to 7 years, designed and standardized in Chile. TADI evaluates four dimensions: cognitive, language, motor and socio-emotional, each of which is a separate

scale, allowing the evaluation of development and learning both in terms of these four components and globally. The birth weight measure for the singletons comes from administrative records and for the twin sample comes from the survey (reported by the mother). In both cases, it is measured in kilograms.

The explanatory variables are separated into 2 groups: characteristics of the mother, characteristics of the children. In the first group of variables I included the schooling attainment of the mother (in grades), a cognitive test score called Wechsler Adult Intelligence Scale (WAIS), which is a test designed to measure intelligence in adult and older adolescents, age of the mother at time of delivery and if they live in a rural or urban zone. The characteristics of the children include: sex of the child, age of the child (in months), and a vector of dummy variables for the month and year the child was born in order to control for seasonal and secular effects.

Table 3.1 provides the main descriptive statistics for the two analytical samples and the variables used in the analysis. As expected, the average birth weight of twins is considerably smaller than for the singletons. The average developmental test scores are slightly smaller for the twins sample, but for all the other variables the two samples are not different.

Table 3. 1 Means and percentage distributions by type of birth

	Singletons		Twins	
	Mean	SD	Mean	SD
TADI Total	38.3	11.1	34.5	12.3
TADI Cognitive	37.1	12.2	33.0	13.5
TADI Motor	36.0	9.8	32.9	11.1
TADI Language	38.5	12.3	34.3	13.5
TADI Socio-Emotional	41.7	11.2	37.8	12.2
Birth weight [gr]	3379.7	510.0	2394.7	540.2
Child characteristics				
Sex child [1=boy] %	50.6	-	50.2	-
Age child [months]	49.7	18.3	45.2	20.4
Mother characteristics				
Schooling attainment [grades]	11.5	2.9	11.8	3.0
WAIS test score Vocabulary	31.9	17.2	26.8	18.5
WAIS test score Numeric	8.8	1.9	8.3	2.7
Age of mother when delivered baby	26.7	7.0	26.8	18.5
Rural %	10.8	-	10.5	-
Observations (N)	12,548		1,978 (978 pairs)	

Results

This section presents the results for the ordinary least squares regressions for the singletons sample first and then the first-differences regressions for the twins sample. Table 3.2 shows for each of the developmental outcomes, the association of birth weight and the test scores, controlling for the maternal and child characteristics. From the table, we can see that the simple associations between birth weight and the test scores are positive and statistically significant for all the developmental measures. The first column of Table 3.2 indicates that a one-unit increase in birth weight, one kilogram, is associated with 0.026 standard deviation increase in the overall test score among singletons. This coefficient ranges from 0.039 for motor skills, to 0.019 for language skills. Maternal education and cognition are all positive and statistically significant, as expected. Living in a rural area is negatively associated with the children's test scores. Girls do better than boys and the older the child (in months) the better the results.

Table 3. 2 Birth weight and Children Test Scores: OLS Estimates

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.026*** (0.005)	0.026*** (0.006)	0.039*** (0.006)	0.019*** (0.006)	0.020*** (0.007)
Mother Characteristics					
Schooling attainment [grades]	0.016*** (0.001)	0.019*** (0.001)	0.009*** (0.001)	0.016*** (0.001)	0.016*** (0.001)
WAIS vocabulary	0.001*** (0.000)	0.002*** (0.000)	-0.000 (0.000)	0.002*** (0.000)	0.002*** (0.000)
WAIS numeric	0.012*** (0.001)	0.010*** (0.002)	0.009*** (0.002)	0.013*** (0.002)	0.013*** (0.002)
Age of mother when delivered bat	-0.000 (0.000)	-0.000 (0.000)	-0.001 (0.000)	0.000 (0.000)	0.000 (0.001)
Rural	-0.043*** (0.009)	-0.056*** (0.010)	-0.018* (0.010)	-0.045*** (0.010)	-0.044*** (0.012)
Child Characteristics					
Sex child [1=boy]	-0.056*** (0.005)	-0.030*** (0.006)	-0.051*** (0.006)	-0.047*** (0.006)	-0.092*** (0.007)
Age child [months]	0.043*** (0.002)	0.046*** (0.002)	0.047*** (0.002)	0.037*** (0.002)	0.037*** (0.002)
Constant	-2.477*** (0.137)	-2.822*** (0.164)	-2.796*** (0.169)	-1.990*** (0.159)	-2.068*** (0.190)
Month of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Year of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Observations	12,548	12,499	12,494	12,520	12,527
R-squared	0.918	0.883	0.878	0.889	0.843

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3.3 examines the associations of low birth weight with each developmental test score. A child that weighed at birth less than 2500 gr. is worse off in terms of cognitive, motor, language and socio-emotional skills, than others who were not low birth weight. Being low birth weight decreases the TADI test score in 0.044 standard deviations. All the maternal and child characteristics behave the same as before.

