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Final Regression Results on the Cognitive Achievement of Children in the Christchurch Health and Development Study with Corrections for Attrition from this Longitudinal Study

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(Contract to Treasury)

ABSTRACT

Econometric analyses of the cognitive development of children have been hampered by data limitations and a variety of methodological and specification issues. Structural models allow for complex causal relationships between child achievement and inputs from parents, schools and communities, but these effects are difficult to isolate. Even reduced-form models suffer from both omitted-variable (e.g., unobserved family and community investments) and simultaneous-equation bias (e.g., endogenous private schooling and class size). The use of panel data offers the best non-experimental solution to these estimation issues. With multiple observations on test performance of children between the ages of 8 and 13 in the Christchurch Health and Development Study, we are able to hold constant individual-specific, time-invariant factors that influence cognitive achievement. These data permit several insights into the dynamic nature of this cognitive achievement process. We cannot reject the null hypothesis that the lagged dependent variable serves as a "sufficient statistic" for all past determinants of cognitive achievement. This provides the first statistical justification for the "value-added approach" recommended of Hanushek (1986), and actually diminishes the need for these longer longitudinal studies. Procedures are developed for testing for the presence of unobserved fixed-effects in this cognitive development process, and correcting for the effects of attrition from this panel. No evidence is found that the value-added to cognitive achievement is influenced by the number of parents in the family, the work status of the mother, the benefit status of the family, the income of the family and the type of school attended. Evidence is also found of a positive effect of class size on cognitive development. Our interpretation is that class size is endogenous, and the causality may be reversed (i.e., children with poor reading performances are intentionally placed in smaller classes). Yet, no evidence is found of the hypothesised negative effect of class size on cognitive achievement with an anti-instrumental-variable approach.

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1. Introduction

Descriptive statistics and regression analysis are used in this report to isolate the possible determinants of the reading abilities of children in the Christchurch Health and Development Study (CHDS). This work constitutes Phase 6 of a study commissioned by Treasury on the overall cognitive development and educational attainment of children in this longitudinal data set.

The Phase 5 Report (14 March 1999) developed an empirical approach and presented initial regression results on the determinants of adjusted scores on the Burt Word Reading Test. An earlier Phase 4 Report (25 November 1998) used internal and external validation procedures to assess the representativeness of the CHDS in terms of the general populations of families with children born at the same time as the CHDS children. Attrition from this panel was found to be substantial and non-random.

The regression analysis in the previous report was built on the notion that cognitive development is a cumulative process. In other words, test scores are a function of all past individual, family and school characteristics and relevant public policies. This meant that reading ability at age 13 could be a function of up to 500 time-invariant and time-varying covariates. In addition to the loss of degrees of freedom, the problem with the inclusion of so many explanatory variables in the regression was the resulting severe collinearity. The Phase 4 report showed that this concern was warranted. Substantial multicollinearity is evident among each of the time-varying covariates.

The Phase 5 Report developed a general methodological approach for estimating the possible determinants of the cognitive achievement of children in the CHDS. Several models were produced to take full advantage of these unique panel data, and provide information on the nature of this cognitive development process. The key was to impose several restrictions on the general model that would limit the number of coefficients that would have to be estimated. The present report modifies and extends this methodology by incorporating a number of suggestions from both an external referee and Treasury. These regression models are developed in Section 2 of this report.

Reduced-form models of cognitive achievement are estimated in this study. No attempts are made to estimate a complete structural model, or identify many of the potentially complex causal channels that may exist between various factors and the reading abilities of CHDS children. In the end, we estimate general linear relationships or partial correlation coefficients between cognitive achievement and several personal, family and school characteristics. A great deal of caution must be used in interpreting these empirical results, and inferring causality from this regression analysis.

For example, the educational attainment of parents has been found in previous studies to be positively related to the achievement of their children, once other observable factors are held constant. Yet, parental education can include both genetic and environmental components. It is important for policy purposes to know how much of this positive association is genetically transmitted, and how much is related to the actual acquisition of qualifications by parents. Public policies will generally have little impact on heredity, but can influence educational attainment. Omitted-variable bias results when these genetic endowments are not held constant in regression analysis. Parental education may also capture neighbourhood or peer effects. The cognitive achievement of a child might be positively related to the quality of neighbourhood attributes or the educational attainment of his or her peers at school. Since the education of the child's parents may be positively correlated with these unobserved neighbourhood of peer factors, the estimated effects of individual parental educational may again be biased upward.

Although reduced-form analysis is used in this study, the availability of longitudinal data makes it possible to develop insights into at least some of the causal relationships in this cognitive achievement process. With multiple observations on test performance for a sample of individuals, we can indirectly hold constant time-invariant determinants (e.g., heredity). However, these panel data do not allow us to disentangle other effects in this study (e.g., parental education vs. neighbourhood or peer effects). The CHDS contains no information on time-varying neighbourhood attributes or the family characteristics of the child's peers or classmates.

Other methodological approaches must be used to address the potential endogeneity of some inputs. The effects of class size on cognitive achievement is one example. Although we expect an exogenous increase in class size to reduce cognitive achievement, the allocation of children across classes is itself a choice variable for both parents and schools. We explore the possibility that children are intentionally placed in small classes because of poor academic achievement in their past. In this way, we attempt to eliminate the "reverse causality" in this relationship.

Section 3 adopts a methodological approach recently developed by Fitzgerald, Gottschalk and Moffitt (1998a and 1998b) for analysing attrition from longitudinal studies, and correcting for the effects of non-random attrition on subsequent regressions. In the end, consistent parameter estimates can be produced by applying Weighted Least-Squares (WLS) to our cognitive achievement regressions. Section 4 estimates the determinants of the incremental attrition from the CHDS, and computes the weights necessary to correct for the effects of this attrition in cognitive achievement regressions. Section 5 presents the regression results on the determinants of the Burt Word Reading Test scores, both with and without the corrections for attrition from this panel. Finally, Section 6 draws some general conclusions from this report, and briefly discusses some of the policy implications of these findings.

2. Regression Specifications for Estimating the Determinants of Cognitive Achievement in the CHDS

The CHDS is a longitudinal study of children born in Christchurch area hospitals between April and August of 1977. Interviews and assessments of these parents and children have been made at birth, age 4 months and annual interviews until the most recent survey available for this study at age 18. The CHDS contains a wealth of information on the personal characteristics of these children, their family backgrounds and home environments, as well as their school characteristics and educational outcomes. In particular, 13 tests of cognitive achievement were administered by the CHDS to these children between the ages of 8 and 18.

To simplify the analysis of overall cognitive achievement, we restrict our attention to the most frequently administered test in the CHDS. The Burt Word Reading Test measures word recognition and reading abilities each year between ages 8 and 13, and again at age 18. Because of the long interval between the tests administered at ages 13 and 18, and the fact that the latter test occurred after some of the children were no longer enrolled in formal education, we concentrate on the tests taken in the 6 consecutive years between ages 8 and 13.[1]

This is one of the key advantages of these data. Other longitudinal studies (e.g., the Panel Study of Income Dynamics and the National Longitudinal Survey of Youth in the United States) have fewer measures of individual cognitive achievement, and 6 consecutive years of results from the same test instrument is unique to the CHDS. These data present us with an opportunity to learn much more about this cognitive development process.

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[1] There is another important difference between the earlier Burt Word Reading Tests and the one administered at age 18. Between ages 8 and 13, cognitive achievement tests were taken only by those children living in the Canterbury region at the time of the survey. The Burt Word Reading Test was administered to all youth at age 18 regardless of geographic location. Furthermore, the Burt Word Reading Test was not designed to test the reading abilities of children older than 12 or 13.

2.1 Deriving a "Value-Added" Regression Specification for Cognitive Achievement

We begin with a general representation of this cognitive achievement process:

$$Y_{it} = Z_i{}'\delta_t + \sum_{j=1}^{t-1} X_{ij}{}'\gamma_t^{t-j} + u_{it} \qquad \begin{array}{l} i = 1, 2, \ldots, N \\ t = 8, 9, \ldots, 13 \end{array}$$

where Y_{it} is the raw score on the Burt Word Reading Test for individual i at age t. We work through various aspects of this specification below, and impose several constraints on this model to make estimation feasible.

There are two types of explanatory variables in equation (1). Time-invariant covariates are included in the vector Z_i (e.g., gender of the child, ethnicity and qualifications of the parents). A subscript for time is attached to the vector of coefficients δ_t associated with these time-invariant regressors. The effects of permanent characteristics on cognitive development may vary with the age of the child (e.g., gender and ethnicity might have different influences on cognitive achievement at each age).

Time-varying covariates are included in the vector X_{ij} (e.g., work status of the mother, marital, income and benefit status of the family). The summation sign in the expression runs forward in time from the first period (j=1) to the period immediately preceding the observed test score (j=t-1). This implies that cognitive achievement is a cumulative process, depending on all past values of these time-varying covariates.

Contemporaneous values of the time-varying variables are excluded from this regression for two reasons. First, we assume that these factors only influence cognitive achievement with a considerable lag. Second, the direction of causality with respect to at least some of these time-varying covariates may be uncertain. For example, although current class size may influence reading skills, school officials may use current academic performance to allocate students to classes of different sizes. Using the natural "time sequence of events" is one way of isolating the direction of causality we want. Although the history of class sizes might influence current test scores, it is less likely that current test performance could have determined earlier choices over class allocation.

Both a subscript and superscript are attached to the vector of coefficients γ_t^{t-j} associated with the time-varying regressors. The subscript allows the parameters to vary by the age of the child (e.g., family income might have larger effects on reading ability at earlier ages), while the superscript allows these effects to vary with the time elapsed since the observation of the characteristic (e.g., current family income might have a larger impact on present reading ability than family income lagged one, two or more periods).

It would be virtually impossible to estimate the individual coefficients in this unrestricted regression. With nine variables in the vector Z_i and seven in X_{ij}, there would be a total of 455 coefficients to estimate. This represents about 10% of individual observations over the entire six-year period. In addition to this reduction in the degrees of freedom, it has already been shown in the Phase 4 report that severe collinearity exists among the annual measures of several time-varying regressors. This multicollinearity reduces the precision of our coefficient estimates by causing standard errors to "blow up", making it difficult to isolate the basic determinants of this economic behaviour.

For these reasons, restrictions must be considered on the coefficients to reduce the number of parameters that need to be estimated. Consider the following general approach. Take the unrestricted equation (1) and lag it one period.

$$Y_{it-1} = Z_i' \delta_{t-1} + \sum_{j=1}^{t-2} X_{ij}' \gamma_{t-1}^{t-j-1} + u_{it-1}$$

Multiply this equation by a scalar λ, which will be defined below, and subtract the resulting expression from the first equation. Adding λY_{it-1} to both sides of this "generalised difference equation" we get:

$$Y_{it} = Z_i'(\delta_t - \lambda\delta_{t-1}) + X_{it-1}' \gamma_t^1 + \sum_{j=1}^{t-2} X_{ij}'(\gamma_t^{t-j} - \lambda\gamma_{t-1}^{t-j-1}) + \lambda Y_{it-1} + (u_{it} - \lambda u_{it-1})$$

Now consider imposing two types of restrictions on this model. First, suppose that the age-specific effects do not exist (i.e., $\delta_8 = \delta_9 = \ldots = \delta_{13} = \delta$ and $\gamma_8^{t-j} = \gamma_9^{t-j} = \ldots = \gamma_{13}^{t-j} = \gamma^{t-j}$). This yields the following regression model:

$$Y_{it} = Z_i' \delta(1-\lambda) + X_{it-1}' \gamma^1 + \sum_{j=1}^{t-2} X_{ij}'(\gamma^{t-j} - \lambda\gamma^{t-j-1}) + \lambda Y_{it-1} + (u_{it} - \lambda u_{it-1})$$

Coefficients on both the time-invariant and time-varying covariates no longer vary by age. The effects of time-varying factors depend only on how "far" they are from the current period. Assuming just the absence of age-specific effects imposes no exclusion restrictions in terms of the variables. However, the number of coefficients to be estimated declines substantially with the implied linear restrictions. With the same nine variables in the vector Z_i

and seven in X_{ij}, there are now 94 rather then the original 455 coefficients to be estimated (including λ) in this model.

Second, suppose there is a constant rate of geometric decay in is the coefficients attached to the time-varying variables.

$$\gamma_t^{t-j} = \gamma_t \lambda^{t-j} \quad 0 < \lambda < 1$$

At a given age t, the effect of a time-varying variable on current reading ability depends on the contemporaneous effect of given covariate γ_t, the length of the lag period t-j since the occurrence of that factor and the rate of decay λ. This assumes that the coefficients attached to a particular characteristic have the same sign, and the effects of past variables on current cognitive development weaken steadily over time.[2]

Substituting equation (5) into (3), we can re-write this model in the following way:

$$Y_{it} = Z_i'(\delta_t - \lambda\delta_{t-1}) + X_{it-1}' \lambda\gamma_t + \sum_{j=1}^{t-2} X_{ij}' \lambda^{t-j}(\gamma_t - \gamma_{t-1}) + \lambda Y_{it-1} + (u_{it} - \lambda u_{it-1})$$

Again, the coefficients on both the time-invariant and time-varying variables depend on age. However, the effects of time-varying factors decay at a constant geometric rate depending on how "far" they are from the current period. This geometric rate of decay imposes no exclusion restrictions in terms of the variables. It does, however, reduce the number of coefficients to be estimated. With the same nine variables in the vector Z_i and seven in X_{ij}, there are now 111 rather then the original 455 coefficients to be estimated (including λ) in this model.

Now impose *both* restrictions simultaneously. Assume an absence of age-specific effects and a constant rate of geometric decay in the time-varying variables. This means that the subscripts on the contemporaneous effects of the variables disappear:

$$\gamma^{t-j} = \gamma \lambda^{t-j} \quad 0 < \lambda < 1$$

as do all time-varying variables prior to the first lag in this restricted regression model:

$$Y_{it} = Z_i'\delta(1 - \lambda) + X_{it-1}'\lambda\gamma + \lambda Y_{it-1} + (u_{it} - \lambda u_{it-1})$$

[2] Although in principle these rates of decay λ could vary across the X-variables, a constant rate across all time-varying variables is necessary for the estimation procedures derived later in this section.

This means that both assumptions are necessary to produce this simple value-added specification from the original generic regression model for cognitive achievement. This "Koyck transformation" (Koyck 1954) allows the δ, γ and λ coefficients to be estimated. It turns a distributed lag into an autoregressive model. These assumptions impose quite strong exclusion restrictions on the resulting regression model. The lagged test score Y_{it-1} is a sufficient statistic for all time-varying covariates before t-1. It also greatly reduces the number of coefficients to be estimated. With the same nine variables in the vector Z_i and seven in X_{ij}, there are now 17 rather then the original 455 coefficients to be estimated (including λ) in this model.

We begin by estimating the restricted, value-added regression model (equation (8)). We next test the validity of both restrictions (an absence of age-specific effects and a constant rate of geometric decay) by estimating the unrestricted, value-added specification (equation (3)). Although the large number of parameters in this model will make it difficult to isolate the effects of any specific factor on test performance, the inclusion of the correlated time-varying variables will not compromise the quality of the overall R^2 statistic. An *F* test can then be used to test the incremental contribution of adding values of the X-variables prior to the first lags to this regression. In other words, we want to determine whether or not the lagged test score is a sufficient statistic for capturing all past determinants of current test performance.

If our *F* test allows us to reject the joint null hypothesis that these restrictions are valid, we will next consider which of these restrictions might be responsible for this outcome. As noted above, each restriction by itself does not lead to any exclusion restrictions in terms of the explanatory variables, but they do impose numerous restrictions in terms of the parameters that need to be estimated. As a result, we will separately estimate equations (4) and (6) and perform the appropriate *F* tests.

2.2 An Instrumental-Variable Approach

Before estimating the regression models developed in section 2.1, it must be recognised that OLS will produce inconsistent coefficient estimates in these specifications due to the inclusion of the lagged dependent variable as a regressor. Even if the disturbances in the original model u_{it} are serially uncorrelated, the lagged dependent variable Y_{it-1} will be correlated with the resulting error term. The reason is that the composite disturbance term in the generalised difference expression includes u_{it-1} which is also included in Y_{it-1}.

To produce consistent coefficient estimates, an instrumental variable (IV) approach is adopted. This means that we must find valid instruments for the lagged dependent variable. These variables must be correlated with the regressor, but uncorrelated with the composite disturbance term. To some extent, the time series properties of the error terms will suggest the variables that might serve as valid instruments. For simplicity, we assume initially that the original disturbances are serially uncorrelated, and use Y_{it-2} as our instrument. Note that this will substantially reduce the number of years of test results that can be directly included in this estimation. We have 6 consecutive years of scores on the Burt Word Reading Test for the children in the CHDS from ages 8 through 13. The generalised differencing approach reduces this to 5 years of test scores. Using Y_{it-2} as an instrument further reduces this to the last 4 years of test scores (ages 10 through 13).

2.3 An "Anti-Instrumental-Variable" Approach in Estimating the Effects of Class Size

One of the estimation problems that arose in earlier phases of this project, and similar studies overseas, is the potential simultaneous equation-bias in estimating the effects of class size on cognitive achievement. Our hypothesis is that an exogenous increase in class size should reduce test performance. Previous results have indicated, however, that this effect is positive. The problem is that the observed variation in class size is unlikely to be exogenous. In particular, it may be related to the past academic achievement of the student. School officials may place children with low reading skills in smaller class sizes to give them more "individual attention" in the classroom.

To derive causal estimates of the effect of class size on test performance, we take advantage of the rich longitudinal data in the CHDS. Our cognitive achievement equations have current test scores dependent on class size in the previous year. Suppose this class size is itself depends on test performance and teacher assessments in all previous years. The fitted value from this regression would capture the reverse causality component outlined above. The *residuals* from this regression would capture the "exogenous" component in the allocation of class size, and could replace actual class size in the cognitive achievement regression. Thus, these earlier lags in test scores and teacher evaluations of classroom performance serve as "anti-instruments", picking up the variation in class size that we want to exclude from our regression on the Burt Word Reading Test.

