

Model Uncertainty Over the Life Course: The Case of Early Health and Educational Attainment*

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Abstract

Identifying the pathways between early health and socioeconomic attainment remains an elusive goal across the social and health sciences. Although birth cohort studies often have extensive information for examining the life course, these studies point to conflicting pathways depending on the hypothesized causal ordering of exposures linking health with subsequent outcomes. This paper introduces a method that accounts for model uncertainty in studying health effects over the life course. We demonstrate the sensitivity of estimates of adolescent cognition among a set of structural equation models that vary in their indirect and direct pathways relating low birth weight and adult socioeconomic attainment. We then implement a model averaging approach to generate estimates of adolescent cognition and behavioral outcomes which are robust to model specification. The results highlight the sensitivity of model estimates to the secondary indirect effects in life course studies and the importance of non-cognitive pathways over the life course.

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1 Introduction

Reports of correlates between early health and later life socioeconomic attainment from across the social and health sciences are often interpreted as reflecting a process of social stratification with origins in early life. Individuals in poor health early in life are attributed with a range of obstacles to both sustaining good health and accruing the means for socioeconomic advancement over the life course. Whether the outcome is adult health, education, income or socioeconomic status, significant regression coefficients of measures of child health in models of adult socioeconomic attainment are interpreted as evidence of the lasting influences of early health in the processes for accumulating health and socioeconomic status over the life course.

While the growing evidence from studies of twins is highly suggestive of such lasting effects (e.g. Oreopoulos et al. 2006; Behrman and Rosenzweig 2004; Conley et al. 2003; Black et al. 2005) These estimates provide only limited information for distinguishing the importance of early life health. A fundamental challenge remains distinguishing the mechanisms which may tie early health to subsequent attainment. Correlates across such a wide span of the life course provide little insight concerning the numerous potential pathways between health and the many requirements for accruing socioeconomic status. Large literatures in demography, economics and epidemiology are alternately devoted to examining childhood trajectories through adolescent health, cognitive development, socio-emotional development and socioeconomic status. Each among these areas of research reports compelling correlates and contribute to a consensus that children with poor early health fare worse in adulthood. However, the pathways to adult disadvantage remain unclear. One problem is identifying the timing of early health effects. There is wide evidence that infants in poor health are at greater risk for adverse health throughout childhood. If such

effects are consequential only for labor market outcomes during adulthood, then the important ties between health and socioeconomic status may be limited to adulthood, irrespective of early health status (Smith 1999; Adams et al. 2003). Yet, evidence from natural experiments (Almond et al. 2005; Bleakley 2007) is consistent with scarring effects from adverse early health which do not manifest until later in life. Longitudinal studies further point to cumulative processes of disadvantage (Case et al. 2005; Smith 2009) where socioeconomic status of origin may incur persistent effects on childhood risks for adverse health shocks.

A second main challenge is accounting for the possible dynamic effects between model covariates. For instance, a large number of hospital-based studies (e.g. Aarnoudse-Moens et al. 2009; Bhutta et al. 2002) consistently show that low birthweight and/or extremely pre-term infants experience relatively lower cognitive outcomes during childhood and educational attainment than comparison groups. Given that both childhood cognitive measures and educational attainment are significant predictors of adult socioeconomic status, both effects likely mediate early health effects on adult socioeconomic status. In this case, a regression coefficient for low birthweight that conditions upon these later life outcomes fails to capture a potentially important part of the risks associated with low birthweight. Jointly modeling cognition and socioeconomic attainment presents one alternative, but the additional required assumptions for modeling both processes often results in overly stylized models of attainment with uncertain benefits for distinguishing pathways. The scope for interrelationships between social and biological processes is especially wide over the long periods of the life course which are necessary for studying the etiology of adult chronic conditions. Identifying the appropriate temporal ordering and their interrelationships remains a major point of departure among analyses of early origins of adult illness (e.g. Tu et al. 2005; Stavola et al. 2006; Kuh et al. 2009; Gamborg et al. 2009).