Table 3. 3 Low birth weight and Children Test Scores: OLS Estimates

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Low birth weight [< 2500 gr.]	-0.044*** (0.013)	-0.046*** (0.015)	-0.053*** (0.016)	-0.032** (0.015)	-0.046*** (0.017)
Mother Characteristics					
Schooling attainment [grades]	0.016*** (0.001)	0.019*** (0.001)	0.009*** (0.001)	0.016*** (0.001)	0.016*** (0.001)
WAIS vocabulary	0.001*** (0.000)	0.002*** (0.000)	-0.000 (0.000)	0.002*** (0.000)	0.002*** (0.000)
WAIS numeric	0.012*** (0.001)	0.010*** (0.002)	0.009*** (0.002)	0.013*** (0.002)	0.013*** (0.002)
Age of mother when delivered bab	0.000 (0.000)	-0.000 (0.000)	-0.001 (0.000)	0.000 (0.000)	0.000 (0.001)
Rural	-0.042*** (0.009)	-0.055*** (0.010)	-0.017* (0.010)	-0.044*** (0.010)	-0.044*** (0.012)
Child Characteristics					
Sex child [1=boy]	-0.054*** (0.005)	-0.028*** (0.006)	-0.047*** (0.006)	-0.046*** (0.006)	-0.090*** (0.007)
Age child [months]	0.043*** (0.002)	0.046*** (0.002)	0.047*** (0.002)	0.037*** (0.002)	0.037*** (0.002)
Constant	-2.381*** (0.136)	-2.724*** (0.163)	-2.653*** (0.167)	-1.920*** (0.158)	-1.991*** (0.188)
Month of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Year of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Observations	12,548	12,499	12,494	12,520	12,527
R-squared	0.918	0.882	0.877	0.889	0.843

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The results stratified by child age are shown in Table 3.4. Birth weights for children between 6 months and 3 years old show positive associations with the test scores, with coefficients that range from 0.067 for motor skills to 0.036 for language skills. For children between 3 and 7 years old the correlation of birth weight with the developmental test scores is still positive, but smaller compared to the results reported for the first group, although the coefficient estimates remain statistically significant for all test score dimensions, except socio-emotional abilities.

Table 3. 4 Birth weight and Children Test Scores by Age: OLS Estimates

Children Aged 0 - 3	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.045*** (0.008)	0.039*** (0.011)	0.067*** (0.012)	0.036*** (0.010)	0.038*** (0.012)
Children Aged 3 - 7					
Birth weight [kg.]	0.018*** (0.006)	0.021*** (0.007)	0.027*** (0.007)	0.012* (0.007)	0.013 (0.009)

Note: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, rural dummy variable, sex and age (in months) of the child, and dummies for month and year of birth of the child.

The previous results suggest that birth weight matters for determining cognition, motor, language and socio-emotional skills. However, we know that those results are associations and do not control for unobserved heterogeneity. The next set of results are the first difference regressions within twins that control for unobserved maternal and child characteristics. Table 3.5 shows the effects of the difference in birth weight between twin i and twin j on the difference between twin i and twin j for each developmental outcome. The results from the twins' estimations are striking. The estimated effects of birth weight on the cognitive test scores are not statistically significant for cognitive, motor and socio-emotional skills, but only positive and statistically significant for language skills. This means that when controlling for unobserved factors, the estimated effects of birth weight on children's developmental outcomes largely disappear. Table 3.6 confirms this result; that one twin is low birth weight and the other is not, does not determine the difference in test scores between twins; the negative effect of low birth weight in test scores that was shown earlier was apparently explained by unobserved maternal, family and child characteristics.

Table 3. 5 First Difference Children Test Scores – Birth weight: Twin 2 - Twin 1

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference birth weight [twin 2 - twin 1]	0.036 (0.030)	0.010 (0.040)	-0.028 (0.040)	0.083** (0.038)	0.050 (0.047)
Constant	-0.013 (0.011)	0.008 (0.014)	-0.019 (0.014)	-0.015 (0.014)	-0.017 (0.017)
Observations	974	962	974	968	974

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. 6 First Difference Children Test Scores - Low Birth weight: Twin 2 - Twin 1

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference Low birth weight [twin 2 - twin 1]	0.009 (0.017)	0.026 (0.023)	-0.024 (0.023)	0.033 (0.022)	-0.012 (0.027)
Constant	-0.005 (0.008)	0.004 (0.011)	-0.021* (0.011)	-0.001 (0.010)	-0.001 (0.013)
Observations	974	962	974	968	974

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Tables 3.7 and 3.8 show the birth weight effect but differentiating between identical and fraternal twins, respectively. These findings suggest that when controlling for unobserved pregnancy, maternal, socioeconomic factors, but most importantly controlling for genetic endowments using identical twins, the positive association between birth weight and developmental test scores for children under 7 years old, becomes insignificant. Only considering identical twins, the differences in birth weight between twins are not relevant for determining differences in cognitive, motor, language and socio-emotional skills.