2.4 Testing for the Presence of Individual-Specific Fixed Effects

One possible mis-specification of our general cumulative model of cognitive achievement is the omission of an individual-specific fixed effect. This amended cognitive achievement process could be written:

$$Y_{it} = Z_i{}'\delta_t + \sum_{j=1}^{t-1} X_{ij}{}'\gamma_t^{t-j} + \alpha_i + u_{it}$$

where α_i captures all unobserved factors specific to an individual that permanently influence test performance. Like the other time-invariant (but observable) factors Z_i, these regressors would not be eliminated by the generalised differencing procedure. In fact, once we have imposed the two restrictions of an absence of age-specific effects and a constant rate of geometric decay, the following value-added specification can be produced:

$$Y_{it} = Z_i'\delta(1 - \lambda) + X_{it-1}'\lambda\gamma + \lambda Y_{it-1} + (1 - \lambda)\alpha_i + (u_{it} - \lambda u_{it-1})$$

This can be contrasted with the value-added specification in equation (8) that excludes this individual-specific intercept term. If these fixed effects exist, then the earlier suggestion of an IV procedure will *not* produce consistent coefficient estimates. The reason is that this fixed effect will appear in the composite error term, which will be correlated with test scores from *any* earlier period. As a result, estimates of λ will be biased upward.

To remove these fixed effects, we use first differences. This gives us:

$$\Delta Y_{it} = \Delta X_{it-1}'\lambda\gamma + \lambda\Delta Y_{it-1} + (u_{it} - (1 + \lambda)u_{it-1} + u_{it-2})$$

which eliminates α_i (and Z_i) from the model. Because the composite disturbance term includes u_{it-2}, Y_{it-2} will not be a valid instrument for ΔY_{it-1}. However, all earlier lags of these test scores (e.g., Y_{it-3}) will serve as appropriate instruments in this estimation.

The following procedure will be used in testing for the presence of these fixed effects. First, because this procedure requires lags in test scores of at least three periods, we restrict the observations directly included in this estimation to ages 11, 12 and 13. Second, to establish the relevant "counterfactual" we estimate equation (10) with these 3 years of data, using Y_{it-3} as the relevant instrument. Third, we estimate equation (11) with the same 3 years of data and the same IV technique. If no fixed effects are present, the estimates of λ from the two regressions should be essentially the same. If fixed effects are present, the estimate of λ from equation (10) should exceed the estimate of λ from equation (11).

2.5 A "Level" Specification for Cognitive Achievement

Suppose both assumptions about an absence of age-specific effects and a constant rate of geometric decay are verified in the preceding analysis. We could use an estimate of the constant rate of decay in these time-varying factors and return to the original specification of this cognitive development process (i.e., equation (1)).

$$Y_{it} = Z_i'\delta + \sum_{j=1}^{t-1} X_{ij}'\gamma\lambda^{t-j} + u_{it}$$

We can then factor out the "contemporaneous" effects γ associated with these time-varying covariates.

$$Y_{it} = Z_i' \delta + \left[\sum_{j=1}^{t-1} X_{ij}' \lambda^{t-j} \right] \gamma + u_{it}$$

The information in brackets is equivalent to the long-run or permanent effects of the time-varying factors on cognitive achievement. With an estimate of λ, these variables can be collapsed into a single vector for each year.

$$Y_{it} = Z_i' \delta + X_{it}^{*\prime} \gamma + u_{it}$$

The new covariates X_{it}^* are simply weighted averages of past time-varying regressors.

3. An Econometric Framework for Analysing Attrition in the CHDS

The regression models for cognitive achievement developed thus far have been based on the implicit assumption that no attrition has taken place over the history of the CHDS. In this section, we consider the fact that considerable attrition has occurred in this panel, and develop procedures for estimating the nature of this attrition and correcting for the possible bias that this attrition may impose on our cognitive achievement regressions.

A loss in sample size through attrition reduces the precision of overall estimation, but it does not necessarily result in biased parameter estimates. The nature of this attrition is the key. If this attrition is entirely random, then coefficient estimates are less efficient but still unbiased. Our concern is that this attrition may be nonrandom, and that procedures must be constructed to mitigate its effects in our econometric analysis.

The Phase 4 report examined both the extent and nature of the attrition that took place over the history of the CHDS. Both internal and external sources of validation were used for this purpose. By age 13 of the children, more than one-half of original families in this study had effectively attrited. Rates of attrition varied significantly by various characteristics and some of the behaviour of these families.

We begin with a general statistical and econometric framework that can be used to understand the consequences of attrition for our pending regression analysis. A specific procedure is then developed for correcting for the effects of attrition in our cognitive achievement regressions.

Suppose a random sample of N individuals is initially drawn from a general population. At some point in the future, an attempt is made to re-interview all members of the original sample. However, information is only available on a subset N* of these individuals (i.e., N*<N). Assume that our primary interest is the deterministic relationship between some generic variables G_i and Y_i within the population. The problem is that this attrition may compromise the representativeness of the original sample, resulting in a biased estimate of this true relationship in the population.

For simplicity, this attrition is initially modelled as a cross-sectional phenomenon. Consider the following regression model:[3]

$$Y_i = \beta_0 + \beta_1 G_i + \_{i}$$
$$A_i^* = \alpha_0 + \alpha_1 G_i + \alpha_2 Hsubi + u_i$$

where:

$$A_i = 1 \;\; if \;\; A_i^* \geq 0$$
$$= 0 \;\; if \;\; A_i^* < 0$$

Let A_i* be a latent variable. Attrition occurs when A_i* is nonnegative, and the corresponding dummy variable A_i is equal to one. No attrition occurs when this index variable is negative, and the dummy variable is equal to zero.

Suppose we only observe Y_i among the non-attiting sample, but we observe G_i and H_i among the entire original sample. This might occur if G_i and H_i are time-invariant variables, or factors observed at the outset of the panel. Consider the two “types” of attrition that could result in this situation.

3.1 Selection on Unobservables

In general, attrition can be based on either “observable” or “unobservable” factors.[4] Selection on unobservables occurs when (conditional on G_i) $\_{i}$ is independent of Z_i, but $\_{i}$ is *not* independent of u_i. This is the more familiar of the two types of attrition to economists (e.g., see Heckman 1979). The same unobservable personal characteristics (e.g., perseverence, drive or motivation) might influence both Y_i and A_i*.

In this case, the conditional mean of the dependent variable for the non-attriting sample can be written:

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[3] This discussion borrows heavily on the work of Fitzgerald, Gottschalk and Moffitt (1998a and 1998b).

[4] This terminology has not been commonly used in econometrics, but is adopted by Fitzgerald, Gottschalk and Moffitt.

$$E(Y_i \mid G_i, H_i, A_i = 0) = \beta_0 + \beta_1 G_i + E(\_{}_i \mid G_i, H_i, A_i = 0)$$

$$= \beta_0 + \beta_1 G_i + E(\_{}_i \mid u_i < -\alpha_0 - \alpha_1 G_i - \alpha_2 H_i)$$

$$= \beta_0 + \beta_1 G_i + \theta \lambda_i$$

where we rely on the assumption that the disturbances ($\_{}_i$ and u_i) are independent of the explanatory variables (G_i and H_i). The conditional expectation of $\_{}_i$ is only related to G_i and H_i through the index variable A_i*. Assuming a bivariate normal distribution for the disturbances implies that this conditional expectation can be written as the mean of a truncated normal distribution or inverse Mills ratio (λ_i).

A two-step procedure is used to correct for sample selection bias on unobservables. First, a probit model is estimated for this probability of attrition, and λ_i is computed for each observation in the original sample. This attrition regression can be written:

$$Prob\ (A_i = 0 \mid G_i, H_i) = \Phi(-\alpha_0 - \alpha_1 G_i - \alpha_2 H_i)$$

where $\Phi(\cdot)$ is the cumulative density function, and λ_i can be computed as:

$$\lambda_i = \frac{\phi(-\alpha_0 - \alpha_1 G_i - \alpha_2 H_i)}{1 - \Phi(-\alpha_0 - \alpha_1 G_i - \alpha_2 H_i)}$$

Second, Y_i is regressed on both G_i and λ_i. If the estimate of θ is significantly different from zero, then we can conclude that sample selection bias on unobservables is present.

Beside the nonlinearities in λ_i, identification of β_1 in equation (17) requires an "exclusion restriction." There must be at least one variable H_i that influences attrition, but not the primary economic behaviour under investigation Y_i. Although not strictly correct, these identifying variables have been referred to in the literature as "instruments."

The problem is that it is often difficult to find valid instruments for attrition. Personal characteristics that influence attrition are also likely to be related to the primary economic behaviour being studied. In the context of the CHDS, it is hard to imagine any factors that might be related to the decision of parents' to discontinue participation in the study or migrate out of the Canterbury region that are completely unrelated to the cognitive achievement and educational attainment of their children. Ideal instruments would be external factors (e.g., differences in interviewers, random variation in payments for participation) that affect attrition without influencing other behaviour. Since there are no such candidates for valid instruments on attrition in the CHDS, we refrain from adopting the above estimation procedure.

3.2 Selection on Observables

Attrition based on observable factors is less familiar to economists. Selection on observables occurs when (conditional on G_i) $\_{i}$ is independent of u_i, but $\_{i}$ is *not* independent of H_i. The key is that the variable H_i does not appear in the structural equation for Y_i. Yet, H_i may be an endogenous variable that is related to Y_i through the disturbance term. For example, Y_i measures performance on a test administered by the CHDS, while H_i might include academic performance as assessed by teachers. Although teacher evaluations wouldn't be included as explanatory variables in the cognitive achievement regressions, attrition related to classroom performance could make the estimated coefficients of cognitive development inconsistent.

Fitzgerald, Gottschalk and Moffitt (1998a) show formally that the complete-population density function of the dependent variable conditional on G_i can be estimated by using Weighted Least-Squares (WLS). The general form of the normalised weights can be written:

$$W\ (G_i,\ H_i) = \left[\frac{Prob\ (A_i = 0 \mid G_i,\ H_i)}{Prob\ (A_i = 0 \mid G_i)} \right]^{-1}$$

where the numerator inside the brackets is the probability of retention in the sample based on the earlier probit model (equation (18)). Because both the weights and the conditional density function for the non-attriting sample are identifiable, we can estimate the complete population density function. This implies that WLS can be applied to the original regression for the non-attriting sample.

If higher values of H_i increase the probability of retention, then weights on these observations fall. If attrition is independent of H_i, then all of the weights equal one and no attrition bias is present. Alternatively, if Y_i and H_i are independent conditional on G_i and A_i=0, then there is no attrition bias. In these situations, OLS and WLS estimates are identical.

The previous discussion on attrition was framed in a cross-sectional context. We now extend this analysis to panel data. An additional subscript for time can be added to the two-equation model:

$$Y_{it} = \beta_0 + \beta_1 G_{it} + \_{it}$$
$$A^*_{it} = \alpha_0 + \alpha_1 G_{it} + \alpha_2 H_{it} + u_{it}$$

where:

$$A_{it} = 1 \text{ if } A^*_{it} \geq 0$$
$$= 0 \text{ if } A^*_{it} < 0$$

On the one hand, little is added to this discussion by recognising the longitudinal nature of the data. Consistent coefficient estimates are still produced by using WLS, where these modified weights can be written:

$$W(G_{it}, H_{it}) = \left[\frac{Prob(A_{it} = 0 \mid G_{it}, H_{it})}{Prob(A_{it} = 0 \mid G_{it})} \right]^{-1}$$

On the other hand, the attrition regressions that must be estimated to compute these weights are potentially more complex, and place heavier demands on the data. The variable H_{it} must be observable for everyone in the original sample prior to any attrition. This is not a problem if the variable is time-invariant or measured at the outset of the panel. However, the possibility of using endogenous variables for H_{it} is ruled out if this behaviour is observed after some of this attrition has already taken place. One possibility, for example, would be to use lagged values of Y_{it} in the attrition equation. These observations are discontinued, of course, once attrition has taken place.

In some ways, this search for an "identifying variable" for selection on observables in a panel situation with continuous attrition brings us full circle to the problem associated with selection on unobservables. If we are restricted to the covariates at the outset of the panel, this "auxiliary endogenous variable" may be nonexistent.

One solution to this problem is to estimate the dynamic nature of this attrition, by breaking it into pieces. We do this by looking at attrition in the context of a "hazard" rate. The probability of *not* attriting by period t can be written:

$$Prob(A_{it} = 0) = Prob(A_{it} = 0 \mid A_{it-1} = 0, K_{it-1}) \bullet$$
$$Prob(A_{it-1} = 0 \mid A_{it-2} = 0, K_{it-2}) \bullet$$
$$\bullet$$
$$\bullet$$
$$\bullet$$
$$Prob(A_{i1} = 0 \mid K_{i0})$$

The probability that individual i "survives" and does not attrite by period t is the product of the conditional probabilities of not attriting in all previous interviews. The first term on the right-hand side of this expression is the incremental probability of not attriting in period t given that the individual remained in the study through period t-1. This probability is also conditional on a vector of covariates in K_{it-1}. These variables could include both the covariates in the primary regression G_{it-1} and those only directly affecting attrition H_{it-1}, or just the common variables in the primary and secondary regressions G_{it-1}. In general, these explanatory variables need to be indexed for an earlier period (e.g., t-1) so that they can be observed for both attritors and non-attritors in period t.

The second term on the right-hand side is the marginal or incremental probability of not attriting in period t-1 given that the individual continued in the study through period t-2 and conditional on the variables in K_{it-2}. Similar terms are suppressed in this expression for period t-3 back to period 2. The last term is the probability of attriting in period 1 (age 1 of the children in the CHDS), conditional on the original sample of families at the outset of the panel and the initial values of the relevant covariates K_{i0}.

This expression implies that the probability of retention in the study for a given individual at a point in time is the product of t conditional probabilities. Each incremental probability can be estimated using maximum likelihood probit, and the required "chain products" can be easily computed.

The key with this specification of retention in the panel is that contemporaneous, endogenous factors can be used to identify the determinants of attrition at a given point in time. We simply have more choices in the covariates to be included in these regressions. Alternatively, if we estimated a single probit model for this probability, we would be restricted to the set of variables that are observed among both attritors and non-attritors (i.e., factors observed at the beginning of the study).

Substituting equation (24) into (23), and simplifying the notation, we have a general expression for the weights associated with continuous attrition in a panel:

$$W(G_{it-1}, G_{it-2}, \ldots, G_{i0}, H_{it-1}, H_{it-2}, \ldots, H_{i0}) =$$

$$\left[\frac{Prob_{A_{it}}(G_{it-1}, H_{it-1}) \bullet Prob_{A_{it-1}}(G_{it-2}, H_{it-2}) \bullet \ldots \bullet Prob_{A_{i1}}(G_{i0}, H_{i0})}{Prob_{A_{it}}(G_{it-1}) \bullet Prob_{A_{it-1}}(G_{it-2}) \bullet \ldots \bullet Prob_{A_{i1}}(G_{i0})}\right]^{-1}$$

where:

$$Prob_{A_{it}}(G_{it-1}, H_{it-1}) = Prob(A_{it} = 0 \mid A_{it-1} = 0, G_{it-1}, H_{it-1})$$

In the context of this particular project, the variables assumed to identify this attrition (H_{it-1}, $H_{it-2}, \ldots, H_{i0}$) are primarily lagged values of individual test performance and teacher evaluations on the academic performance of children. Since this test performance is monitored at ages 8 through 13 and teachers evaluations recorded at ages 7 through 12, there is little scope for identifying attrition prior to age 8. In other words, all of family and personal characteristics that enter into the attrition model prior to age 8 (G_{it-1}, G_{it-2}, . . . , G_{i0}) are already directly included in the cognitive achievement regression (e.g., ethnicity, education, income and social welfare beneficiary status). This simplifies the earlier expression for the attrition weights:

$$W(G_{it-1}\ ,\ G_{it-2}\ ,\ \ldots\ ,\ G_{i7}\ ,\ H_{it-1}\ ,\ H_{it-2}\ ,\ \ldots\ ,\ H_{i7}) =$$

$$\left[\frac{Prob_{A_{it}}(G_{it-1}\ ,\ H_{it-1}) \bullet Prob_{A_{it-1}}(G_{it-2}\ ,\ H_{it-2}) \bullet \ldots \bullet Prob_{A_{i8}}(G_{i7}\ ,\ H_{i7})}{Prob_{A_{it}}(G_{it-1}) \bullet Prob_{A_{it-1}}(G_{it-2}) \bullet \ldots \bullet Prob_{A_{i8}}(G_{i7})}\right]^{-1}$$

and requires two sets of 6 probit equations to be estimated. The first set excludes variables H_{it-1}, H_{it-2}, . . . , H_{i7}, while the second set includes these covariates in the estimation.

4. Regression Results on Attrition from the CHDS

The preceding section outlined the estimation procedure for considering the possible effects of attrition in our regressions on Burt Word Reading Test scores. The first step involves the estimation of two sets of maximum likelihood probit equations on the incremental attrition from the CHDS between the ages of 8 and 13. The first set of regressions include only those covariates that will be directly included in the regression on reading ability. We label this estimation as taking place without “auxiliary endogenous” variables. The second set of regressions also include covariates that are contemporaneous with the period prior to possible attrition. These factors may themselves be choice variables for the family or the result of other aspects of economic behaviour. Although they are not considered as possible determinants of cognitive achievement, these factors may be directly related to attrition from the CHDS. They could be thought of as being determined simultaneously with this cognitive development. These additional covariates include separate measures of the interviewer’s perceptions of either the high or low living standards of the family, a scale score on the symptoms of maternal depression and the teacher’s overall assessment of the child’s classroom performance (i.e., a “grade point average” on reading, writing, spelling and mathematics). See Appendix B for further details on the definitions of these variables.

This analysis of attrition in the CHDS is restricted to the interviews in which the child was between 8 and 13 years old. The reason for ignoring earlier attrition in the panel is that the variables used to identify this attrition (regressors that appear in the attrition regression, but not the cognitive achievement regression) were not available before the age of 7 (interviewer assessments of the family’s living standards, maternal depression scores and teacher assessments of the child’s classroom performance). Thus, the remaining explanatory variables in the attrition regression at earlier ages are already included in the regressions on the Burt Word Reading Test scores.

We examine “incremental” attrition in these regressions. Attrition at age 8, for example, looks at the proportion of families who were “at risk” of attriting at that age (i.e., still in the sample at age 7), as a function of the regressors observed at age 7. It should be noted that this attrition at age 8 captures the elimination of a large number of original families in the CHDS, because they had moved out of the Canterbury region by this time and, as a result, did not have the Burt Word Reading Test administered to their children. Attrition at age 9 examines the attrition that took place between 8 and 9, and so on until age 13. In the end, the predicted probabilities from these two sets of regressions are used to construct the weights that will be used to estimate the cognitive achievement models.

To be consistent with the structure of the value-added specifications of the cognitive achievement regressions, we use covariates in these attrition regressions that would appear in these value-added equations.