Sorting the dynamics among processes of socioeconomic status attainment faces similar complications. Heckman's framework of human capital accumulation (Heckman 2007;

Cunha and Heckman 2008) describes a dynamic process between cognitive skills and non-cognitive measures that may be further subject to the influences of families, schools and labor markets. Such dynamics are complicated by the wide ranging possible influences of early health on non-cognitive outcomes. Evidence from both the health sciences (Aarnoudse-Moens et al. 2009) and economics (Currie and Stabile 2006) raise the importance of early health for socio-emotional measures such as attention and self-regulation. These measures have themselves been shown to be good predictors of the test taking abilities that are critical for performing in the common assessments of cognitive ability (Duncan et al. 2007). Whether the outcomes of these assessments are further inputs to subsequent measures of *both* cognitive and non-cognitive outcomes raises a large number of possible pathways by which early health could influence subsequent socioeconomic status.

Finally, even studies that examine similar pathways may be unamenable to comparisons given differences in study design. Study attributes such as the sample definition, the time period of the analysis and the chosen set of control variables may have large impacts on study results. Differences in functional form alone have been shown to result in largely conflicting results (Sala-I-Martin 1997). In such a setting, developing a framework for distinguishing the relative importance among these related processes is essential to identifying the pathways from health to socioeconomic attainment over the life course. Such a framework must account for the range of differences in data and model specification across such wide ranging literatures in adjudicating their results and policy consequences. This challenge is complicated by accompanying supportive evidence for each approach that may meet reasonable standards for measures of model fit, but stand in contrast with conflicting policy recommendations. While meta-analytic techniques exist for evaluating potential publication bias when models are similar, they are less appropriate in accounting for the often conflicting conclusions emerging from more widely varying models.

2 Bayesian Model Averaging over the Life Course

This paper introduces a method that accounts for model uncertainty in studying health effects over the life course. We adapt a method of model averaging for assessing the sensitivity of estimates of low birthweight effects from structural equation models of life course attainment. We remain agnostic concerning the true model for describing early health effects. Instead, we examine a family of candidate models and generate a probability that each model is the true model. A set of structural equation models are estimated to examine the relative importance of cognitive and non-cognitive pathways in the relationship between birthweight and adult socioeconomic status. This family of candidate models includes a wide range of different direct and indirect effects between family socioeconomic status during childhood, cognition and non-cognitive behavioral measures along the pathways to adult socioeconomic status. We treat each model *a priori* as revealing equal information about the true underlying model. We then average over the resulting model estimates for the effect of low birthweight, weighting each model's information according to its probability. Model averaging has been applied in macroeconomics (Leamer 1978; Sala-I-Martin et al. 2004) and more recently in public finance (Brock et al. 2003). We adopt Raftery's framework (Raftery et al. 1997; Sirakaya 2006) and extend it to a structural equation model of individual development over the life course.

The models are estimated using the British Cohort Study (BCS), a prospective longitudinal study of nearly all children born in a single week in 1970 in Great Britain (England, Scotland, and Wales). Medical, social, demographic and economic data have been collected on cohort members from birth through age 34, including follow-up interviews their parents, teachers, doctors, or their partners at ages 5, 10, 16 and 26. This sample's wide coverage, periodic measures and long follow-up have made the BCS a popular cohort for studying health over the life course and an ideal dataset for our analysis.

We first demonstrate the sensitivity of estimates of adolescent cognition among a set of structural equation models that vary in their indirect and direct pathways relating low

birth weight and adult socioeconomic attainment. Including a set of behavioral measures reported by cohort members' teachers demonstrates a possible parallel set of pathways relating early health to behavioral measures of attention, cooperation and self-regulation. The range in the resulting estimates of low birthweight effects across a set of 35 different models which vary in the types of direct and indirect influences concerning the cognitive and non-cognitive measures demonstrates the consequences of model uncertainty for studying health.

We then implement a model averaging approach to generate estimates of adolescent cognition and behavioral outcomes which are robust to model specification. The resulting estimates for low birthweight remain significant. Moreover, they provide a method for measuring the bounds of model uncertainty that may be attributed to including specific sets of pathways. These results highlight the sensitivity of model estimates to the secondary indirect effects in life course studies and the importance of non-cognitive pathways over the life course.

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