Table 3. 7 First Difference Children Test Scores – Birth weight by Zygosity: Twin 2 - Twin 1

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference birth weight [twin 2 - twin 1]	0.048 (0.035)	0.001 (0.050)	0.063 (0.051)	0.055 (0.046)	0.053 (0.058)
Constant	-0.015 (0.013)	0.011 (0.018)	-0.038** (0.018)	-0.001 (0.016)	-0.026 (0.021)
Observations	560	552	560	558	560

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. 8 First Difference Children Test Scores – Birth weight by Zygosity: Twin 2 - Twin 1

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference birth weight [twin 2 - twin 1]	0.020 (0.054)	0.021 (0.067)	-0.159** (0.064)	0.122* (0.066)	0.050 (0.081)
Constant	-0.009 (0.018)	0.003 (0.023)	0.008 (0.022)	-0.033 (0.023)	-0.006 (0.028)
Observations	414	410	414	410	414

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Non-significant results in the first-difference estimations may be driven by alternative explanations. Here, I explore three of these explanations: sample size, measurement error and effects stratified by age.

Sample size. It could be the case that the non-significant result from the twins regressions for the full sample from 6 months to 7 years are due to the insufficient statistical power in the estimations, i.e., the sample size is too small to capture a significant effect with high probability. I test for this in Table A1 and A2 in the Appendix where I show the same OLS regression from Table 3.2 (which uses the singletons sample), but limiting the sample size to the same number of observations as in the twins sample. I bootstrapped 5,000 replications of random samples of sizes 1,000 and 500, respectively. Even though the overall associations of birth weight and test

scores are not significant (this is the case either using a sample size of 500 or 1,000), when I divide the sample by age I see that for children between 0 and 3 years old there is a positive and significant association (see Tables A3 and A4). Therefore, it seems implausible that the non-significant results from the first difference are only explained because of the small sample size.

Measurement error in the birth weight variable. Birth weight data are not from administrative data, but reported by the mother in the survey, thus allowing for a recall bias: if mothers do not remember exactly the birth weight of each child, then the misreporting leads to measurement error. I examine this by using 320 observations from the twins sample which have both the reported birth weight but also the administrative data, so the comparison between these two measures can give us an estimate of the measurement error in the variable. Figure A1 in the Appendix shows the histogram with the difference between the reported birth weight and the administrative data for each twin. More than 60% of the observations show exactly the same birth weight as the administrative data. 25% of them show an error of 100 grams or less. Therefore, even if these 320 observations are not randomly selected, because the children from which I have these data are all born in 2011, it can be argued that the misreporting error should not be a big issue.

Effects stratified by age. Results by children's age are shown in Tables 3.9 and 3.10. An interesting pattern arises; for younger children, the estimated effects of birth weight differences are not different from zero. However, when considering children between 3 and 7 years old, the differences in birth weight among twins are statistically significant in explaining the differences in the language and socio-emotional skills dimensions of the TADI test score. These last results may arise from two different possibilities. The first is that birth weight effects are reflected in better outcomes later in the children's lives. The second is that there are other factors, that are different within twin-pairs, affecting children developmental outcomes in a later period of the child's life. Some examples of this could be differential parental investments or different schooling factors that interact with birth weight generating the differential test scores outcomes. These could be channels through which birth weight works, but should not cause biases.

Table 3. 9 First Difference Children Test Scores – Birth weight by Age: Twin 2 - Twin 1

Children Aged 0 - 3	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference birth weight [twin 2 - twin 1]	-0.046 (0.038)	-0.053 (0.062)	-0.074 (0.066)	0.000 (0.051)	-0.080 (0.058)
Constant	0.009 (0.013)	0.017 (0.021)	-0.015 (0.022)	0.012 (0.017)	0.025 (0.020)
Observations	414	410	414	410	414

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. 10 First Difference Children Test Scores – Birth weight by Age: Twin 2 - Twin 1

Children Aged 3 - 7	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference birth weight [twin 2 - twin 1]	0.079* (0.043)	0.043 (0.053)	-0.003 (0.051)	0.127** (0.054)	0.118* (0.068)
Constant	-0.024 (0.016)	0.004 (0.019)	-0.019 (0.018)	-0.030 (0.020)	-0.040 (0.025)
Observations	560	552	560	558	560

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

These last set of results are consistent with previous studies, which show that the effects of birth weight and low birth weight on early childhood are smaller than previous empirical evidence showed (Almond, Chay, & Lee, 2005; Black et al., 2007) or insignificant (Datar & Jacknowitz, 2009) and opens the question about age profiles in the effects of birth weight on cognitive and non-cognitive development, in particular if the birth weight effects on developmental outcomes in pre-school children could be smaller than for school-age children.