The attrition regressions (with and without the auxiliary endogenous variables) are reported in Tables A1 and A2 in Appendix A of this report. The dummy dependent variable in these maximum likelihood probit regressions takes on a value of one if the family attrited from the CHDS at the indicated age; zero if they remained in the study. The means of these dependent variables are shown at the bottom of the tables. A relatively large amount of attrition occurs at age 8. Approximately 21% of families interviewed continuously through age 7 were effectively out of the study by age 8 for the purposes of our analysis of cognitive achievement. Annual attrition rates fall to around 4% by age 13.

The results in Table A2 are mixed on the effects of the identifying, auxiliary endogenous variables on attrition. Symptoms of maternal depression are positive and significantly different from zero in 3 of the 6 years. Holding other things constant, mothers who exhibit more symptoms of depression are more likely to attrite by the following year. Grade point average has a positive and significant impact on attrition at age 8, but a negative and significant effect at age 9. In all other years, teacher assessments of classroom performance appear to be unrelated to attrition. Lagged values of the Burt Word Reading Test score are also included in these attrition regression. Again, the results are mixed. Reading ability is positively related to attrition at age 9, but negatively related to attrition at age 11. In all other years, it has no measurable impact on this behaviour.

One way to summarise the overall contributions of these instruments to the explanatory power of these models is to examine the Pseudo R^2 statistics at the bottom of the two tables. This summary statistic is computed as one minus the ratio of the log likelihood function in this regression relative to the log likelihood function with no covariates. On average across the six years, 7.1% of the variation in attrition can be explained by the regressions excluding instrumental variables (Table A1). This explanatory power rises to an average of 10.1% in the regressions including auxiliary endogenous variables (Table A2).

What matters, of course, is whether or not the “corrections” for this attrition have any impact on the Burt Word Reading Test regressions. We examine these weighted least-squares regressions in Section 5. In the meantime, some simple descriptive statistics are produced to examine the overall effects of this correction procedure. Again these weights are constructed by taking the ratio of the products of the estimated probabilities of "surviving" and remaining in the study at various ages. (See this discussion in Section 3.) The difference between the numerator and denominator of this ratio is the presence of the auxiliary endogenous variables in the numerator. The computer program LIMDEP was used to estimate these probit regressions on attrition and construct these weights. These variables were then merged with the original data from the CHDS prior to the estimation of the cognitive achievement regressions.

The descriptive statistics in Tables A3 and A4 in Appendix A suggest that these weights have little impact on the overall sample of non-attriting families. Table A3 shows the means of selected regressors, both unweighted and weighted by the variables computed to correct for attrition from this panel. The differences in the means of these variables are relatively minor. In particular, there is no difference between the weighted and unweighted proportions of Maori or Pacific Island families. This is despite the fact that Maori or Pacific Island families are much more likely to attrite from the CHDS then non-Maori and non-Pacific Island families. However, it is important to note that this is primarily due to the fact that ethnicity is already directly included in the cognitive achievement regression. This results in ethnicity appearing in both sets of probit regressions on attrition, with their effects appearing in both the numerator and denominator of the weighting formula. The effects of ethnicity essentially "cancel out" unless it is somehow related to the inclusion of the auxiliary endogenous variables in the second set of regression results.

This inability to separately identify this attrition through the weights is confirmed in Table A4. The mean values of the normalised weights should be substantially higher than one for observations from demographic groups that are more likely to attrite. However, most of the mean values for these weights are very close to one. Again, the problem is that many of the factors related to attrition are already included in the regressions on the Burt Word Reading Test scores. The results from these tables suggest that our attempts to control for the other observable differences in attrition from the CHDS will have relatively minor effects on the cognitive achievement regressions to be analysed in the next section.

5. Regression Results on Cognitive Achievement, without and with Corrections for Attrition

We examine the results from the estimation of the regression models developed earlier in this report on the cognitive achievement of the children in the CHDS. Various specifications of these models are analysed. All of these results are reported both without and with the use of the correction procedure (weighted least-squares) for attrition from this study.

5.1 Preliminary Descriptive Statistics

There were 1,263 families originally selected to participate in the CHDS. Table 1 shows the attrition that took place, both prior to and during the administration of the Burt Word Reading Tests, to the children between the ages of 8 and 13. At age 8, 1,026 original participants remained in the study. However, only 839 children were tested at that time. This relatively low number was due primarily to the fact that cognitive achievement tests were not given to children in families living outside the Canterbury region. This restriction holds for all tests administered between the ages of 8 and 13. In addition, there were a number of key covariates for the regression analysis that were missing among the non-attriting families. In the end, only 802 families (63.5% of the study's original participants) were interviewed, lived in the Canterbury region, had children who were tested and supplied the necessary information on key covariates. By age 13, this nonattriting sample had dropped to 605, representing 47.9% of the original families in this study.

A very restrictive definition of attrition is used in this analysis. Once a family has attrited (e.g., refused or unable to be interviewed, a child who was not tested), they are not allowed to return and re-enter the sample. This notion of "cumulative" attrition is used to keep the sample sizes comparable in estimating both the "value added" and "level" regression models.

Table 2 shows some descriptive statistics on the raw scores on the Burt Word Reading Tests that will be used as the dependent variable in our regressions. The test scores are the number of words correctly read from a list of 110 words. From ages 8 to 13, the mean test score rises steadily from 45.153 to 85.175. The standard deviations on these test scores are relatively stable over the ages.

One of the issues that arises in this study is that test scores may be truncated at their minimum or maximum values for large proportions of test takers at some ages. This would mean that the test scores might not accurately reflect the true reading abilities of these children. In particular, the "topping out" of scores at the upper threshold of 110 might bias our estimated determinants of this cognitive achievement process, and this would be more likely to occur at older ages.

Very few children in the CHDS scored either 0 or 110 on the Burt Word Reading Test. No children between the ages of 8 and 13 received the top test score. Only 2 of the 605 test takers at age 13 (0.33%) scored a perfect 110. By this measure, "topping out" would not appear to be problem in this study.

However, this discussion raises the possibility that the raw test scores might still give misleading indications of basic reading ability.[5] One way of assessing this issue is to consider "normalising" these test scores to reflect the relevant reading ages of these children. Gilmore, Croft and Reid (1981) produced Equivalent Age Band (EAB) norms for the use of the Burt Word Reading Test in New Zealand. These age norms range from 6.00 to 12.11 years. Thus, the maximum age of our test takers isn't too far outside this range.

[5] The validity of the Burt Word Reading Test was examined in earlier reports in this project by examining the simple correlation coefficients with other cognitive achievement tests (e.g., PAT Reading Comprehension Test and the Test of Scholastic Abilities). The correlations were around 0.7 and higher, and there was no evidence to suggest that these relationships weakened at higher ages.

Gilmore, Croft and Reid report that raw scores on the Burt Word Reading Test below 20 and above 80 have no EAB norms. In other words, we cannot covert these test scores into effective reading ages outside the range of 20 to 80. The results reported in Table 2 show that it was not uncommon to exceed this upper threshold for older children. Nearly 24% of test takers at age 10 scored above 80 on the Burt Word Reading Test. This figure increased to over 69% by age 13. This isn't surprising since we would expect most 13 year-old children to have reading levels beyond the upper EAB threshold of 12.11 years. It does, however, suggest that topping out may be a problem among older children. For example, this may be one reason why the standard deviation of test scores *declined* from 20.2 at age 10 to 17.5 at age 13, after initially *rising* from 17.3 at age 8.

Although it might be conceptually attractive to convert scores on the Burt Word Reading Test to their EAB norms, the substantial proportion of test scores outside the bands makes this infeasible. We use the raw test score as the dependent variable in all subsequent regression analysis. To test the nature of this production process, dummy variables for the age of the test taker will be added to the list of the regressors under each specification.

Table 3 provides disaggregate statistics on the Burt Word Reading Test scores for children between the ages of 8 and 13. To ease the analysis of these summary statistics, these test scores are standardised to have zero means and unit variances among the test takers in the CHDS in each year. We show how the means of these standardised test scores vary by several individual, family and school characteristics that are of interest in this study. Later regression results will show how each factor is related to test performance, once other determinants are held constant. The simple mean values reported in this table show how overall test performance varies by each factor, without holding anything else constant. These descriptive statistics should aid us in interpreting the "partial" effects estimated in these regressions, and help us understand more about the possible "direct" and "indirect" effects on test performance.

Females consistently perform better, on average, than males on these tests. Across all ages, the mean test scores are 0.108 for girls and -0.111 for boys. However, the gender gap in reading ability declines with age. The average difference in test scores between the sexes is 0.303 of a standard deviation at age 8. This difference declines to 0.178 of a standard deviation by age 13.

On average, children of Maori or Pacific Island parents have lower test scores than children of parents of other ethnicities. Across all ages, the mean score is -0.230 for Maori or Pacific Island children and 0.029 for Pakeha or European children. This ethnic gap in reading ability declines with age. The average difference in test scores between the two ethnic groups is 0.359 of a standard deviation at age 8. This difference declines to 0.074 of a standard deviation by age 13.

The highest qualifications of parents are clearly related to the reading abilities of their children. These average test scores increase steadily as we move from parents with no qualifications to those with school, post-school and university qualifications. Across all ages, children with parents with a school, post-school and university qualifications have average test scores that are respectively 0.275, 0.535 and 0.906 of a standard deviation higher than children with parents with no formal qualifications. Unlike gender and ethnicity, there is no strong evidence in the descriptive statistics to suggest that these differences in test performance by parental qualifications change over the ages of the children.

On average, children in families with a single parent at the time of the Burt Word Reading Test have lower scores than children in families with two parents. Across all ages, the mean test score is -0.266 in single-parent families and 0.047 in two-parent families. Again, there is little evidence to suggest that the average differences in reading ability by family type change systematically with the age of the child.

The overall relationship between the mother's work status and the child's test performance does not appear to be very strong. Across all ages, the mean test scores are -0.076 where the mother is not employed at the time of the interview, 0.074 where the mother is currently working part-time (less than 30 hours per week) and -0.038 where the mother is currently working full-time (30 or more hours per week). These differences in test scores by the mother's work status are both relatively small and unstable over the ages of the children.

There appears to be a relatively strong positive relationship between family income and the child's performance on the Burt Word Reading Test. To produce a measure of "permanent income," we use real family income (measured in 1996 dollars by the Consumer Price Index) averaged over all previous periods in this table. For example, across all ages, children from families with annual income in the range of $30,000-39,999, $50,000-59,999 and $70,000 and above have average test scores that are respectively 0.315, 0.681 and 1.020 of a standard deviation higher than children from families with income less than $20,000 in annual income.

On average, children from families receiving social welfare benefits at the time of the Burt Word Reading Test have lower test scores than children in families not receiving benefits. Across all ages, the mean test score is -0.244 for children in families receiving benefits and 0.045 for children in families not receiving benefits. There is some evidence that these differences in reading ability based on benefit status decline with the age of the child.

Children enrolled in church or private schools scored better on the Burt Word Reading Test than children enrolled in public schools. Across all ages, the mean test scores are 0.166 among children in church or private schools and -0.031 for children in public schools. There is weak evidence that this gap in reading ability increases with age. The average differences in test scores rise from 0.095 at age 8 to 0.241 of a standard deviation by age 13.

A positive relationship between class size and reading ability is found. We would expect class size to have a negative impact on cognitive achievement. Smaller classes give students more individual attention from their teachers. However, it has been quite common in the empirical literature to find positive effects of class size on test performance. One explanation for this result has been that schools specifically place students with reading difficulties in smaller classes. The statistics in Table 3 seem to support this hypothesis. Students in classes with fewer than 14 pupils score substantially lower than students in larger classes. There doesn't appear to be any clear relationship between class size and test scores for the other class-size categories, although children in very large classes (more than 38 students) perform better than the average (0.098) across all ages. A regime where children with reading difficulties are intentionally placed in smaller classes, and children with exceptional reading abilities are selected into larger classes would clearly produce the observed distribution of test performances in this table.

Several "trajectories" in the growth of cognitive achievement over ages 8 to 13 are produced for various demographic subgroups. The idea is to see if lower intercepts are related to steeper slopes in these plots, possibly due to the targeting of government assistance at the disadvantaged. These trajectories are only produced for several time-invariant factors. To eliminate the confounding effects of attrition on these plots, we restrict our analysis to the subsample of children who were tested in all 6 years.

Figure 1 shows that girls, on average, consistently outscored boys on the Burt Word Reading Test. There was only a slight narrowing of this gender gap between ages 8 and 13. Figure 2 tells a similar story for ethnic differences in measured reading ability. The average child of non-Maori and non-Pacific Island parents received a higher test score than the average child with a Maori or Pacific Island parent. There is some evidence that this gap narrows for these same children after age 11.

Figure 3 shows the differences in mean test scores for children who attended pre-school vs. those who did not. Children who attended some preschool, on average, outscored the children with no preschool at every age. Like the ethnic differences in the earlier figure, these differences in test scores appear to narrow after age 11.

Finally, Figure 4 breaks the overall sample into 4 educational categories based on the highest educational attainment of parents. These categories refer to the receipt of a university degree, a post-school qualification (other than a university degree), a school qualification, and no school or post-school qualification. On average, children of more highly educated parents also score higher on the Burt Word Reading Test. The distances between these trajectories are relatively constant over the 6 ages. In other words, there is no obvious tendency for these gaps to narrow as the child ages.

5.2 Results from the Restricted Value-Added Regressions

The results reported in Table 4 are from the estimation of the *restricted* value-added regressions developed in Section 2.1. This resulted in a simple regression specification (equation (8)), where test performance in the current year is a linear function of a vector of time-invariant characteristics, a vector of time-varying factors in the previous year and the lagged test score. The presence of the lagged test score immediately restricts the relevant sample of observations to ages 9 through 13. All regressions are estimated both with and without age dummies.

Section 2.2 pointed out that instrumental variables must be used because the lagged dependent variable will be correlated with the disturbance term in this value-added specification. To test the effects of this estimation procedure, we estimate these regressions with both OLS and this IV technique. The individual's own test score lagged two periods is used as the instrument for the test score lagged one period. This mans that the relevant sample of observations is now restricted to ages 10 through 13. To ease the comparison of these regression results, both the OLS and IV estimation will use this same restricted sample.

Finally, the same IV estimation is used with weighted least-squares, where these weights control for the attrition from this panel study. This means that 6 separate regressions are reported in this Table 4. The OLS, IV and IV/WLS estimation techniques are used for regression models both without and with the dummy variables for the age of the test takers.

The sample size for observed test scores between the ages of 10 and 13 is 2,584. The R^2 statistics on these regressions range from 0.920 to 0.923. The most important explanatory variable in these regressions is the lagged test score. Under OLS, the estimated coefficient on this regressor is 0.919 (without the age dummies) and 0.945 (with the age dummies). With standard errors of 0.006 and 0.007, respectively, these estimated coefficients are significantly different from zero at better than a 1% level. Under IV, these estimated coefficients are only slightly larger at 0.921 (without the age dummies) and 0.953 (with the age dummies). They too are statistically significant. The first-stage results of this IV procedure yield R^2 statistics of around 0.9. This is consistent with the high correlation coefficients in test scores over time for these children.

When IV estimation takes place under weighted least-squares (the last 2 columns of Table 4), the estimated coefficients on the lagged dependent variable are essentially unchanged. This isn't surprising given the difficulty mentioned in the previous section in identifying this attrition behaviour once other explanatory variables already included in the cognitive achievement regression have been held constant.

The coefficients on the age dummies in 3 of the 6 regressions tell an interesting story. Three dummies are included for ages 11, 12 and 13 (with age 10 being the omitted category). All three estimated coefficients are negative and statistically significant at better than a 1% level.

Once we hold other factors constant, including the lagged test score, an additional year of age reduces the test score. These negative effects appear to increase in absolute magnitude with age, particularly between age 11 and 12. These results might be related to the "topping out" of test scores mentioned earlier.

Unless otherwise mentioned, all of the other regressors have insignificant effects on the value-added to the Burt Word Reading Test score. There is very little evidence that having Maori or Pacific Island parents has any impact on reading ability, once other factors have been held constant. The estimated coefficients on this variable are positive and weakly significant in 2 of the 6 regressions. When age dummies are included or weights are used for attrition, these estimated coefficients are no longer statistically significant.

Some evidence is found that the educational attainment of parents have positive effects on the value-added to reading ability. All of the estimated coefficients in these regressions are positive, and most are statistically significant. In particular, the estimated coefficients on parents with school qualifications are statistically significant in all 6 regressions. However, it is curious that these positive effects of parental education weaken when age dummies are included in the estimation.

The mother's emotional responsiveness score (a proxy for the parenting skills of the mother) has a positive and weakly significant effect on the cognitive achievement of her offspring in all regressions without age dummies.

The part-time work of the mother in the previous year has a positive and statistically significant effect in all 6 regressions. Its impact on test performance increases slightly in magnitude when age dummies are included in the estimation. Yet, the estimated coefficients on the dummy variable for the mother's lagged full-time work are insignificant in all regressions.

The child's enrolment in a church or private school in the preceding year has a positive, but very weak statistical effect on reading ability in 2 of the 6 regressions. This estimated coefficient becomes insignificant once the age dummies are included in the estimation.

The estimated coefficients on lagged class size are positive and significantly different from zero in 4 of the 6 regressions. These results are at odds with our hypothesis that larger class sizes should result in lower test scores. In Section 5.4 we experiment with an "anti-instrumental variable" approach to remove at least some of the potential simultaneous-equation bias that might lie behind these perverse findings.

5.3 Results from the Unrestricted Value-Added Regressions

The specification of the regression model estimated in the previous section was based on two restrictions; an absence of age-specific effects across all regressors, and a constant rate of geometric decay across the time-varying covariates. We first test the validity of both restrictions simultaneously by estimating the unrestricted value-added regression model (equation (3) in Section 2.1). Simple F tests will indicate whether or not these restrictions were appropriate. If these null hypotheses can be rejected, we need to consider which of the two restrictions (or both) may have to be relaxed.

To perform these F tests we need to estimate the R^2 statistics from this general specification that essentially interacts all time-invariant and time-varying explanatory variables with age dummies. These time-varying covariates are lagged for all previous years in the sample period. Finally, the lagged test score on the Burt Word Reading Test is also included. As before, we need to use an IV approach to produce consistent parameter estimates. Since test performance lagged 2 periods will again be used as the relevant instrumental variable, the sample is restricted to ages 10 through 13 (n=2,584).

Table 5 reports the summary results from this estimation. For purposes of comparison, the results from the IV estimation of the *restricted* model in the middle 2 columns of Table 4 are reproduced in the first 2 columns of Table 5. The number of coefficients estimated in these 2 expressions k were 17 (without the age dummies) and 20 (with the age dummies), respectively. The R^2 statistics are 0.920 and 0.922.