It is out of the scope of this paper to unravel the exact mechanism that could explain this age profile in the effects of birth weight. However, some alternatives may be explored. Accordingly, I examine the association of birth weight with other physical measures of development later in life, specifically weight-for-age Z scores (WAZ) and height-for-age Z scores (HAZ) and how these

measures affect the developmental test scores. Tables 3.11 shows the effects of the difference in birth weight between twin *i* and twin *j* on the difference between twin *i* and twin *j* in WAZ and HAZ; Table 3.12 shows the effects of these two measures on the developmental outcomes, controlling for birth weight. These results show a positive association between birth weight and physical measures, and a positive association between these same measures and the developmental outcomes (controlling for birth weight), which suggests that birth weight could be acting through later-in-life physical channels to affect the developmental outcomes. However, more of these potential mechanisms should be explored to provide a fuller picture of age profiles in the effects of birth weight on cognitive and non-cognitive test scores.

Table 3. 11 First Difference WAZ and HAZ - Birth weight: Twin 2- Twin 1

	WAZ	HAZ
Difference birth weight [twin 2 - twin 1]	0.463*** (0.099)	0.388*** (0.097)
Constant	0.113*** (0.034)	0.029 (0.033)
Observations	934	931

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3. 12 First Difference Children Test Scores – WAZ, HAZ and Birth weight: Twin 2- Twin 1

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio- Emotional
Difference WAZ [twin 2 - twin 1]	0.032*** (0.012)	0.048*** (0.016)	0.017 (0.016)	0.026 (0.016)	0.036* (0.020)
Difference HAZ [twin 2 - twin 1]	0.025** (0.012)	0.023 (0.016)	0.021 (0.016)	0.004 (0.016)	0.045** (0.020)
Difference birth weight [twin 2 - twin 1]	0.010 (0.033)	-0.027 (0.044)	-0.032 (0.043)	0.044 (0.043)	0.038 (0.053)
Constant	-0.018 (0.011)	-0.001 (0.015)	-0.029* (0.015)	-0.013 (0.015)	-0.027 (0.018)
Observations	889	877	889	883	889

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Conclusions

This paper provides evidence of the effects of birth weight on early childhood cognitive, motor, language and socio-emotional development. Ordinary least squares models for singletons births show that the associations between birth weight and the developmental test scores are positive and statistically significant. Other factors prove to be relevant to explain the test score variations. Among these are education and cognitive test score of the mother, the more educated the mother, the better the cognitive development of the child, and the sex of the child -girls have better outcomes than boys. These results are adjusted for seasonality and secular effects, dummies for months and years of birth are added to the regressions. The estimation that looks at low birth weight as a marker of poor neonatal health (<2500 gr.) using singletons shows that being born with low weight is worse for the cognitive, motor, language and socio-emotional development of the child, than when I compare it to a not low birth weight child.

The models using twins, first-difference models, show that birth weight does not have a significant effect on the developmental test scores in general, there is only a positive and statistically significant coefficient in the language test score, and this is confirmed when using the low birth weight marker; the difference in the birth weight is not explaining the differences in cognitive, motor, language or socio-emotional test scores. When stratifying the sample between identical and fraternal twins, it can be established that even if I see some significant coefficient in the fraternal twins estimations, when controlling for the genetic composition (MZ estimation) I confirmed that the differences in test scores are not explained by differences in birth weights. The conclusion from these results is that when I control for unobserved maternal, pregnancy, family related factors, and genetics factors the effects of differences in birth weight on developmental test scores in children are apparently zero.

Finally, given that some evidence points to the fact that in early childhood the effects could be smaller than later in life, the last part of the paper uses twins fixed effects to investigate this possibility. Our conclusion is that birth weight effects are stronger later in life, but more research needs to be done in order to determine whether this occurs because of unobserved differences within twins occurring during this first period of life or whether other reasons are at play.

APPENDIX

Chapter 2 Appendices

Appendix A1

Question in Survey of Parental Investments						
In the last 7 days, how often the mother/father did the following activities with the child:		Never	1-3 times	4-6 times	Every day	Not apply
1	Read or look at books with the child	1	2	3	4	5
2	Tell stories to the child	1	2	3	4	5
3	Sing to/with the child	1	2	3	4	5
4	Go to the park or playground with the child	1	2	3	4	5
5	Go to museum, zoo, library with the child	1	2	3	4	5
6	Spent time with the child talking or painting	1	2	3	4	5
7	Invite the child to participate in household activities	1	2	3	4	5
8	Take the child to the grocery store	1	2	3	4	5
9	Share a meal (breakfast, lunch or dinner) with the child	1	2	3	4	5
10	Teach animals or sounds of animals to the child	1	2	3	4	5
11	Teach colors to the child	1	2	3	4	5
12	Go visit friends or family with the child	1	2	3	4	5
13	Teach numbers to the child	1	2	3	4	5
14	Teach letters to the child	1	2	3	4	5

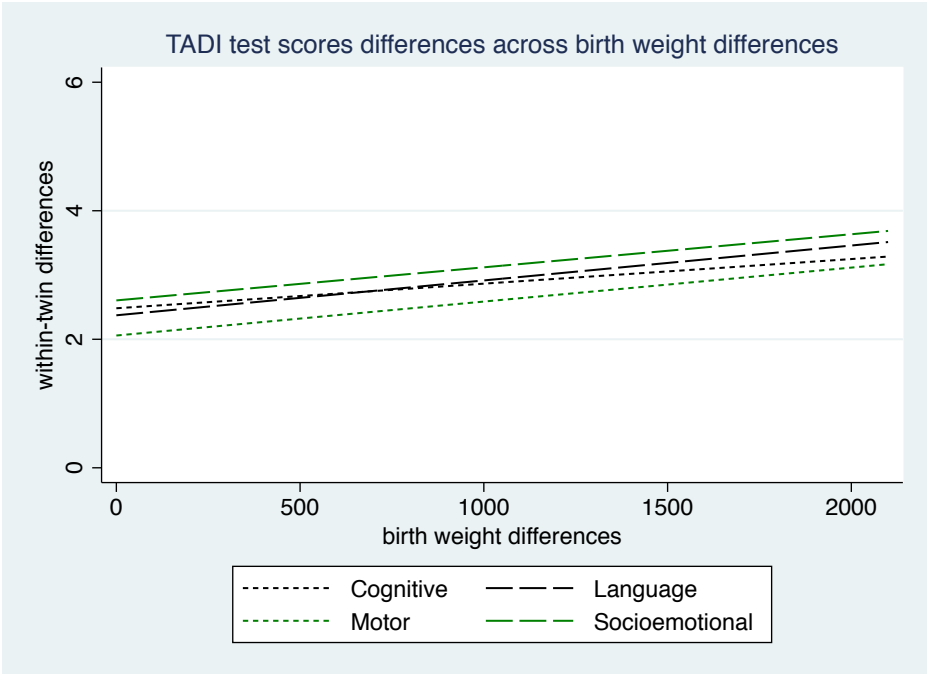
Appendix A2

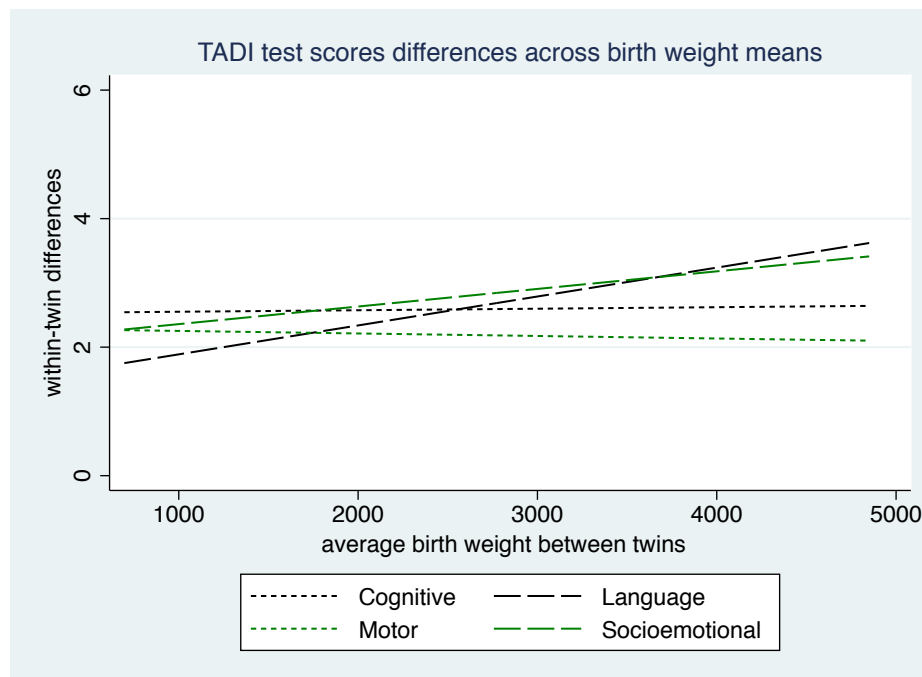
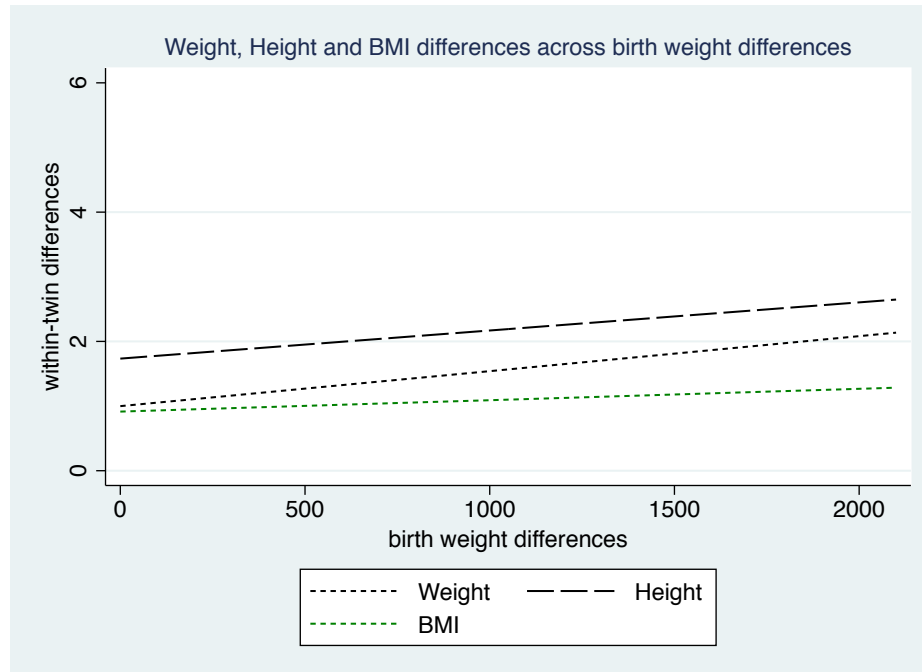
Question selected from HOME 1 (6 to 36 months)		Yes	No
1	The mother speaks to the child at least twice during the visit.	1	0
2	The mother praises the qualities of the child at least twice during the interview.	1	0
3	You can see the mother kissing or cuddling the child, at least once during the visit.	1	0
4	The mother shows some positive emotional response to praise towards the child performed by the interviewer.	1	0
5	The mother responds quickly to the needs and vocalizations of the child.	1	0
6	The mother does not yell at the child during the visit.	1	0
7	The mother does not express hospitality towards the child.	1	0
8	The mother does not hit the child during the visit.	1	0
9	The mother does not scold or criticizes the child during the visit.	1	0
10	The mother tends to keep the child within visual range and look at it often.	1	0
11	The mother speaks to the child as she answered the survey.	1	0
12	The mother knows a lot about the child, is good informant.	1	0
13	The mother subjected the child to a constant and rapid overstimulation; the child is overwhelmed.	1	0
14	The mother signals to the child when going out of the room.	1	0
15	The mother notes and identifies interesting things in the environment to the child.	1	0