The summary results from the *unrestricted* model are shown in the last 2 columns of Table 5. When both restrictions were lifted, the number of coefficients estimated increases to 260 (without the age dummies) ans 263 (with the age dummies).[6] Since severe collinearity makes the estimation and interpretation of the partial regression coefficients quite difficult, these results are not reported. However, both the adjusted and unadjusted R^2 statistics are displayed. The removal of these restrictions has only a minimal effect on the adjusted R^2 statistics. In fact, there is virtually no change in this statistic between the restricted and unrestricted regressions with age dummies (both are 0.922). Yet, the unadjusted R^2 statistics increase under both specifications with the removal of these restrictions.

The critical values for this *F* test on the joint restrictions are 1.236, 1.156 and 1.120 for 1%, 5% and 10% significance levels, respectively. The computed *F* statistics with the degrees of freedom in these regressions are 1.153 without the age dummies and 1.078 with the age dummies. This means that the null hypothesis of the joint restrictions can only be rejected at a 10% level in the model without age dummies, while the same null hypothesis *cannot* be rejected at a 10% level in the model with age dummies.

These tests suggest that there is little statistical evidence of an increase in the overall explanatory power of these regression models when both restrictions are removed. We cannot reject the validity of an absence of age-specific effects and a constant rate of geometric decay. This means that the lagged dependent variable is a sufficient statistic for capturing all earlier determinants of current test performance. Furthermore, these results indicate that there is little reason to estimate equations (4) and (6) that isolate the effects of each of restrictions separately on the regression model.

5.4 Results from the Restricted Value-Added Regressions Including "Anti-Instruments" for Class Size

Section 2.4 discussed the inherent problems in using class size as an explanatory variable in cognitive achievement regressions. Although *exogenous* changes in class size may have negative effects on reading ability, class size itself may be positively related to past academic performance. Thus, the regression model as it now stands may be mis-specified. Simultaneous-equation bias may result in positive coefficients on class size, because the

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[6] These are substantially lower then the 455 parameters discussed Section 2. However, this number was based on the assumption that all 6 years of test scores would be included in the estimation. The lower numbers of coefficients reflect the fact that only 4 years of data are actually used in these value-added IV regressions.

“causality”is essentially running in the opposite direction. One potential solution to this problem is to try to isolate the reverse causality be regressing current class size on both lagged scores on the Burt Word Reading Test and teacher evaluations of individual classroom performance.

This first-stage procedure was performed for class sizes at ages 9 through 12 (these are the lagged class sizes in the regressions on the Burt Word Reading Test scores at ages 10 through 13). Up to 4 lagged values of test scores and 5 lagged values of grade point average were included in these auxiliary regressions. The R^2 statistics were quite low, ranging from 0.012 to 0.016. Little variation in the allocation of class size is related to individual test or classroom performance in previous years.

Nonetheless, the residuals from these class size regressions were used to replace actual lagged class size in the cognitive achievement regressions. These results are reported in Table 6. The estimated coefficients on these class size residuals are still positive, but now statistically insignificant in all regressions. The inclusion of these anti-instruments for class size has minimal effects on other parameter estimates in these regressions. On the one hand, this procedure was “successful.” We no longer find any evidence that class size has a positive impact on reading ability. On the other hand, this procedure was “unsuccessful” if one believes that exogenous increases in class size really do reduce cognitive achievement. Perhaps further work with this anti-IV approach may eventually produce evidence of this hypothesised negative effect. At this point, the results suggest that class size simply doesn’t matter in terms of reading ability.

5.5 Testing for the Presence of Latent Fixed Effects

Section 2.5 raised the issue of a potential mis-specification of the original structure of the cognitive achievement production function by omitting possible individual-specific fixed effects. To test this possibility, we developed 2 regression models. The first we can call a “level specification.” We adopt essentially the same structure as the basic regression model used in Table 4. The only difference is that we further restrict the age range to between 11 and 13, because test scores lagged 3 periods (compared to the previous 2 periods) are now used as instrumental variables. As a result, sample size drops to 1,893. The second model is a “first differences” specification. The dependent variable is now the change in individual test scores between 2 adjacent years. The time-invariant factors are eliminated from the expression by first differencing, and the lagged time-varying factors are now first-differences. The test score lagged 3 periods is used as the instrument for the change in the lagged dependent variable. If latent fixed-effects do not exist in this regression model, the estimated coefficients on the instrumented lagged dependent variable in the level and first-differences specifications should be essentially identical.

Table 7 displays the results from 6 regressions. Like the results reported in Table 4, OLS, IV and weighted IV techniques are used. These approaches are used for both level and first-differences specifications. To conserve on space, we report only the regressions that include age dummies. As before, the value-added regressions produce estimates for λ above 0.9.

With the IV and weighted IV estimation, the estimated coefficients are 0.915 and 0.923, respectively. Both are statistically significant at better than a 1% level. When OLS is used under first differences, the estimated value of λ drops to 0.331. When valid instruments are used for this lagged dependent variable (test scores lagged 3 periods), however, the estimated coefficients are 0.823 (unweighted) and 0.818 (weighted). These figures are still below those found earlier in the level specifications. If we doubled the estimated standard errors and added them to these estimated coefficients, we would still be below the 0.9 figure. Since first differencing removed any individual fixed effects, we would have to conclude that these effects are present and did result in an upward bias on the earlier estimates of λ.

5.6 Results from the Restricted Level Regressions

Previous results have produced two important findings. First, we are unable to reject the joint hypotheses of an absence of age-specific effects across all explanatory variables and a constant rate of geometric decay in time-varying covariates. Second, the first-differencing approach of the value-added regressions with instrumental variables produced unbiased estimates of this constant rate of geometric decay λ. With these two results, the original level specification of the cognitive achievement production function can be estimated. Section 2.5 lays out the construction of this simplified level specification (equations (13) and (14)). Composite variables are constructed for these time-varying factors, appropriately weighting all historical data using a consistent estimate of λ (0.82) and the relevant elapsed time. One advantage of this approach is that we can directly use test results from all 6 years (ages 8 through 13) in the estimation, because there is no need to use instrumental variables. Another advantage is that this level specification might do a better job picking up the effects of family background on cognitive achievement earlier in the child's life.

Table 8 shows the results from 4 level regressions, without and with age dummies and without and with corrections for attrition. Sample size is increased to 4,104 for the test scores from ages 8 through 13. The R^2 statistics on these regressions range from 0.150 to 0.153 for specifications without age dummies, to 0.465 to 0.471 with age dummies. Since there is clear evidence that these age effects are extremely important in these regressions, we restrict our discussion of the parameter estimates to these two regressions.

Once other factors are held constant, the estimated coefficients on the age dummies are all positive and significantly different from zero at better than a 1% level. As expected, the estimated coefficients increase in magnitude as the child ages. Note, however, that the *differences* in successive coefficient estimates decline with age, from 9.891 between ages 8 and 9 to 5.863 between ages 12 and 13. This is consistent with earlier results from the value-added regressions, where negative estimated coefficients on these age dummies were found.

Being female and having Maori or Pacific Island parents both increase reading ability. The estimated coefficients are both positive and significant at better than a 1% level.
These level regressions suggest that overall differences in average reading abilities between Maori or Pacific Islanders relative to other ethnic groups can be explained by differences in

other measured determinants of cognitive achievement. The statistics in Table 3 showed that Maori or Pacific Island children scored *lower* on the Burt Word Reading Test than children from other ethnic groups. Yet, once the educational qualifications of parents, number of siblings, family income and type of school attended are held constant, Maori or Pacific Island children scored *higher* than children from other ethnic groups. Differences in family and school characteristics between the ethnic groups account for the relatively poor test performance of Maori and Pacific Island children.

It should be noted that the CHDS is a poor data source for this particular analysis because of a lack of ethnic diversity. This is partly due to the generally low level of Maori or Pacific Island representation in the Canterbury region. For example, only 8.6 and 4.5% of children assessed at age 13 had fathers and mothers, respectively, who identified themselves as Maori or Pacific Islanders. A second problem is the relationship between ethnicity and attrition from the longitudinal study. Ethnicity appears to be related to attrition rates, and non-attriting Maori or Pacific Island families may be quite different to attriting Maori or Pacific Island families. The fact that the ethnicity of the former does not reduce test performance, does not imply that the same would be true for the latter group. Yet, when corrections are made for attrition from this study, the estimated coefficient on Maori or Pacific Island parents *increases* from 1.957 to 2.369.

The educational attainment of parents are found to have positive and significant impacts on the reading abilities of their children. The estimated coefficients under WLS are 3.169, 5.664 and 8.788 for a school, post-school and university qualification, respectively. All three are significantly different from zero at better than a 1% level. These results imply that if both parents have university degrees, this directly increases the child's reading ability by an average of 17.576 points (twice the estimated coefficient on this variable), relative to a child with parents who had no formal school, post-school or tertiary qualifications.

Years of preschool education have no measurable effect on scores from the Burt Word Reading Test. This reinforces the earlier finding on the same variable in the value-added regression.

The estimated coefficient on the mother's emotional responsiveness is positive and significant at better than 1% level. Based on the evidence from earlier value-added regressions of a substantially smaller and often insignificant effect, we could conclude that either most of the long-term effects of parenting ability on reading performance occur prior to age 8, or that this measure of the mother's parenting ability is proxying for permanent, unobserved characteristics that independently influence the child's cognitive achievement.

The number of siblings in the family has a negative impact on reading ability. The estimated coefficient is significant at better than a 1% level. It should ne noted, however, that no evidence was found earlier of any effects of family size on the value-added to cognitive achievement. These results suggest that the number of siblings in the family might proxy for parental attitudes or behaviour which independently affect cognitive achievement.

Once other factors are held constant, there is no evidence of any effect from the presence of two parents in a household on reading ability. This same qualitative result was found earlier in the value-added regression. Since Table 3 shows that children from two-parent families score higher, on average, then children from single-parent families, we would have to conclude that factors other than family composition are responsible for these overall differences in reading ability.

One of the hypotheses to be tested in this study is whether work outside the home by the mother has any impact on the cognitive achievement of her child. There is evidence in these level regressions that full-time work by the mother (30 or more hours per week) has a detrimental impact on a child's reading ability. The estimated coefficients on full-time work are -6.952 and -6.634 in the regressions with age dummies. Both are significant at better than a 1% level. Yet, part-time work the mother has no measurable impact on test performance.

We can combine these findings on the mother's work status in the level regressions with the earlier findings on the same variables in the value-added regressions. The value-added results suggest that the mother's part-time work has a *positive* effect on her child's reading ability, while full-time work has no measurable effect. The level results now suggest that the mother's full-time work has a *negative* effect on her child's reading ability, while part-time work has no measurable effect. How can we reconcile these results? Perhaps full-time work early in the life of the child is detrimental, while part-time work later in the life of the child has a positive incremental effect on cognitive achievement. At least equally likely, however, is the possibility that the market work of the mother is a proxy for permanent, unobserved factors that independently influence the reading ability of the child. It would be best to conclude that the lack of significant coefficients on these variables in the regressions that control for latent fixed effects (Table 7), indicates that the mother's work has no impact on her child's cognitive achievement.

The benefit status of the family has no direct measurable effects on the Burt Word Reading Test scores in both the value-added and level regressions. The estimated coefficients on this variable are negative, but insignificant in Table 8. These results could be viewed in the context of the literature on the intergenerational transmission of disadvantage. Most of the empirical results in this area (e.g., see the literature review by Corcoran and Boggess, 1994), have concentrated on estimating the effects of the beneficiary status of the parents on their children's own welfare and work histories, out-of-wedlock births, and educational attainment. These is no evidence in our regressions that a family's benefit status has a direct, negative impact on the reading ability of the child. These results can be contrasted with those from Table 3 that showed that families receiving benefits, on average, have children with lower reading levels.

The estimated coefficient on family income are 1.356 under OLS and 1.325 under WLS. Both are statistically significant at better than a 1% level. They indicate the average effects of a $10,000 increase in family income (between one-fifth and one-quarter of the sample mean) on the child's test performance. The magnitudes of these partial effects of family income on reading ability are substantially smaller than the overall differences in average test scores by income levels reported in Table 3. This suggests that factors other than income (e.g., parental education) may be more directly responsible for the overall differences in the average reading abilities of children across the income categories. Moreover, since these positive coefficients on family income were *not* found in earlier value added regressions, there is some support for possibility that family income is proxying for permanent, unobserved factors that independently influence reading ability.

Only two measures of the characteristics of schools attended by the children in the CHDS could be included in these regressions on reading ability. The first is a dummy variable that takes on a value of one if the child attended either a church or private school, and zero if he or she attended a public school. The estimated coefficients on this variable are positive and significant at better than a 1% level in Table 8. This suggests that, other things held constant, enrolment in a church or private school increases reading ability by an average of 3.126 and 3.270.

Although these regressions hold constant a variety of observed personal and family characteristics that are potentially related to the decision to attend a church or private school (e.g., education of parents, family income), this does not eliminate the possibility that this estimated effect suffers from simultaneous-equation bias. The basic concern here is that this school attendance is a choice variable for the family. Since some of the factors that influence this decision could also be related to the cognitive achievement of the child, the estimated coefficient on this regressor may be biased. Our view is that this bias would likely overestimate the effect of church or private school attendance on reading ability. This is because unmeasured factors that increase the likelihood that parents will pay out-of-pocket tuition fees for non-public schools will be positively related to the cognitive development of their children. Of course, these "permanent" differences across families would be eliminated under the earlier value-added estimation. Thus, we are unable to rule out the possibility that this impact of church or private schools is entirely the result of simultaneous-equation or omitted-variable bias.

The second explanatory variable related to school characteristics is class size. As mentioned earlier, we would expect larger classes to lower test performance, because teachers in larger classes generally have less time to spend with any particular student. However, overseas research has rarely found evidence of this negative effect of class size on cognitive achievement. In fact, a number of studies have estimated positive effects. The estimated coefficients on past class sizes in Table 8 are also positive, and significant at better than a 1% level. This result supports the earlier finding of a positive effect of class size on reading ability in the first set of value-added regressions.

One potential problem with this measure of class size is that there is no information on whether or not the child was in an "open plan classroom." In these situations, more than one teacher may be working in the room at the same time. It is unclear how common open plan classrooms are in this survey, but this measurement error could, at least partly, be responsible for this "perverse" result. Even more likely, however, is the possibility that class size is an endogenous variable. Schools may intentionally place children with reading problems in classrooms with fewer children. This contention is supported by the descriptive statistics found in Table 3. In a sense, the causality in this regression is reversed. Small classes do *not* cause children to have poorer reading abilities, children with poorer reading abilities are selected into smaller classes.

Unlike the earlier value-added regressions, no attempts were made to use “anti-instruments” for class size. One of the problems is that instrumental variables are needed for class size. In this situation, lagged class size begins at age 7 and previously used instruments (earlier test scores and grade point average) do not exist prior to this age. Thus, this anti-instrumental variable technique can only be used in the level regressions if a new set of instruments can be found.

5.7 Results from Estimating Heterogeneous Responses to Family and School Characteristics

It has been assumed implicitly in all regressions thus far that the effects of various family and school characteristics on reading ability are the same across all demographic groups. It is possible, however, that heterogeneous responses may exist across various subpopulations. In other words, coefficients on some of the determinants of this cognitive development may vary by a child’s gender, and the ethnicity and qualifications of his or her parents.

To test these possibilities, we re-estimated the restricted value-added and level regressions (both unweighted and weighted for attrition) after interacting all of the time-varying covariates with these three time-invariant factors. These results are reported in Tables 9, 10 and 11. If we cannot reject the null hypothesis that an estimated coefficient on an interacted variable is equal to zero, then there is no statistical evidence of this particular type of response heterogeneity.

Table 9 shows that the effect of a two-parent family on reading ability seems to vary by the gender of the child. This is true of both the value-added and level regressions. Recall that the estimated coefficients on this variable were insignificant in Tables 4 and 8. At least in the level regression, we now estimate a *positive* effect of a two-parent family for boys, but a *negative* effect for girls. Another striking result is the differential effect of the family’s benefit status on the cognitive achievement of boys and girls. In the level specification of Table 8, we saw that no direct effects of benefit status were found for the entire sample. This same level specification in Table 9, now shows that benefit status has a *positive* effect on the reading ability of boys, but a *negative* effect for girls.

Table 10 interacts these time-varying factors by the ethnicity of the parents. These results suggest that the part-time or full-time work status of the mother has a relatively larger *positive* effects on the reading ability of children with Maori or Pacific Island parents. On the other hand, family income is found to have a *negative* impact on the reading ability of children with Maori or Pacific Island parents in all regressions. For children with non-Maori and non-Pacific Island parents, the estimated effects of income are either nonexistent (under the value-added estimation) or positive (under the level specification). Although attendance at a private or church school are estimated to be positive in the level regressions for all children, these incremental effects are found to be three-times higher among Maori or Pacific Island children.

The regression results in Table 11 show the effects of interacting the time-varying covariates with the three levels of educational qualifications of parents. Previous regression results have shown little evidence of any overall effects of two-parent families on cognitive achievement. The level regressions in Table 11 suggest that two-parent families have a *negative* effect of the reading ability of their children if the parents have no school or post-school qualifications. *Positive* effects of two-parent families on test performance increase steadily in magnitude with the highest educational attainment of the parents.

Earlier regression results showed little evidence of any direct effect of the family's benefit status on a child's cognitive achievement. Results in Table 11 suggest that benefit status has a *negative* and significant effect on reading ability if the parents possess a university degree. Previous level regressions have shown that family income has a positive overall effect on reading ability. Similar level regressions in this table show that family income has essentially no impact on the child's reading ability for families where the highest educational attainment of the parents is a post-school qualification.

One of the clearest results from Table 11 involves the impact of the child attending a church or private school. The incremental effects of this enrolment are largest for unqualified parents, and drop significantly as the educational attainment of the parents increase. It is also worth noting that the positive effects of class size on reading ability are significantly smaller in both the value-added and level regressions for parents with a school qualification.

Clearly, the results in Tables 9 through 11 point to the need to consider the possible heterogeneity in responses across various subpopulations. The effects of several time-varying covariates in both the value-added and level specifications of these regression vary by the gender of the child and both the ethnicity and qualifications of the parents.

6. Summary and Conclusions

A number of general findings can be deduced from our examination of six consecutive years of test scores on the Burt Word Reading Test for children in the CHDS. First, statistical evidence supports the reduction in a general, cumulative model of cognitive achievement to a simpler value-added specification. Joint hypotheses on the absence of age-specific effects and a constant rate of geometric decay in all time-varying regressors cannot be rejected. This means that the lagged dependent variable (individual test performance in the previous year) is a sufficient statistic for capturing all earlier determinants of this behaviour. This finding reduces the advantages of this unique longitudinal study relative to other panel data sets with only two observations on individual test performance.

Second, an instrumental-variable approach was used to produce consistent coefficient estimates under these autoregressive specifications. The individual test score lagged two periods served as the relevant instrument. This IV technique had little impact on the estimated parameters found under OLS.

Third, an "anti-instrumental-variable" approach was used to examine the robustness of the estimated positive effects of class size on reading ability. When the portion of class size that depended on past individual test and classroom performance was effectively removed from this variable, the estimated coefficients on these class size residuals were no longer significantly different from zero. Yet, there is no evidence in this study to suggest that exogenous increases in class size are detrimental to cognitive achievement.

Fourth, the potential mis-specification of the original setup of the cognitive achievement production process was tested. If individual fixed-effects exist, unbiased coefficient estimates can only be produced by using a first-differences, IV approach. The resulting drop in the estimated coefficient on the lagged dependent variable from around 0.92 to 0.82 suggests that these latent individual effects are present.

Fifth, once an unbiased estimate for this geometric rate of decay became available, the original cognitive achievement production function was converted to a "level" specification. The estimation of this regression also relied on the absence of any age-specific effects. It showed that many of the time-invariant and time-varying factors that were found to be statistically insignificant in the value-added regressions are statistically significant in this alternative specification. This suggests that many of the family background factors that influence reading ability may occur prior to these tests between the ages of 8 and 13. These results support the view that "early intervention" matters most.

Finally, an econometric procedure was developed for correcting for the effects of the considerable attrition that has taken place over the history of the CHDS. A weighted least-squares approach was developed and applied to all regression models on cognitive achievement. It proved to be difficult to separately identify this attrition from factors that were already being held constant in the cognitive achievement regressions. In the end, these corrections for attrition bias had little impact on our parameter estimates.

We sort the specific empirical results on the basic determinants of reading abilities by each of these personal, family or school characteristics below. Any broad policy implications or particular empirical issues related to these independent variables will be discussed under the appropriate headings.

A great deal of caution should be exercised in inferring causality from these numerous regression results. No attempts have been made to estimate a complete structural model of this cognitive achievement process. The causal channels that link personal, family, community and school characteristics to cognitive development may be quite complex. Drawing meaningful interpretations from these reduced-form estimates is problematic.

However, some general points in interpreting these regression results can be made at the outset. If a given variable (e.g., family income) has a significant effect on reading ability in our level regressions but an insignificant effect in the value-added regressions, these results support the view that this variable is proxying for latent, permanent factors that independently influence cognitive achievement. Yet, an alternative interpretation of these overall findings cannot be ruled out. The observed variable may significantly influence cognitive development *prior* to the ages at which the Burt Word Reading Tests were administered. In other words, only early interventions matter. Family income, for example, might have a significant effect on reading ability prior to a child's entry into school. Once in school, the influence of family income on further "incremental gains" in reading proficiency might fade.

♦ ***Gender***. Girls, on average, score higher than boys on the Burt Word Reading Test. However, there is some evidence of a slight narrowing with age in the gender gap in reading ability. This finding is reinforced by the regression results under both the value-added and level specifications. Very little of the overall differences in reading abilities between boys and girls can be explained by other family background or school characteristics included in these regressions. Evidence is also found that gender and family background interact to influence reading ability. Under both the value-added and level specifications, boys benefit more than girls from the presence of two parents in the family. Only under the level specification are girls disadvantaged relative to boys if the family receives social welfare benefits.

♦ ***Ethnicity***. Children of Maori or Pacific Island parents, on average, score lower on the Burt Word Reading Test than children of parents from other ethnic backgrounds. However, this relative disadvantage of Maori or Pacific Island children in reading ability can be entirely explained by other family and school characteristics in the value-added and level regressions. In fact, holding other factors constant, the average test performance of Maori or Pacific Island children is *higher* than that of other children. It is possible that these estimated results might not reflect the actual relationship between ethnicity and reading ability in the general population, due to the small number of Maori or Pacific Island families at the outset of the CHDS, and the higher attrition rates experienced by Maori or Pacific Island families. Although our attempts to correct for the effects of this attrition in our regressions did *not* alter the above qualitative findings, it should be noted that this approach does not consider the possibility that Maori or Pacific Island families that attrited were different from those that did not attrite in terms of unobservable characteristics. We have not allowed for attrition bias based on unobservable factors in this report. Evidence is also found that ethnicity interacts with both family and school characteristics to influence reading ability. The mother's work status has a relatively larger positive (or smaller negative) effect on the cognitive achievement of Maori or Pacific Islanders compared to other ethnicities. Family income has a negative impact on the reading ability of Maori or Pacific Island children, while it has a positive impact (at least in the level regressions) on the reading ability of children of other ethnicities. Enrolment in a church or private school has a relatively larger positive effect on the reading ability of Maori or Pacific Islanders compared to other ethnicities.

♦ ***Qualifications of Parents***. The educational attainment of parents have some of the strongest and most consistent effects on the test performance of children in this study. The higher the qualifications of parents, the higher the average scores on the Burt Word Reading Test. Regression results under both the value-added and level specifications show positive and significant effects of the parents' school, post-school and university qualifications on their child's reading ability. Very little of the overall gaps in reading abilities of children who have parents with different qualifications are explained by other family or school characteristics included in these regressions. The fact that these positive effects are found in the value-added regressions is particularly important. Since the dependent variable is the change in test scores from one year to another, this differencing essentially eliminates the possibility that the educational attainment of the parents might entirely proxy for permanent, unobserved factors that independently influence cognitive development. There are numerous “channels” through which the qualifications of parents might influence the reading ability of their children. In particular, the relatively smaller effects estimated in the value-added regressions supports the view that the educational attainment of parents proxies for the transmission of genetic endowments to children. We also find evidence that the effects of the parents’ qualifications on the child’s reading ability vary by family background and school characteristics. At least under the level specification, university qualifications have a relatively larger impact on this cognitive achievement if there are two parents present in the family. Being on the benefit has a relatively larger detrimental impact on reading ability when the parents have university degrees.

- ***Preschool Education***. No evidence is found in our regressions that years of preschool education have any effects on the reading ability of children in the CHDS.

- ***Parenting Skills or Capacities***. Little information is available in the CHDS on the quality of parenting. Such factors are, of course, difficult to quantify. However, we do have a single measure of the emotional responsiveness of the mother taken when the child was three years old. Our regressions suggest that there is a positive relationship between the mother’s parenting skills and the child’s performance on the Burt Word Reading Test, once other factors are held constant. The estimated coefficients are significant in both the value-added and level regressions. However, the effects are much stronger in the level specification, suggesting that this variable may proxy for unobserved, permanent factors that independently influence reading ability.

- ***Number of Siblings***. Results from our level regression show that the number of siblings in the family has a negative and significant effect on test performance. Other things held constant, a larger number of children in the family will lower the average score on the Burt Word Reading Test. However, no measurable effect is found in the value-added regression on the same variable. These results raise the possibility that the number of siblings might proxy for the attitudes or behaviour of parents’ that influence both the size of families and the achievement of children.

- ***Number of Parents in the Family***. Children from single-parent families, on average, score lower on the Burt Word Reading Test than children from two-parent families. However, once other factors are held constant in our regressions under both the value-added and level specifications, there is no statistical evidence that family structure has any impact on reading ability. As mentioned earlier, however, evidence is found that family structure interacts with both the gender of the child and the educational attainment of the parents to influence reading ability (see the discussions under "Gender" and "Qualifications of Parents").

- ***The Mother's Work Status***. Descriptive statistics show very weak evidence of a positive relationship between the mother's market work (particularly part-time work) and the child's reading ability. Evidence of a positive effect of the mother's part-time is found in the value-added regressions. Evidence of a negative effect of the mother's full-time work is found in the level regressions. However, when explicit attempts are made to control for individual-specific fixed effects, there is no statistical evidence of any effects of the mother's work status on the child's reading ability. As mentioned earlier, evidence is found that the mother's work status interacts with the ethnicity and educational attainment of the parents to influence reading ability (see the discussions under "Ethnicity" and "Qualifications of Parents").

- ***The Family's Benefit Status***. Children from families receiving social welfare benefits, on average, score lower on the Burt Word Reading Test compared to children from families not receiving benefits. However, the lower reading abilities of children from households on the benefit can be entirely explained by other family background and school characteristics. The estimated coefficients on the benefit status of the family are insignificant in both the value-added and level regressions. As mentioned earlier, evidence is also found that the family's benefit status interacts with both the gender of the child and the educational attainment of the parents to influence reading ability (see the discussions under "Gender" and "Qualifications of Parents").

- ***Family Income***. We know from our descriptive statistics that there is a very strong positive relationship between the average gross income of the family and the reading ability of the child. The estimated coefficients on family income are positive and significant in the level regressions. However, there is no statistical evidence in the value-added regressions of any impact of family income on the reading ability of children. Either family income proxies for permanent, unobserved factors that independently influence cognitive achievement, or family income raises reading ability prior to the ages of the test takers in the CHDS. As mentioned earlier, evidence is also found that family income interacts with the ethnicity of the parents to influence reading ability (see the discussions under "Ethnicity").

- ***Type of School Attended***. Children attending church or private schools, on average, score higher on the Burt Word Reading Test than children attending public schools. No statistical evidence is found in the value-added regression that enrolment in a church or private school has any impact on reading ability. Yet, these estimated effects are positive and significant in the level regressions. The fact that this positive effect on church or private school attendance is *not* found in the value-added regressions is particularly important. The type of school attended might proxy for permanent, unobserved factors that independently influence cognitive development. For example, children with higher scholastic abilities (reading levels in particular) may self-select and attend church or private schools. Similarly, parents who place greater emphasis on academic achievement may enrol their children in church or private schools. As mentioned earlier, evidence is also found that the type of school attended interacts with both the ethnicity and educational attainment of the parents to influence reading ability (see the discussions under “Ethnicity” and “Qualifications of Parents”).

- ***Class Size***. A negative effect is hypothesised in terms of the likely effects of class size on reading ability. Holding other things constant, students in larger classes receive less attention from teachers, and this should translate, on average, into lower test scores on reading ability. Positive effects, however, have often been found in overseas studies. Descriptive statistics in the CHDS show that children in the smallest classes have far *lower* levels of reading ability compared to children in larger classes. Moreover, once other things are constant, our value-added and level regressions both show clear evidence of a positive effect of class size. Our interpretation of these perverse findings is that class size is endogenous. In fact, causality may be running from right to left in our equations. Children with low levels of reading ability (and low expected growth rates in this cognitive achievement) are intentionally placed by school administrators into smaller classes so that they can receive more attention by their teachers. Our descriptive statistics support this interpretation, because children in the very smallest classes have substantially lower test scores, while the relationship between class size and test performance among the other categories of class size is not very clear. Our use of an anti-instrumental-variable approach, however, showed that very little of the overall variation in class sizes could be explained by past individual test and classroom performance. Yet, this approach was able to eliminate the significant positive effects of class size on reading ability.

One final point should be stressed in depicting these empirical findings. These results have been generated from analyses based on a particular measure of cognitive achievement. The possibility exists that the Burt Word Reading Test may be inadequate as a general indicator of the academic or mental development of children in the CHDS. Earlier reports in this project produced some preliminary analyses on the six other tests of cognitive achievement administered to these same children (the Revised Wechsler Intelligence Scale for Children at ages 8 and 9, the Progressive Achievement Test of Reading Comprehension at age 10 and 12, the Progressive Achievement Test of Mathematics at age 11 and the Test of Scholastic Abilities at age 13). The advantage of the Burt Word Reading Test is that the same instrument was administered in six consecutive years, while these alternative tests varied over the sample period. In this way, we lose some of the potential advantages of these longitudinal data if we concentrate on these alternative tests. Yet, we may be able to at least evaluate the robustness of some of our specific findings with the Burt Word Reading Test against these other measures of overall cognitive development in the future.

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Table 1

Sample Sizes and Attrition in the CHDS

Year	Age of Child	Families Remaining In Study	Families in Study & Children Tested	Families in Study, Children Tested & Valid Covariates	Previous Column Relative to Original Families in CHDS
1985	8	1,026	839	802	63.5%
1986	9	1,009	758	718	56.8%
1987	10	996	734	691	54.7%
1988	11	974	707	658	52.1%
1989	12	946	680	630	49.9%
1990	13	929	656	605	47.9%

Notes: These are "cumulative" attrition rates at the time of each CHDS survey. Attrition can occur if the family is not interviewed, the child is not tested or the covariates used in later cognitive achievement regressions are not available at a given survey. By definition, this attrition *cannot* be reversed if the respondent re-enters the study. Cognitive achievement tests were only administered to children between the ages of 8 and 13 if they were living in the Canterbury region at the time of the interview.

Table 2

Descriptive Statistics on the Burt Word Reading Test Scores

Year	Age of Child	Number of Children Tested	Mean Test Score	Standard Deviation	% with Minimum Test Score of 0	% with Test Score < 20	% with Test Score > 80	% with Maximum Test Score of 110
1985	8	802	45.153	17.285	0.12	4.36	3.24	0.00
1986	9	718	53.797	18.788	0.14	1.81	9.19	0.00
1987	10	691	63.919	20.189	0.29	0.58	23.88	0.00
1988	11	658	72.464	20.067	0.15	0.30	40.88	0.00
1989	12	630	79.203	19.007	0.00	0.16	54.44	0.00
1990	13	605	85.175	17.519	0.00	0.17	69.09	0.33

Notes: These statistics are based on raw test scores from the Burt Word Reading Test administered by the Christchurch Health and Development Study.

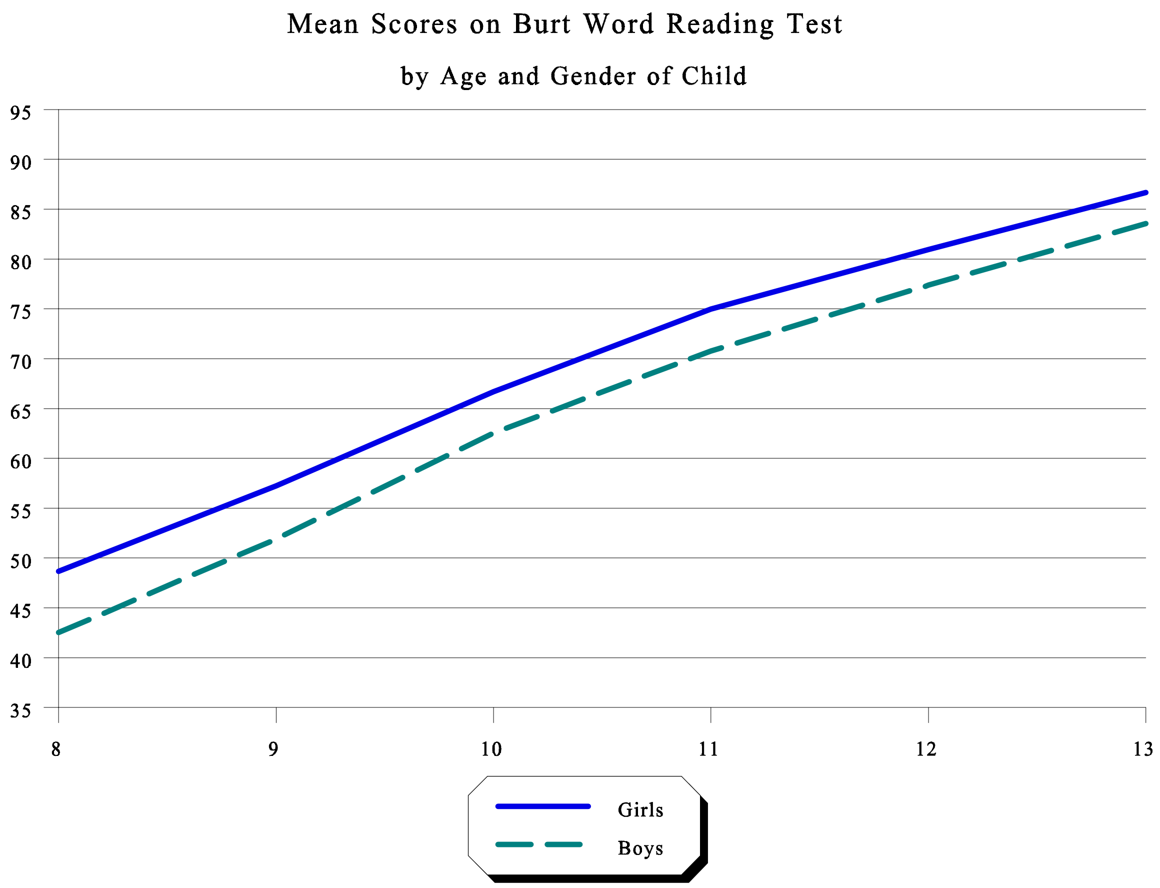
Table 3

Standardised Mean Scores on the Burt Word Reading Test: Ages 8 to13
by Selected Personal and Family Characteristics

Variables	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	*All Ages*
Gender of Child:							
Male	-0.151	-0.121	-0.093	-0.105	-0.096	-0.092	-0.111
Female	0.152	0.117	0.090	0.102	0.092	0.086	0.108
Ethnicity of Parents:							
Maori or Pacific Islander	-0.316	-0.310	-0.260	-0.234	-0.118	-0.066	-0.230
All Other Ethnicities	0.043	0.041	0.034	0.028	0.014	0.008	0.029
Highest Qualification Parents:							
No Qualification	-0.294	-0.332	-0.354	-0.333	-0.353	-0.335	-0.332
School Qualification	-0.092	-0.074	-0.026	-0.063	-0.039	-0.042	-0.057
Post-School Qualification	0.208	0.205	0.193	0.226	0.202	0.181	0.203
University	0.594	0.672	0.608	0.596	0.588	0.559	0.604
Type of Family:							
Single Parent	-0.303	-0.265	-0.258	-0.229	-0.265	-0.274	-0.266
Two Parents	0.046	0.046	0.048	0.039	0.047	0.053	0.047
Work Status of Mother:							
Not Employed	-0.052	-0.085	-0.087	-0.050	-0.091	-0.107	-0.076
Employed Part-Time	0.095	0.098	0.081	0.032	0.100	0.032	0.074
Employed Full-Time	-0.153	-0.086	-0.032	0.011	-0.104	0.091	-0.038
Real Income of Family:							
Less Than $20,000	-0.527	-0.495	-0.419	-0.555	-0.653	-0.679	-0.541
Between $20,000 and $29,999	-0.242	-0.262	-0.244	-0.209	-0.180	-0.231	-0.231
Between $30,000 and $39,999	-0.212	-0.210	-0.198	-0.168	-0.218	-0.251	-0.209
Between $40,000 and $49,999	0.147	0.043	0.041	-0.038	-0.014	0.036	0.042
Between $50,000 and $59,999	0.154	0.215	0.144	0.103	0.114	0.117	0.140
Between $60,000 and $69,999	0.386	0.329	0.286	0.416	0.487	0.390	0.376
$70,000 or More	0.493	0.805	1.032	0.747	0.515	0.556	0.686
Benefit Status of Family:							
Receiving Benefit	-0.325	-0.253	-0.313	-0.227	-0.176	-0.164	-0.244
Not Receiving Benefit	0.052	0.040	0.063	0.042	0.040	0.032	0.045
Type of School:							
Public School	-0.012	-0.024	-0.037	-0.040	-0.033	-0.045	-0.031
Church or Private School	0.083	0.142	0.217	0.200	0.154	0.196	0.166
Number of Children in Class:							
Less Than 14	-0.492	-1.378	-0.739	-0.204	-0.164	-1.637	-0.578
Between 14 and 19	0.043	0.145	-0.411	-0.332	0.141	-0.097	-0.074
Between 20 and 23	-0.318	-0.046	-0.009	0.249	0.047	0.274	0.018
Between 24 and 27	0.119	-0.134	-0.117	-0.107	-0.084	0.001	-0.044
Between 28 and 31	-0.048	0.032	0.008	0.073	-0.055	-0.032	-0.007
Between 32 and 37	0.063	0.104	0.069	-0.044	0.144	0.027	0.058
Greater Than 38	0.791	-0.497	0.475	0.123	-0.347	0.137	0.098

Notes: Scores on the Burt Word Reading Tests are standardised for the purposes of this table to have zero means and unit variances in each annual sample.