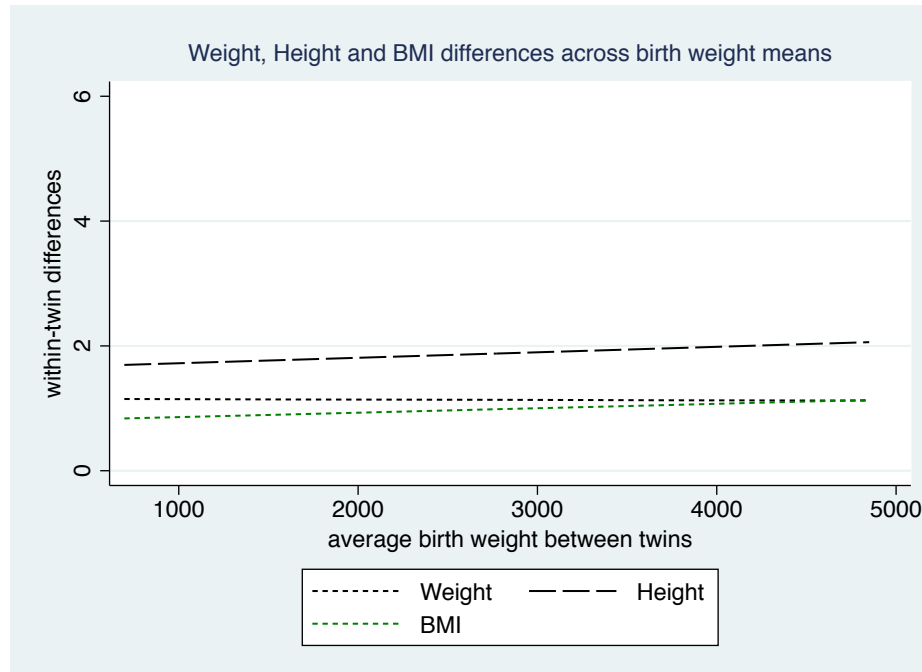
Question selected from HOME 2 (37 months – onwards)

	Yes	No
1 The mother speaks to the child at least twice during the visit.	1	0
2 The mother verbally answer questions or requests of the child.	1	0
3 The mother usually replied verbally to the child when he/she communicates with her.	1	0
4 The mother praises the qualities of the child at least twice during the interview.	1	0
5 The mother gives kisses, caresses and hugs the child during the visit.	1	0
6 The mother helps the child to demonstrate some of its achievements during the visit.	1	0
7 The mother does not scolds, abrogate or yells at the child during the visit.	1	0
8 The mother does not make use of physical coercion during the visit (send him to the room, stop at a corner, etc.).	1	0
9 The mother does not hit the child during the visit.	1	0
10 The mother knows a lot about the child, is good informant.	1	0

Appendix A3







Appendix A4

Table A4 – 1: Missing data

	Twin pairs with birth weight data
	% with missing data
Parental Investments	
Maternal Time (Activities)	0.0
Home (Adapted version)	1.6
Healthy food	0.0
Outcomes	
TADI Cognitive Test Score	4.15
TADI Language Test Score	3.51
TADI Motor Test Score	2.87
TADI Socio-Emotional Test Score	2.87
Weight (kg)	7.26
Height (cm)	7.61
Body Mass Index	16.20

Table A4 – 2: Logit Outcomes with Missing Data

	TADI Cognitive	TADI Language	TADI Motor	TADI Socioemotional	Weight	Height	BMI
Birth weight twin i	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	0.001* (0.000)	0.001* (0.000)	0.000 (0.000)
Birth weight twin j	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	-0.000 (0.000)	-0.001*** (0.000)	-0.001** (0.000)
Male	-0.056 (0.324)	0.029 (0.350)	0.044 (0.384)	0.044 (0.384)	-0.321 (0.256)	-0.454* (0.255)	-0.056 (0.183)
Maternal schooling	-0.015 (0.053)	-0.068 (0.057)	-0.026 (0.063)	-0.026 (0.063)	-0.011 (0.042)	-0.008 (0.041)	0.036 (0.030)
Constant	-2.908*** (1.121)	-2.759** (1.210)	-3.373** (1.339)	-3.373** (1.339)	-2.902*** (0.888)	-0.829 (0.795)	1.767*** (0.619)
Observations	999	999	999	999	999	999	999

Appendix B1

Table B1 - 1: Parental Preferences

Outcome	Parental Preferences	Parental Preferences Low-Educated	Parental Preferences High-Educated
TADI Total	0.076	0.079	0.310
TADI Cognitive	0.087	0.092	0.265
TADI Language	0.091	0.089	0.626
TADI Motor	0.060	0.062	0.138
TADI Socioemotional	0.055	0.069	0.377
Weight	0.005	0.022	-0.159
Height	0.058	0.119	-0.511
BMI	0.626	0.103	-0.871

Step 1: Estimation of the production function in relation (2) using three (=m) different measures of parental investments in each child.

$$\log O_i = \alpha_g \log G_i + \sum_{s=1}^m \alpha_{mS} \log S_{mi} = \alpha_g \log G_i + \alpha_S \log S_i \quad (2)$$

I first estimated a OLS regression for each outcome O_i (TADI Total, Cognitive, Language, Motor, Socioemotional and Weight, Height and BMI) using birth weight to represent endowments and three different investment variables: activities, home and healthy food (more description of these is in the Data section). All the variables are in logarithms with an error term added to each regression because of random shocks or measurement error in the dependent variables.

Step 2: Using the weights estimated in this procedure (α_{mS}), I combined the three parental investments into one aggregate investment, which I then used to estimate relation (4).

To compute the left-side variables of relation (4) I first calculated the following weighted sum:

$$\log S_i = \alpha_1 * \log S_{1i} + \alpha_2 * \log S_{2i} + \alpha_3 * \log S_{3i}$$

The estimated coefficients were used for the weights for each investment. Hence, each of the alphas is the coefficient from the previous estimation and was multiplied by the respective investment variable. I compute this for each outcome and for each twin. Then I divide this value for twin i by that for twin j, and take the logarithm of that ratio, which yields the left-side variable in relation (4).

Chapter 3 Appendices

Table A1 Birthweight and Children Test Scores: OLS Estimates Random Samples (N=1,000)

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.026 (0.019)	0.026 (0.022)	0.039* (0.023)	0.019 (0.022)	0.020 (0.025)
Mother Characteristics					
Schooling attainment [grades]	0.016*** (0.004)	0.019*** (0.004)	0.009** (0.004)	0.016*** (0.004)	0.016*** (0.005)
WAIS vocabulary	0.001** (0.001)	0.002*** (0.001)	-0.000 (0.001)	0.002** (0.001)	0.002* (0.001)
WAIS numeric	0.012** (0.005)	0.010 (0.006)	0.009 (0.007)	0.013** (0.006)	0.013* (0.007)
Age of mother when delivered baby	-0.000 (0.001)	-0.000 (0.002)	-0.001 (0.002)	0.000 (0.002)	0.000 (0.002)
Rural	-0.043 (0.031)	-0.056 (0.037)	-0.018 (0.038)	-0.045 (0.035)	-0.044 (0.043)
Child Characteristics					
Sex child [1=boy]	-0.056*** (0.018)	-0.030 (0.023)	-0.051** (0.023)	-0.047** (0.022)	-0.092*** (0.026)
Age child [months]	0.043*** (0.006)	0.046*** (0.007)	0.047*** (0.007)	0.037*** (0.007)	0.037*** (0.008)
Constant	-2.477*** (0.481)	-2.822*** (0.564)	-2.796*** (0.578)	-1.990*** (0.581)	-2.068*** (0.653)
Month of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Year of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Observations	1,000	1,000	1,000	1,000	1,000
R-squared	0.918	0.883	0.878	0.889	0.843

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A2 Birthweight and Children Test Scores: OLS Estimates Random Samples (N=500)