Figure 1

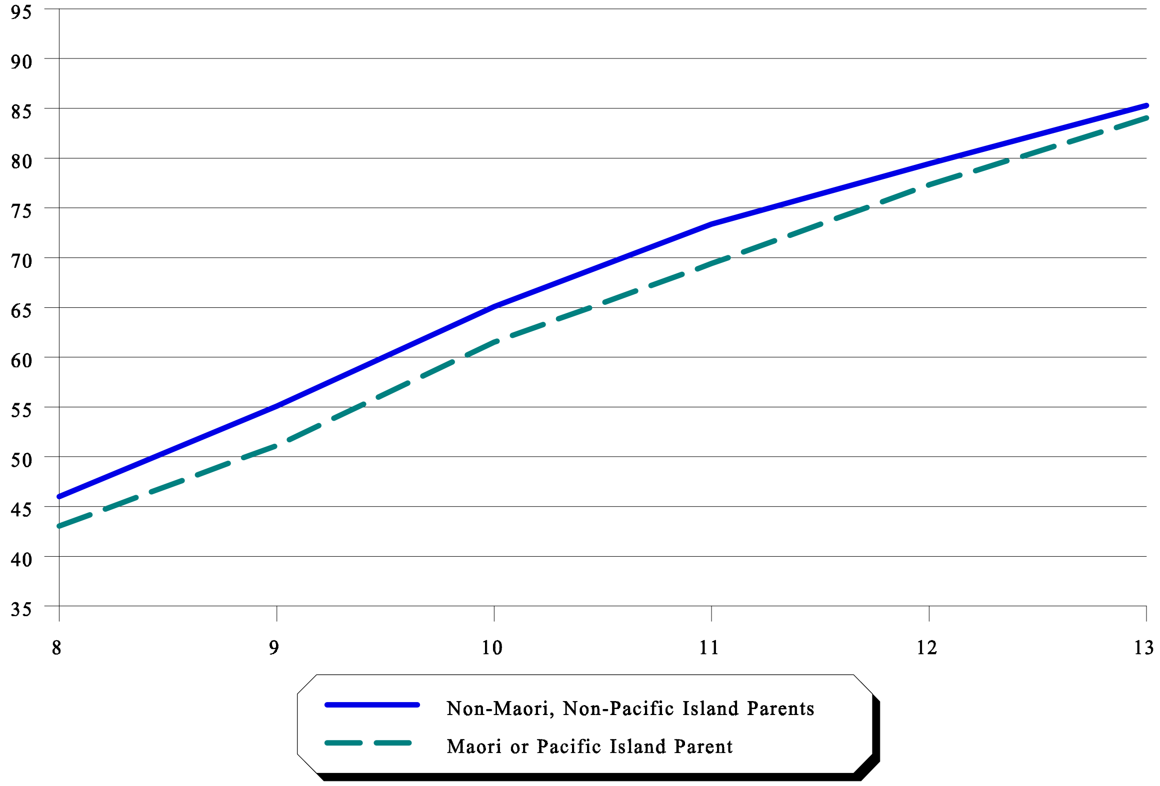


Notes: These plots are based on mean Burt Word Reading Test scores for girls (n=313) and boys (n=292) who were observed in all six periods. This latter restriction mitigates the effects that attrition may have on these trajectories.

Figure 2

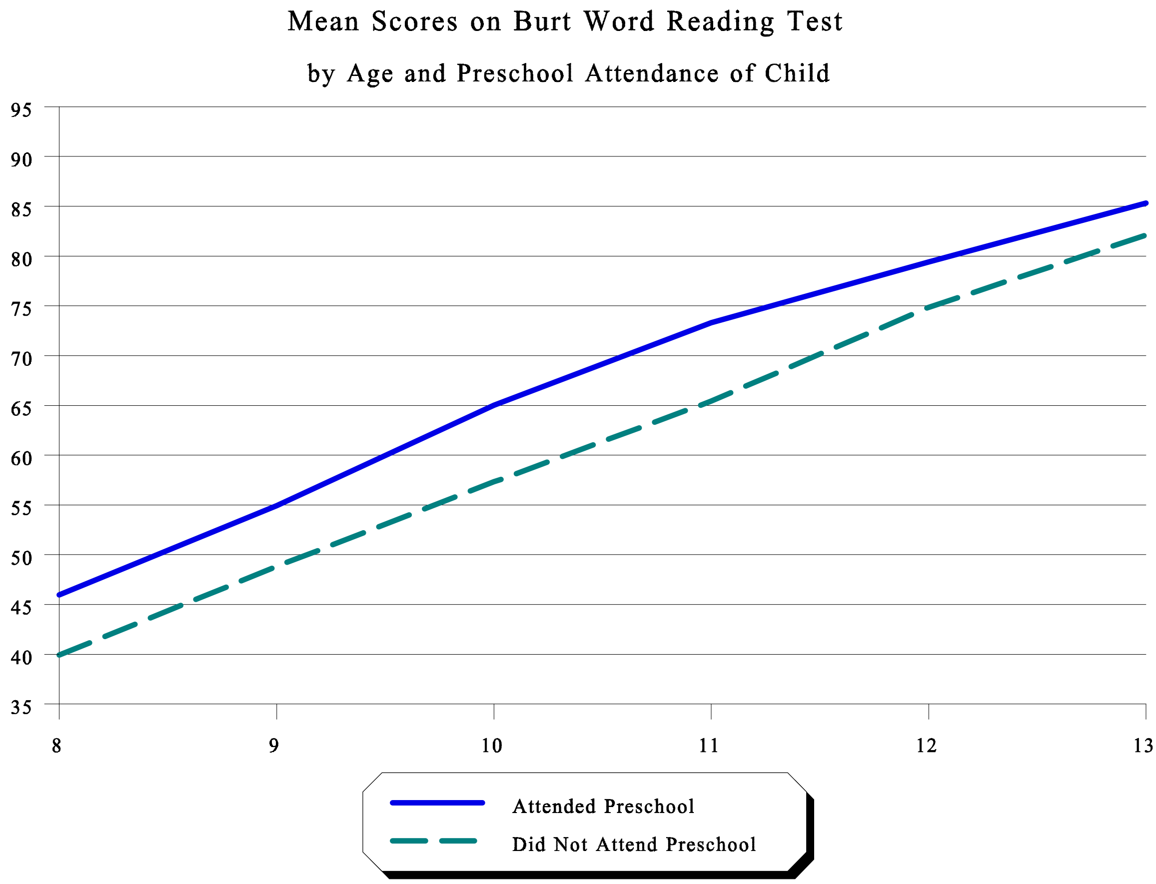
Mean Scores on Burt Word Reading Test

by Age of Child and Ethnicity of Parents



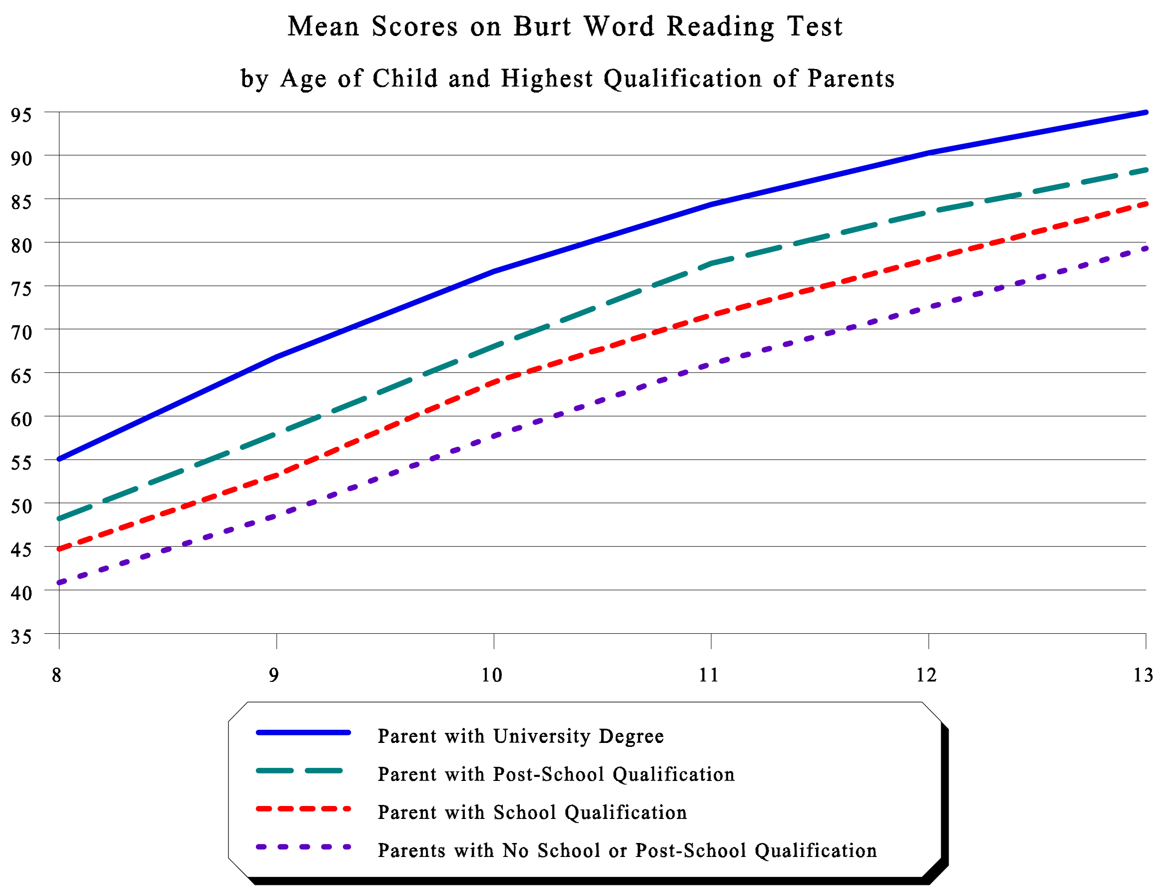
Notes: These plots are based on mean Burt Word Reading Test scores for children with at least one parent who was Maori or a Pacific Islander (n=63) and all other children (n=542) who were observed in all six periods. This latter restriction mitigates the effects that attrition may have on these trajectories.

Figure 3



Notes: These plots are based on mean Burt Word Reading Test scores for children who attended some preschool (n=578) and those that did not attend preschool (n=27) who were observed in all six periods. This latter restriction mitigates the effects that attrition may have on these trajectories.

Figure 4



Notes: These plots are based on mean Burt Word Reading Test scores for children with parents whose highest educational qualification was a university degree (n=74), another type of post-school qualification (n=134), a school qualification (n=230) or no school or post-school qualification (n=167). This sample is restricted to children who were observed in all six periods. This restriction mitigates the effects that attrition may have on these trajectories.

Table 4

Estimated Determinants of Burt Word Reading Test Scores: Ages 10 to 13
Restricted Value-Added Regressions

Independent Variables	OLS Estimation		IV Estimation for Lagged Test Score		IV and WLS Estimation for Attrition	
	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies
Constant	10.085*** (1.172)	10.745*** (1.159)	10.030*** (1.173)	10.638*** (1.159)	10.269*** (1.165)	10.936*** (1.151)
Age 11	—	-1.295*** (0.327)	—	-1.378*** (0.328)	—	-1.427*** (0.326)
Age 12	—	-2.772*** (0.346)	—	-2.920*** (0.349)	—	-2.897*** (0.346)
Age 13	—	-2.763*** (0.368)	—	-2.961*** (0.373)	—	-2.937*** (0.369)
Female	-0.133 (0.239)	-0.228 (0.236)	-0.142 (0.239)	-0.259 (0.236)	-0.141 (0.239)	-0.248 (0.235)
Parents Maori or Pacific Islander	0.520* (0.311)	0.416 (0.307)	0.516* (0.311)	0.398 (0.307)	0.461 (0.313)	0.320 (0.309)
Parents have School Qualification	0.429** (0.187)	0.325* (0.184)	0.421** (0.187)	0.297* (0.185)	0.474** (0.186)	0.353** (0.183)
Parents have Post-School Qualification	0.451** (0.241)	0.253 (0.239)	0.438** (0.242)	0.205 (0.239)	0.438** (0.240)	0.198 (0.237)
Parents have University Degree	0.497* (0.319)	0.164 (0.317)	0.478* (0.320)	0.088 (0.318)	0.501* (0.319)	0.132 (0.317)
Years of Preschool Education	-0.125 (0.163)	-0.130 (0.160)	-0.126 (0.163)	-0.134 (0.160)	-0.154 (0.162)	-0.161 (0.159)
Mother’s Emotional Responsiveness Score	0.159* (0.093)	0.096 (0.092)	0.154* (0.093)	0.078 (0.092)	0.158* (0.093)	0.083 (0.092)
Number of Siblings	-0.130 (0.122)	-0.009 (0.121)	-0.127 (0.122)	0.006 (0.121)	-0.127 (0.120)	0.002 (0.119)
Two-Parent Family	0.058 (0.454)	-0.046 (0.447)	0.054 (0.454)	-0.062 (0.448)	0.066 (0.447)	-0.014 (0.441)
Mother Part-Time Work	0.466* (0.271)	0.536** (0.267)	0.465* (0.271)	0.538** (0.267)	0.457* (0.270)	0.526** (0.266)
Mother Full-Time Work	0.058 (0.376)	0.263 (0.371)	0.058 (0.376)	0.278 (0.372)	0.108 (0.376)	0.327 (0.372)
Family on Benefit	0.251 (0.434)	0.407 (0.429)	0.243 (0.434)	0.395 (0.428)	0.305 (0.429)	0.493 (0.423)
Gross Family Income	-0.005 (0.072)	0.025 (0.071)	-0.008 (0.072)	0.019 (0.071)	-0.013 (0.072)	0.011 (0.072)
Church or Private School	0.506* (0.341)	0.464 (0.336)	0.500* (0.341)	0.442 (0.336)	0.477 (0.340)	0.433 (0.335)
Class Size	0.046** (0.024)	0.034* (0.024)	0.046** (0.024)	0.032 (0.024)	0.036* (0.024)	0.023 (0.024)
Lagged Burt Word Reading Test Score	0.919*** (0.006)	0.945*** (0.007)	0.921*** (0.006)	0.953*** (0.007)	0.921*** (0.006)	0.952*** (0.007)

N	2,584	2,584	2,584	2,584	2,584	2,584
R^2	0.920	0.922	0.920	0.922	0.920	0.923

Table 4 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw score on the Burt Word Reading Test. Data from ages 10 through 13 are pooled in this estimation. The test score lagged two years is used as the instrument in the regression results reported in the last four columns. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Table 5

Summary of Regression Result on Burt Word Reading Test Scores: Ages 10 to 13
Restricted and Unrestricted Value-Added Regressions

	Restricted IV Estimation		Unrestricted IV Estimation	
	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies
Lagged Burt Word Reading Test Score	0.921*** (0.006)	0.953*** (0.007)	0.921*** (0.006)	0.953*** (0.007)
N	2,584	2,584	2,584	2,584
k	17	20	260	263
Adjusted R^2	0.919	0.922	0.922	0.922
R^2	0.920	0.922	0.930	0.930
F Statistic: Null Hypothesis on Validity of Both Restrictions	—	—	1.153	1.078

Notes: Standard errors are in parentheses. The dependent variable is the raw score on the Burt Word Reading Test. Data from ages 10 through 13 are pooled in this estimation. The test score lagged two years is used as the instrument in the IV regressions. Standard errors are corrected for this IV procedure. The unrestricted regressions include all earlier values of time-varying covariates.