	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.026 (0.026)	0.026 (0.032)	0.039 (0.032)	0.019 (0.031)	0.020 (0.036)
Mother Characteristics					
Schooling attainment [grades]	0.016*** (0.005)	0.019*** (0.006)	0.009 (0.006)	0.016** (0.006)	0.016** (0.007)
WAIS vocabulary	0.001 (0.001)	0.002* (0.001)	-0.000 (0.001)	0.002 (0.001)	0.002 (0.001)
WAIS numeric	0.012 (0.007)	0.010 (0.009)	0.009 (0.009)	0.013 (0.009)	0.013 (0.010)
Age of mother when delivered baby	-0.000 (0.002)	-0.000 (0.002)	-0.001 (0.002)	0.000 (0.002)	0.000 (0.003)
Rural	-0.043 (0.044)	-0.056 (0.052)	-0.018 (0.055)	-0.045 (0.052)	-0.044 (0.062)
Child Characteristics					
Sex child [1=boy]	-0.056** (0.027)	-0.030 (0.032)	-0.051 (0.033)	-0.047 (0.031)	-0.092** (0.036)
Age child [months]	0.043*** (0.009)	0.046*** (0.010)	0.047*** (0.010)	0.037*** (0.010)	0.037*** (0.012)
Constant	-2.477*** (0.697)	-2.822*** (0.824)	-2.796*** (0.830)	-1.990** (0.816)	-2.068** (0.948)
Month of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Year of birth dummy variables	Yes	Yes	Yes	Yes	Yes
Observations	500	500	500	500	500
R-squared	0.918	0.883	0.878	0.889	0.843

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A3 Birthweight and Children Test Scores: OLS Estimates Random Samples (N=1,000)

Children Aged 0 - 3	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.045*** (0.015)	0.039** (0.020)	0.067*** (0.021)	0.036** (0.018)	0.038** (0.019)
Children Aged 3 - 7	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.018 (0.019)	0.021 (0.023)	0.027 (0.023)	0.012 (0.023)	0.013 (0.027)

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, rural dummy variable, sex and age (in months) of the child, and dummies for month and year of birth of the child.

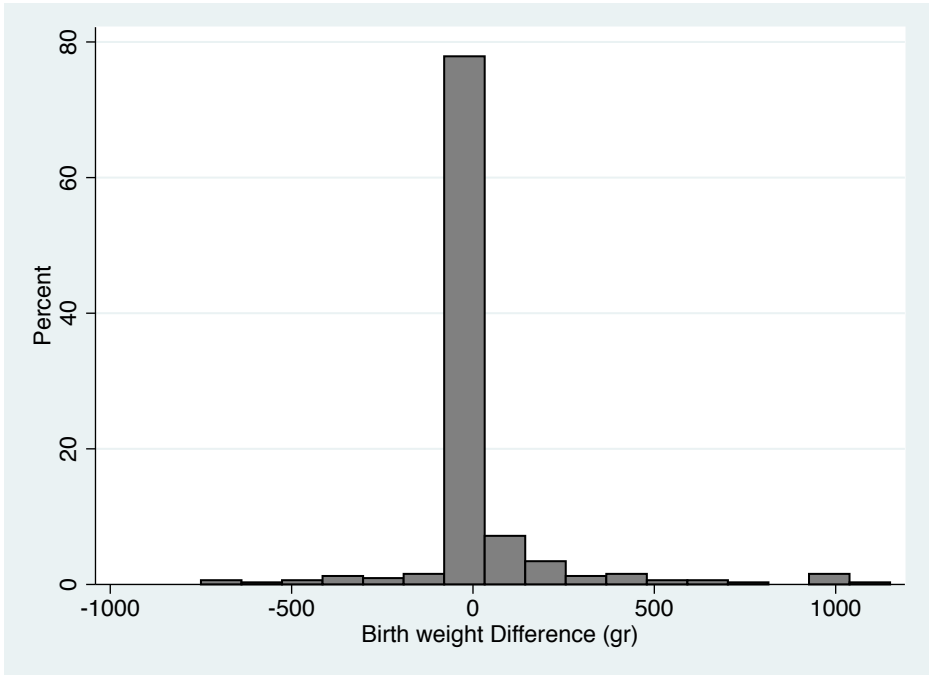
Table A4 Birthweight and Children Test Scores: OLS Estimates Random Samples (N=500)

Children Aged 0 - 3	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.045** (0.022)	0.039 (0.028)	0.067** (0.031)	0.036 (0.025)	0.038 (0.028)
Children Aged 3 - 7	TADI Total	TADI Cognitive	TADI Motor	TADI Language	TADI Socio-Emotional
Birth weight [kg.]	0.018 (0.028)	0.021 (0.033)	0.027 (0.033)	0.012 (0.033)	0.013 (0.039)

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Other control variables not shown are mother's schooling attainment and WAIS test score (vocabulary and numeric), the age of the mother at delivery, rural dummy variable, sex and age (in months) of the child, and dummies for month and year of birth of the child.

Figure A1: Differences in birth weight between Administrative Data and Reported Data



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