Table 6

Estimated Determinants of Burt Word Reading Test Scores: Ages 10 to 13

Restricted Value-Added Regressions Including "Anti-Instruments" for Class Size

	OLS Estimation		IV Estimation for Lagged Test Score		IV and WLS Estimation for Attrition	
Independent Variables	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies
Constant	11.400*** (0.960)	11.724*** (0.952)	11.335*** (0.962)	11.550*** (0.954)	11.295*** (0.958)	11.572*** (0.950)
Age 11	—	-1.283*** (0.327)	—	-1.367*** (0.328)	—	-1.419*** (0.326)
Age 12	—	-2.780*** (0.346)	—	-2.928*** (0.349)	—	-2.902*** (0.346)
Age 13	—	-2.805*** (0.367)	—	-3.001*** (0.371)	—	-2.966*** (0.367)
Female	-0.125 (0.239)	-0.225 (0.236)	-0.134 (0.239)	-0.256 (0.236)	-0.134 (0.239)	-0.246 (0.235)
Parents Maori or Pacific Islander	0.525* (0.312)	0.417 (0.307)	0.521* (0.312)	0.399 (0.307)	0.466 (0.313)	0.321 (0.309)
Parents have School Qualification	0.423** (0.187)	0.322* (0.184)	0.415** (0.187)	0.295* (0.185)	0.466** (0.186)	0.351** (0.183)
Parents have Post-School Qualification	0.453** (0.241)	0.253 (0.239)	0.440** (0.242)	0.205 (0.239)	0.438** (0.240)	0.197 (0.237)
Parents have University Degree	0.497* (0.319)	0.163 (0.317)	0.477* (0.320)	0.087 (0.318)	0.499* (0.319)	0.131 (0.317)
Years of Preschool Education	-0.127 (0.163)	-0.130 (0.160)	-0.128 (0.163)	-0.134 (0.160)	-0.155 (0.162)	-0.161 (0.159)
Mother's Emotional Responsiveness Score	0.161* (0.093)	0.097 (0.092)	0.156* (0.093)	0.078 (0.092)	0.160* (0.093)	0.083 (0.092)
Number of Siblings	-0.136 (0.122)	-0.010 (0.121)	-0.133 (0.122)	0.005 (0.121)	-0.133 (0.120)	0.001 (0.119)
Two-Parent Family	0.079 (0.454)	-0.040 (0.447)	0.076 (0.454)	-0.058 (0.448)	0.084 (0.447)	-0.010 (0.441)
Mother Part-Time Work	0.470* (0.271)	0.538** (0.267)	0.469* (0.271)	0.539** (0.267)	0.461* (0.270)	0.527** (0.266)
Mother Full-Time Work	0.057 (0.376)	0.263 (0.372)	0.057 (0.376)	0.278 (0.372)	0.108 (0.376)	0.327 (0.372)
Family on Benefit	0.263 (0.434)	0.411 (0.428)	0.255 (0.434)	0.398 (0.428)	0.317 (0.429)	0.495 (0.424)
Gross Family Income	-0.006 (0.072)	0.025 (0.071)	-0.008 (0.072)	0.019 (0.071)	-0.013 (0.072)	0.011 (0.072)
Church or Private School	0.437 (0.341)	0.443 (0.336)	0.431 (0.341)	0.426 (0.336)	0.413 (0.340)	0.420 (0.335)
Class Size Residuals	0.028 (0.024)	0.029 (0.024)	0.028 (0.024)	0.028 (0.024)	0.019 (0.024)	0.019 (0.024)
Lagged Burt Word	0.919***	0.946***	0.921***	0.954***	0.922***	0.953***

Reading Test Score	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)
N	2,584	2,584	2,584	2,584	2,584	2,584
R^2	0.920	0.922	0.920	0.922	0.920	0.923

Table 6 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw score on the Burt Word Reading Test. Data from ages 10 through 13 are pooled in this estimation. The test score lagged two years is used as the instrument in the regression results reported in the last four columns. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A. The variable class size is replaced by the residuals from a regression of class size on all lagged values of Burt Word Reading Test Scores and grade point averages.

Table 7

Estimated Determinants of Burt Word Reading Test Scores: Ages 11 to 13

Restricted Value-Added Regressions

Independent Variables	Level Specification			First Differences		
	OLS Estimation	IV Estimation	IV & WLS Estimation	OLS Estimation	IV Estimation	IV & WLS Estimation
Constant	12.096*** (1.289)	12.186*** (1.293)	12.065*** (1.284)	—	—	—
Age 12	-1.277*** (0.316)	-1.248*** (0.317)	-1.291*** (0.315)	2.357** (1.008)	-1.123 (1.189)	-0.852 (1.169)
Age 13	-1.123*** (0.333)	-1.072*** (0.337)	-1.198*** (0.333)	3.767*** (0.307)	0.740** (0.384)	0.745** (0.382)
Female	0.102 (0.261)	0.115 (0.262)	0.083 (0.261)	—	—	—
Parents Maori or Pacific Islander	0.562* (0.345)	0.572* (0.345)	0.478 (0.348)	—	—	—
Parents School Qualification	0.290 (0.205)	0.303* (0.205)	0.310* (0.204)	—	—	—
Parents Post-School Qualification	0.364 (0.263)	0.385* (0.264)	0.291 (0.262)	—	—	—
Parents University Degree	0.196 (0.348)	0.230 (0.350)	0.175 (0.348)	—	—	—
Years of Preschool Education	-0.153 (0.177)	-0.151 (0.177)	-0.182 (0.176)	—	—	—
Mother’s Emotional Responsiveness Score	0.076 (0.102)	0.084 (0.102)	0.058 (0.102)	—	—	—
Number of Siblings	-0.059 (0.132)	-0.066 (0.132)	-0.051 (0.130)	—	—	—
Two-Parent Family	-0.311 (0.487)	-0.302 (0.487)	-0.216 (0.481)	-0.075 (0.640)	-0.337 (0.748)	-0.375 (0.731)
Mother Part-Time Work	0.373 (0.300)	0.370 (0.300)	0.381 (0.298)	0.423 (0.318)	0.234 (0.372)	0.269 (0.368)
Mother Full-Time Work	0.147 (0.406)	0.138 (0.406)	0.229 (0.407)	1.141** (0.483)	0.724 (0.565)	0.861 (0.566)
Family on Benefit	0.475 (0.460)	0.482 (0.460)	0.591 (0.455)	0.942** (0.520)	0.478 (0.608)	0.627 (0.598)
Gross Family Income	0.091 (0.077)	0.094 (0.077)	0.076 (0.077)	-0.139** (0.084)	-0.047 (0.099)	-0.047 (0.099)
Church or Private School	0.089 (0.368)	0.098 (0.368)	0.060 (0.366)	-0.112 (0.549)	-0.416 (0.641)	-0.355 (0.640)
Class Size	0.010 (0.026)	0.010 (0.026)	-0.003 (0.026)	0.053** (0.026)	0.032 (0.031)	0.026 (0.030)
Lagged Burt Word Reading Test Score	0.918*** (0.007)	0.915*** (0.008)	0.927*** (0.007)	0.331*** (0.019)	0.823*** (0.031)	0.818*** (0.031)
N	1,893	1,893	1,893	1,893	1,893	1,893
R^2	0.922	0.922	0.922	—	—	—

Table 7 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw test score on the Burt Word Reading Test. Data from ages 10 through 13 are pooled in this estimation. The test score lagged two years is used as the instrument in some of these regression results. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Table 8

Estimated Determinants of Burt Word Reading Test Scores: Ages 8 to 13
Restricted Level Regressions

Independent Variables	OLS Estimation		WLS Estimation for Attrition	
	w/o Age Dummies	w/ Age Dummies	w/o Age Dummies	w/ Age Dummies
Constant	4.846 (3.956)	4.290 (3.143)	4.019 (3.945)	3.397 (3.159)
Age 9	—	8.318*** (0.884)	—	8.524*** (0.889)
Age 10	—	18.209*** (0.897)	—	18.321*** (0.902)
Age 11	—	26.907*** (0.916)	—	26.727*** (0.921)
Age 12	—	33.390*** (0.933)	—	32.901*** (0.938)
Age 13	—	39.253*** (0.949)	—	38.817*** (0.953)
Female	3.746*** (0.692)	3.556*** (0.546)	3.681*** (0.691)	3.440*** (0.550)
Parents Maori or Pacific Islander	0.953 (0.895)	1.957*** (0.707)	1.334* (0.899)	2.369*** (0.715)
Parents have School Qualification	3.452*** (0.543)	3.046*** (0.428)	3.634*** (0.541)	3.169*** (0.430)
Parents have Post-School Qualification	4.381*** (0.704)	5.268*** (0.556)	4.851*** (0.699)	5.664*** (0.556)
Parents have University Degree	7.323*** (0.930)	8.764*** (0.735)	7.529*** (0.931)	8.788*** (0.741)
Years of Preschool Education	-0.132 (0.475)	0.098 (0.375)	-0.110 (0.473)	0.114 (0.377)
Mother's Emotional Responsiveness Score	2.121*** (0.268)	2.206*** (0.212)	2.258*** (0.268)	2.311*** (0.213)
Number of Siblings	-0.447 (0.360)	-1.905*** (0.286)	-0.411 (0.358)	-1.842*** (0.286)
Two-Parent Family	-5.218** (2.184)	0.269 (1.727)	-5.427** (2.165)	-0.181 (1.725)
Mother Part-Time Work	5.242*** (1.151)	0.610 (0.913)	5.362*** (1.149)	0.775 (0.919)
Mother Full-Time Work	3.243* (1.970)	-6.952*** (1.569)	3.397* (1.963)	-6.634*** (1.575)
Family on Benefit	2.372 (2.135)	-0.349 (1.687)	1.784 (2.128)	-0.891 (1.694)
Gross Family Income	2.735*** (0.333)	1.356*** (0.265)	2.588*** (0.334)	1.325*** (0.267)
Church or Private School	6.180*** (1.108)	3.270*** (0.877)	6.045*** (1.106)	3.126*** (0.882)

Class Size	0.908***	0.436***	0.916***	0.449***
	(0.078)	(0.063)	(0.078)	(0.063)
N	4,104	4,104	4,104	4,104
R^2	0.150	0.471	0.153	0.465

Table 8 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw test score on the Burt Word Reading Test. Data from ages 8 through 13 are pooled in this estimation. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Table 9

Estimated Determinants of Burt Word Reading Test Scores

Restricted Regressions: Gender Interactions

	Value-Added Specification		Level Specification	
Independent Variables	IV Estimation	IV & WLS Estimation	OLS Estimation	WLS Estimation
Constant	10.500*** (1.395)	10.647*** (1.396)	-1.483 (3.815)	-2.559 (3.837)
Age 9	—	—	8.351*** (0.880)	8.558*** (0.886)
Age 10	—	—	18.277*** (0.893)	18.390*** (0.899)
Age 11	-1.374*** (0.327)	-1.422*** (0.326)	26.937*** (0.913)	26.764*** (0.919)
Age 12	-2.908*** (0.348)	-2.884*** (0.346)	33.418*** (0.930)	32.936*** (0.936)
Age 13	-2.948*** (0.372)	-2.921*** (0.369)	39.342*** (0.946)	38.916*** (0.951)
Female	0.246 (1.664)	0.586 (1.651)	20.524*** (5.165)	20.254*** (5.156)
Parents Maori or Pacific Islander	0.382 (0.307)	0.306 (0.309)	1.567** (0.710)	1.988*** (0.718)
Parents School Qualification	0.282* (0.184)	0.336** (0.184)	2.922*** (0.428)	3.049*** (0.430)
Parents Post-School Qualification	0.226 (0.239)	0.229 (0.238)	5.396*** (0.556)	5.818*** (0.556)
Parents have University Degree	0.093 (0.317)	0.135 (0.317)	8.941*** (0.733)	8.941*** (0.739)
Years of Preschool Education	-0.122 (0.160)	-0.149 (0.160)	0.066 (0.376)	0.089 (0.378)
Mother's Emotional Responsiveness Score	0.077 (0.092)	0.082 (0.092)	2.180*** (0.212)	2.286*** (0.213)
Number of Siblings	0.016 (0.122)	0.014 (0.121)	-1.821*** (0.288)	-1.769*** (0.288)
Two-Parent Family	0.479 (0.599)	0.660 (0.594)	8.621*** (2.260)	7.981*** (2.272)
Two-Parent Family ·Female	-1.195 (0.884)	-1.481* (0.873)	-20.162*** (3.462)	-19.348*** (3.454)
Mother Part-Time Work	0.573* (0.390)	0.548 (0.391)	0.842 (1.291)	1.041 (1.300)
Mother Part-Time Work · Female	-0.129 (0.531)	-0.109 (0.531)	-0.546 (1.799)	-0.592 (1.809)
Mother Full-Time Work	0.194 (0.510)	0.277 (0.513)	-6.674*** (2.013)	-6.077*** (2.021)
Mother Full-Time Work · Female	0.170 (0.738)	0.098 (0.741)	0.504 (3.116)	-0.349 (3.131)
	0.342	0.488	6.204***	5.723**

Family on Benefit	(0.585)	(0.583)	(2.216)	(2.239)
Family on Benefit · Female	0.009 (0.844)	-0.109 (0.838)	-16.329*** (3.357)	-16.008*** (3.363)
Gross Family Income	0.014 (0.094)	0.004 (0.095)	1.293*** (0.349)	1.310*** (0.353)
Gross Family Income · Female	0.014 (0.130)	0.016 (0.131)	-0.010 (0.472)	-0.010 (0.478)
Church or Private School	0.126 (0.451)	0.096 (0.451)	2.404** (1.190)	2.305** (1.199)
Church or Private School · Female	0.708 (0.669)	0.743 (0.668)	2.010 (1.749)	1.881 (1.758)
Class Size	0.025 (0.033)	0.017 (0.033)	0.367*** (0.087)	0.384*** (0.087)
Class Size · Female	0.013 (0.047)	0.010 (0.047)	0.098 (0.124)	0.094 (0.124)
Lagged Burt Word Reading Test Score	0.952*** (0.007)	0.951*** (0.007)	—	—
N	2,584	2,584	4,104	4,104
R^2	0.922	0.923	0.476	0.469

Table 9 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw test score on the Burt Word Reading Test. The test score lagged two years is used as an instrument in the regression results reported in the first two columns. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Table 10

Estimated Determinants of Burt Word Reading Test Scores
Restricted Regressions: Ethnicity Interactions

Independent Variables	Value-Added Specification: IV Estimation	Value-Added Specification: IV & WLS Estimation	Level Specification: OLS Estimation	Level Specification: WLS Estimation
Constant	10.317*** (1.187)	10.587*** (1.184)	3.941 (3.220)	3.050 (3.232)
Age 9	—	—	8.304*** (0.880)	8.511*** (0.885)
Age 10	—	—	18.222*** (0.893)	18.343*** (0.898)
Age 11	-1.406*** (0.326)	-1.455*** (0.326)	26.849*** (0.912)	26.689*** (0.917)
Age 12	-2.923*** (0.347)	-2.901*** (0.345)	33.281*** (0.930)	32.812*** (0.935)
Age 13	-2.974*** (0.371)	-2.948*** (0.368)	39.103*** (0.945)	38.680*** (0.950)
Female	-0.241 (0.235)	-0.229 (0.235)	3.694*** (0.547)	3.591*** (0.550)
Parents Maori or Pacific Islander	3.016 (2.412)	3.100 (2.444)	6.849 (7.826)	8.730 (7.989)
Parents School Qualification	0.295* (0.184)	0.348** (0.184)	3.238*** (0.429)	3.382*** (0.431)
Parents Post-School Qualification	0.184 (0.239)	0.176 (0.238)	5.190*** (0.555)	5.616*** (0.556)
Parents University Degree	0.017 (0.317)	0.060 (0.318)	8.437*** (0.737)	8.501*** (0.743)
Years of Preschool Education	-0.108 (0.160)	-0.133 (0.161)	0.062 (0.376)	0.060 (0.378)
Mother’s Emotional Responsiveness Score	0.087 (0.092)	0.092 (0.092)	2.207*** (0.212)	2.292*** (0.213)
Number of Siblings	0.012 (0.120)	0.009 (0.119)	-1.827*** (0.286)	-1.771*** (0.286)
Two-Parent Family	-0.045 (0.475)	-0.002 (0.469)	-0.330 (1.815)	-0.628 (1.810)
Two-Parent Family · Parents Maori or Pacific Islander	-0.122 (1.055)	-0.079 (1.074)	1.514 (4.631)	0.904 (4.695)
Mother Part-Time Work	0.437* (0.279)	0.447* (0.279)	-0.013 (0.946)	0.041 (0.952)
Mother Part-Time Work · Parents Maori or Pacific Islander	1.233* (0.766)	1.022 (0.767)	11.537*** (2.926)	12.321*** (2.949)
Mother Full-Time Work	0.117 (0.391)	0.173 (0.392)	-6.041*** (1.671)	-5.478*** (1.672)
Mother Full-Time Work · Parents Maori or Pacific Islander	1.953** (0.904)	1.879** (0.923)	5.287 (3.961)	3.369 (4.032)
	0.292	0.382	-0.997	-1.395

Family on Benefit	(0.452)	(0.449)	(1.775)	(1.779)
Family on Benefit · Parents Maori or Pacific Islander	0.097 (0.995)	0.127 (1.017)	0.236 (4.331)	-0.361 (4.407)
Gross Family Income	0.056 (0.073)	0.048 (0.074)	1.678*** (0.273)	1.654*** (0.276)
Gross Family Income · Parents Maori or Pacific Islander	-0.574** (0.232)	-0.555** (0.233)	-4.966*** (0.834)	-4.918*** (0.845)
Church or Private School	0.346 (0.347)	0.338 (0.349)	2.997*** (0.904)	2.852*** (0.910)
Church or Private School · Parents Maori or Pacific Islander	1.034 (1.032)	0.979 (1.021)	6.395** (2.647)	6.553** (2.639)
Class Size	0.037* (0.024)	0.028 (0.024)	0.421*** (0.065)	0.435*** (0.065)
Class Size · Parents Maori or Pacific Islander	-0.042 (0.073)	-0.048 (0.073)	0.246 (0.174)	0.212 (0.177)
Lagged Burt Word Reading Test Score	0.953*** (0.007)	0.952*** (0.007)	—	—
N	2,584	2,584	4,104	4,104
R^2	0.922	0.923	0.477	0.471

Table 10 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw test score on the Burt Word Reading Test. The test score lagged two years is used as an instrument in the regression results reported in the first two columns. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Table 11

Estimated Determinants of Burt Word Reading Test Scores
Restricted Regressions: Parents Educational Interactions

	Value-Added Specification		Level Specification	
Independent Variables	IV Estimation	IV & WLS Estimation	OLS Estimation	WLS Estimation
Constant	8.378*** (1.622)	8.422*** (1.621)	-2.430 (3.945)	-3.345 (4.556)
Age 9	—	—	8.392*** (0.871)	8.585*** (0.877)
Age 10	—	—	18.407*** (0.884)	18.510*** (0.890)
Age 11	-1.377*** (0.326)	-1.430*** (0.326)	27.081*** (0.904)	26.892*** (0.910)
Age 12	-2.942*** (0.348)	-2.929*** (0.346)	33.589*** (0.921)	33.079*** (0.927)
Age 13	-2.983*** (0.371)	-2.971*** (0.369)	39.484*** (0.937)	39.019*** (0.942)
Female	-0.251 (0.237)	-0.242 (0.236)	3.409*** (0.545)	3.272*** (0.549)
Parents Maori or Pacific Islander	0.345 (0.307)	0.264 (0.309)	1.679** (0.703)	2.133** (0.711)
Parents School Qualification	2.124* (1.276)	2.642** (1.248)	12.981*** (4.135)	12.763*** (4.114)
Parents Post-School Qualification	0.770 (1.638)	0.585 (1.616)	9.417* (5.449)	9.031* (5.395)
Parents University Degree	5.365*** (2.025)	5.368*** (2.044)	-12.203** (6.125)	-11.075* (6.217)
Years of Preschool Education	-0.132 (0.161)	-0.165 (0.161)	0.080 (0.375)	0.090 (0.378)
Mother's Emotional Responsiveness Score	0.077 (0.092)	0.082 (0.092)	2.245*** (0.212)	2.343*** (0.213)
Number of Siblings	0.018 (0.121)	-0.024 (0.120)	-1.799*** (0.285)	-1.742*** (0.286)
Two-Parent Family	0.142 (0.687)	0.170 (0.683)	-5.493** (2.576)	-6.133** (2.571)
Two-Parent Family · Parents School Qualification	-0.195 (0.708)	-0.252 (0.694)	3.651 (2.770)	3.945 (2.769)
Two-Parent Family · Parents Post-School Qualification	0.050 (0.970)	0.203 (0.914)	6.438* (4.211)	7.478** (4.106)
Two-Parent Family · Parents University Degree	-1.041 (1.196)	-1.182 (1.197)	26.657*** (4.756)	26.858*** (4.826)
Mother Part-Time Work	0.852** (0.455)	0.783* (0.454)	1.563 (1.661)	1.647 (1.665)
Mother Part-Time Work · Parents School Qualification	-0.620* (0.396)	-0.600* (0.395)	-1.909 (1.365)	-1.633 (1.373)
Mother Part-Time Work ·	0.213	0.392	2.809*	2.742*

Parents Post-School Qualification	(0.534)	(0.531)	(1.770)	(1.779)
Mother Part-Time Work ·	0.381	0.391	-2.064	-2.359
Parents University Degree	(0.632)	(0.633)	(2.065)	(2.079)
	1.095*	1.121*	-6.229**	-7.269***
Mother Full-Time Work	(0.624)	(0.630)	(2.529)	(2.548)
Mother Full-Time Work ·	-0.728	-0.694	2.475	3.077
Parents School Qualification	(0.577)	(0.580)	(2.708)	(2.724)
Mother Full-Time Work ·	-0.545	-0.414	-3.430	0.110
Parents Post-School Qualification	(0.723)	(0.726)	(3.235)	(3.200)
Mother Full-Time Work ·	-0.895	-0.912	5.427	5.402
Parents University Degree	(0.897)	(0.894)	(4.079)	(4.096)
	0.391	0.460	-2.327	-2.802
Family on Benefit	(0.630)	(0.630)	(2.427)	(2.436)
Family on Benefit ·	0.188	0.100	2.156	2.192
Parents School Qualification	(0.675)	(0.664)	(2.718)	(2.726)
Family on Benefit ·	-0.358	-0.142	-1.574	-1.104
Parents Post-School Qualification	(1.039)	(0.993)	(4.537)	(4.536)
Family on Benefit ·	0.265	0.532	-13.143**	-13.531***
Parents University Degree	(1.522)	(1.493)	(5.069)	(5.115)
	-0.091	-0.101	1.572***	1.704***
Gross Family Income	(0.140)	(0.141)	(0.501)	(0.506)
Gross Family Income ·	0.101	0.095	-0.015	-0.164
Parents School Qualification	(0.110)	(0.111)	(0.406)	(0.412)
Gross Family Income ·	0.158	0.165	-1.611***	-1.728***
Parents Post-School Qualification	(0.123)	(0.125)	(0.500)	(0.507)
Gross Family Income ·	-0.106	-0.096	0.454	0.366
Parents University Degree	(0.149)	(0.149)	(0.561)	(0.567)
	-0.111	-0.114	8.561***	8.054***
Church or Private School	(0.653)	(0.650)	(1.719)	(1.724)
Church or Private School ·	0.616	0.570	-2.014*	-1.624
Parents School Qualification	(0.522)	(0.519)	(1.341)	(1.344)
Church or Private School ·	0.275	0.302	-6.356***	-6.251***
Parents Post-School Qualification	(0.613)	(0.614)	(1.551)	(1.562)
Church or Private School ·	-0.456	-0.394	-8.179***	-7.994***
Parents University Degree	(0.715)	(0.718)	(1.877)	(1.892)
	0.110***	0.110***	0.763***	0.770***
Class Size	(0.042)	(0.042)	(0.106)	(0.106)
Class Size ·	-0.062*	-0.075**	-0.432***	-0.415***
Parents School Qualification	(0.036)	(0.036)	(0.094)	(0.094)
Class Size ·	-0.051	-0.055	-0.071	-0.069
Parents Post-School Qualification	(0.044)	(0.045)	(0.126)	(0.127)
Class Size ·	-0.116**	-0.113**	-0.159	-0.187
Parents University Degree	(0.053)	(0.054)	(0.148)	(0.151)
Lagged Burt Word Reading Test	0.955***	0.954***		
Score	(0.007)	(0.007)	—	—
N	2,584	2,584	4,104	4,104
R^2	0.923	0.923	0.489	0.482

Table 11 Continued

Table 11 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable is the raw test score on the Burt Word Reading Test. The test score lagged two years is used as an instrument in the regression results reported in the first two columns. Standard errors are corrected for this IV procedure. Estimated weighting variables for attrition come from the maximum likelihood probit results reported in the tables in Appendix A.

Appendix A
Table A1

Estimated Determinants of Incremental Attrition: Ages 8 to 13
Maximum Likelihood Probit Estimation without "Auxiliary Endogenous" Variables

Independent Variables	Age of Children					
	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
Constant	-1.822*** (0.496)	-1.975*** (0.635)	-0.936 (0.856)	-1.830** (0.848)	0.106 (0.831)	-1.814** (0.944)
Female	-0.050 (0.093)	-0.252** (0.129)	0.121 (0.179)	0.038 (0.172)	-0.163 (0.191)	-0.276 (0.200)
Parents Maori or Pacific Islander	0.450*** (0.106)	0.153 (0.162)	0.104 (0.204)	0.444** (0.174)	-0.017 (0.239)	0.109 (0.221)
Parents have School Qualification	-0.020 (0.074)	0.079 (0.101)	-0.024 (0.147)	-0.040 (0.130)	0.295** (0.145)	-0.073 (0.148)
Parents have Post-School Qualification	0.074 (0.088)	0.233** (0.120)	0.093 (0.178)	-0.150 (0.200)	-0.109 (0.223)	-0.194 (0.226)
Parents have University Degree	-0.023 (0.115)	0.162 (0.156)	0.260 (0.223)	-0.109 (0.267)	0.179 (0.262)	-0.399 (0.391)
Years of Preschool Education	-0.069 (0.061)	0.187** (0.090)	-0.018 (0.126)	0.141 (0.120)	-0.142 (0.124)	0.056 (0.125)
Mother's Emotional Responsiveness Score	0.233*** (0.043)	0.101** (0.053)	-0.064 (0.068)	0.014 (0.064)	-0.108* (0.072)	0.004 (0.073)
Number of Siblings	-0.052 (0.051)	0.130** (0.066)	0.011 (0.096)	-0.163* (0.102)	-0.084 (0.097)	-0.052 (0.099)
Two-Parent Family	-0.152 (0.215)	0.666** (0.302)	-0.262 (0.325)	0.214 (0.341)	0.567* (0.389)	0.705** (0.348)
Mother Part-Time Work	-0.098 (0.104)	-0.010 (0.143)	-0.086 (0.200)	0.108 (0.206)	0.291 (0.238)	-0.252 (0.223)
Mother Full-Time Work	-0.147 (0.181)	0.330* (0.212)	-0.027 (0.287)	-0.079 (0.300)	0.533* (0.304)	-0.327 (0.318)
Family on Benefit	-0.463** (0.209)	0.288 (0.255)	-0.328 (0.360)	0.437 (0.305)	0.494* (0.335)	0.572** (0.270)
Gross Family Income	0.056* (0.039)	-0.095* (0.055)	-0.012 (0.060)	0.002 (0.070)	-0.056 (0.050)	-0.015 (0.058)
Church or Private School	-0.270** (0.150)	-0.807*** (0.247)	0.034 (0.264)	-0.229 (0.296)	-0.071 (0.263)	-0.013 (0.285)
Class Size	-0.029*** (0.007)	-0.034*** (0.010)	-0.003 (0.018)	-0.012 (0.017)	-0.043*** (0.016)	-0.010 (0.021)
N	1,015	802	718	691	658	630
Dependent Variable Mean	0.210	0.105	0.038	0.048	0.043	0.040
Log Likelihood Function	-484.18	-245.05	-112.79	-124.32	-103.83	-97.01
Pseudo R^2	0.072	0.089	0.020	0.062	0.103	0.078

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable equals one if the family attrited at the indicated age of the child; zero otherwise.

Table A2

Estimated Determinants of Incremental Attrition: Ages 8 to 13

Maximum Likelihood Probit Estimation with "Auxiliary Endogenous" Variables

	Age of Children					
Independent Variables	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13
Constant	-2.248*** (0.523)	-0.834 (0.741)	-0.767 (1.021)	-3.199*** (1.118)	0.049 (1.079)	-1.593* (1.076)
Female	-0.081 (0.096)	-0.206* (0.133)	0.167 (0.186)	0.090 (0.183)	-0.092 (0.202)	-0.237 (0.209)
Parents Maori or Pacific Islander	0.432*** (0.109)	0.178 (0.165)	0.104 (0.206)	0.511*** (0.185)	-0.006 (0.258)	0.090 (0.223)
Parents have School Qualification	-0.013 (0.075)	0.069 (0.104)	-0.021 (0.151)	0.042 (0.138)	0.330** (0.152)	-0.083 (0.154)
Parents have Post-School Qualification	0.096 (0.091)	0.226** (0.124)	0.128 (0.185)	-0.075 (0.211)	-0.058 (0.236)	-0.206 (0.232)
Parents have University Degree	-0.014 (0.118)	0.141 (0.167)	0.383* (0.240)	0.105 (0.292)	0.291 (0.278)	-0.392 (0.407)
Years of Preschool Education	-0.079 (0.062)	0.192** (0.090)	-0.004 (0.129)	0.201* (0.132)	-0.136 (0.128)	0.086 (0.128)
Mother's Emotional Responsiveness Score	0.228*** (0.043)	0.110** (0.055)	-0.044 (0.071)	0.020 (0.069)	-0.091 (0.075)	0.004 (0.075)
Number of Siblings	-0.055 (0.052)	0.145** (0.067)	0.013 (0.096)	-0.185* (0.113)	-0.075 (0.104)	-0.060 (0.101)
Two-Parent Family	-0.132 (0.216)	0.742** (0.307)	-0.302 (0.324)	0.329 (0.363)	0.649* (0.420)	0.715** (0.354)
Mother Part-Time Work	-0.117 (0.105)	-0.002 (0.146)	-0.098 (0.205)	0.209 (0.221)	0.329 (0.258)	-0.220 (0.229)
Mother Full-Time Work	-0.210 (0.186)	0.359* (0.218)	-0.119 (0.297)	-0.050 (0.321)	0.522* (0.328)	-0.301 (0.324)
Family on Benefit	-0.468** (0.210)	0.263 (0.263)	-0.388 (0.362)	0.467 (0.326)	0.629** (0.351)	0.525** (0.275)
Gross Family Income	0.089** (0.042)	-0.146** (0.062)	0.031 (0.067)	0.022 (0.078)	-0.053 (0.060)	-0.002 (0.065)
Church or Private School	-0.293** (0.151)	-0.820*** (0.249)	0.055 (0.269)	-0.238 (0.318)	-0.033 (0.272)	-0.037 (0.292)
Class Size	-0.032*** (0.007)	-0.038*** (0.010)	0.002 (0.019)	-0.006 (0.019)	-0.042*** (0.016)	-0.011 (0.021)
High Living Standards	-0.149* (0.103)	0.169 (0.141)	-0.296 (0.216)	-0.238 (0.279)	-0.014 (0.260)	-0.004 (0.246)
Low Living Standards	-0.010 (0.196)	-0.025 (0.208)	0.095 (0.313)	-0.431 (0.389)	-0.871* (0.496)	0.238 (0.213)
Maternal Depression Score	0.027*** (0.008)	0.007 (0.011)	-0.001 (0.016)	0.053*** (0.013)	0.028** (0.015)	-0.004 (0.016)
Grade Point Average	0.101* (0.060)	-0.335*** (0.107)	-0.191 (0.158)	0.134 (0.154)	-0.129 (0.177)	-0.103 (0.155)
Standardised Burt Word	—	0.254***	0.085	-0.238*	-0.122	0.094

Reading Score		(0.092)	(0.145)	(0.142)	(0.152)	(0.138)
N	1,015	802	718	691	658	630
Dependent Variable Mean	0.210	0.105	0.038	0.048	0.043	0.040
Log Likelihood Function	-476.75	-238.86	-110.81	-114.48	-98.50	-96.09
Pseudo R^2	0.086	0.112	0.037	0.136	0.149	0.086

Table A2 Continued

*** Significant at 1.0% level, two-tailed test.
** Significant at 7.5% level, two-tailed test.
* Significant at 15.0% level, two-tailed test.

Notes: Standard errors are in parentheses. The dependent variable equals one if the family attrited at the indicated age of the child; zero otherwise.

Table A3

Unweighted and Weighted Means of Selected Regressors
All Individual Observations: Ages 8 to 13

Variables	Unweighted	Weighted for Attrition
Female	0.508	0.509
Maori or Pacific Islander	0.113	0.113
School Qualification	0.386	0.388
Post-School Qualification	0.213	0.212
University	0.120	0.120
Two Parents	0.876	0.874
Mother Employed Part-Time	0.393	0.393
Mother Employed Full-Time	0.084	0.084
Real Income of Family	$44,417	$44,290
Family Receiving Benefit	0.134	0.134
Child in Church or Private School	0.138	0.138
Class Size	28.794	28.792
Burt Word Reading Test Score	65.331	65.393

Notes: Estimated weighting variables for attrition come from the maximum likelihood probit results reported in Tables A1 and A2.

Table A4

Mean of Weighting Variable for Selected Subsamples
All Individual Observations: Ages 8 to 13

Females	1.0037
Males	0.9969
Maori or Pacific Islander	1.0001
Other Ethnic Groups	1.0004
School Qualification	1.0044
Post-School Qualification	0.9935
University	0.9994

Notes: Estimated weighting variables for attrition come from the maximum likelihood probit results reported in Tables A1 and A2.

Appendix B

Description of Variables Used in Regression Analysis

Burt Word Reading Test	This test instrument was administered to all children in the CHDS resident in the Canterbury region at ages of 8, 9, 10, 11, 12 and 13. The raw test score is the number of words correctly read from a list of 110 words.
Female	Dummy variable equal to one if the child is female; zero if male.
Parents Maori or Pacific Islander	This variable equals one if either the mother or father was identified as Maori or Pacific Islander; two if both the mother and father were identified as Maori or Pacific Islander; zero otherwise.
Parents have School Qualification	This variable equals one if one parent's highest educational qualification was a "secondary qualification" (i.e., School Certificate, University Entrance, Bursary, etc.); two if this was true for both parents; zero otherwise. This information was solicited at the birth of the child, and again when the child was seven years old.
Parents have Post-School Qualification	This variable equals one if one parent's highest educational qualification was a "tertiary qualification" (i.e., technical diploma, etc.); two if this was true for both parents; zero otherwise. This information was solicited at the birth of the child, and again when the child was seven years old.
Parents have University Degree	This variable equals one if one parent's highest educational qualification was a university degree; two if this was true for both parents; zero otherwise. This information was solicited at the birth of the child, and again when the child was seven years old.
Years of Preschool Education	Number of years of preschool education received by the child between the ages of 2 and 5. All forms of early childhood education were counted including: kindergarten, playcentre, day care centre, organised play groups, etc.
Mother's Emotional Responsiveness Score	Measure of the quality of mother-child interactions obtained using the maternal emotional responsiveness subscale of the Home Observation for Measurement of Environment Inventory when the child was 3 years old. This scale score measures the extent of positive maternal responses to the child. Scores range from 0 to 10, with high scores indicating high levels of positive responsiveness by the mother. For additional information on the variable see Bradley and Caldwell (1977) and Elardo, Bradley and Caldwell (1979).
Number of Siblings	The number of siblings (including step and adopted children) living with the family. This information is available at the birth of the child, and again at ages 5, 10 and 15.
Two-Parent Family	Dummy variable equal to one if the child was living in a two-parent family at the time of the interview (either legally married or in de facto relationship); zero otherwise.
Mother Part-Time Work	Dummy variable equal to one if the mother worked fewer than 30 hours outside the home at the time of the interview; zero otherwise.
Mother Full-Time Work	Dummy variable equal to one if the mother worked more than 30 hours outside the home at the time of the interview; zero otherwise.
Family on Benefit	Dummy variable equal to one if either the mother or father (if present in the family) received some form of social welfare benefit at the time of the interview; zero otherwise. Information on the "type" of benefit received is incomplete, but nearly all benefits received came from the Domestic Purposes Benefit.

Gross Family Income	Annual measure of real, before-tax family income. All figures are measured in tens of thousands of 1996 dollars, using the quarterly values of the Consumer Price Index. This estimate is based on a combination of the reported weekly gross income of both the mother and father (if present in the family). After-tax social welfare benefits were scaled up by a factor of 1.2 to derive estimates of their equivalent gross values.
Church or Private School	Dummy variable equal to one if the school attended at the time of the interview was either a private (including integrated private) or church (including integrated church) school; zero otherwise.
Class Size	Number of pupils in the child's class at the time of the interview. Note that some of these may be "open plan classrooms" with more than one teacher working in the room at the same time.
High Living Standards	This variable equals one if the interviewer rates the family's living standard as "good or better than average"; two if their living standard is "obviously affluent, well to do"; zero otherwise.
Low Living Standards	This variable equals one if the interviewer rates the family's living standard as "below average, obviously not well off"; two if their living standard is "obviously poor or very poor"; zero otherwise.
Maternal Depression Score	Scale score based on the mother's answers, between ages 6 and 13 of her child, to 37 questions on the Levine-Pilowsky Depression Inventory. High scores indicate a large number of depressive symptoms at the time of the interview. Additional information on this variable can be found in Horwood and Fergusson (1986).
Grade Point Average	The child's grade point average is based on the teacher's annual assessment of classroom performance on reading, writing, spelling and mathematics. Ratings were made on 5-point scales ranging from 5 for very good to 1 for very poor.