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First and foremost, this paper was a labor of love for our mentor, life coach, and friend, Michael Grossman. We (and at least 115 others) had the rare mentor who is not only brilliant, but also has a heart the size of Texas. Mike, we can't thank you enough for your extraordinary generosity with time, advice, and anything else that was needed to keep us going and even thrive. Your impact on our careers and our lives (and those of countless others) goes way beyond our product here. The authors would also like to thank Grace Hillman and Erik Adamcik for extensive research assistance in the preparation of this article. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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ABSTRACT

Michael Grossman's seminal publication on the demand for health and health production (Grossman 1972) has spawned a substantial body of research focusing on the production of infant health. This article provides a systematic review of the published literature to date on infant health production and how it has evolved over the past 3-4 decades as data have become more available, computing has improved, and econometric methods have become more sophisticated. While empirical research in most fields has expanded in corresponding ways, the infant health production research has become an important part of the broader and inherently multidisciplinary literature on intergenerational health. The strongest and most robust findings are that policies matter for infant health, particularly those affecting access to health care, and that prenatal smoking and other chemical exposures substantially compromise infant health. Promising directions for future research include elucidating relevant pathways, reconciling the largely inconsistent estimated effects of nutrition and education, and exploring the roles of pre-conceptional and lifetime health care, paternal factors, social support, housing, complementarity and substitutability of inputs, factors that modify effects of inputs, and evolving medical technologies.

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Introduction

Michael Grossman's seminal publication on the demand for health and health production (Grossman 1972) has spawned a substantial body of research focusing specifically on the production of infant health, wherein maternal prenatal inputs affect the health of the next generation at the earliest stage of the lifecourse. This work was pioneered by Grossman himself, with his first published piece on the topic in 1981, and has led to a growing body of research across the globe. This increasingly influential research in health economics has complemented studies of maternal and child health in other disciplines and instilled methodological rigor into the broader and inherently interdisciplinary literature. While it is difficult to link any one set of studies to the enactment of specific policy changes, the body of research focusing on infant health that has been produced directly or indirectly by Michael Grossman has contributed a rich portfolio of strong scientific evidence that has been available to policymakers, program administrators, and advocates interested in maternal and child health. This research includes evidence on direct effects of policy, such as Medicaid expansions, food stamps, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and cigarette regulations, and on the effects of factors such as pollution, education, and job loss that can be influenced by policy levers.

In this article, we describe the infant health production function framework and the various ways that economic research on infant health production has evolved over the past 3 to 4 decades. Data have become vastly richer and more available, computing power has improved enormously, and econometric methods have become more sophisticated. Inputs considered have evolved substantially. Early studies focused on the role of healthcare inputs, particularly prenatal care (and insurance expansions that made prenatal care more available) and cigarette smoking. Subsequent studies investigated the effects of inputs such as education, maternal employment, public programs that provide income or material assistance, and healthcare technology, and very recent studies broadened

the lens to consider the effects of in utero stress stemming from maternal exposure to pollution and natural disasters while pregnant, based on the fetal origins hypothesis in the medical literature (Barker 1992). Outcomes considered have expanded beyond infant mortality to include measures of birthweight, gestational age, fetal loss, and infant morbidity.

The objective of this paper is to provide a review of the published literature to date on infant health production—that by and inspired by Michael Grossman—from our unique vantage point as three of Grossman's former students and mentees. Owing to the sheer size of the relevant literature, we will limit this review to infant health in high income countries as classified by the World Bank and highlight salient examples rather than provide an exhaustive review. To the extent possible, we underscore work by Grossman's former students and protégés, whose research most directly stemmed from the source.

The origins of the infant health production function

Grossman published his now-classic treatise on the concept of health capital and the demand for health in 1972 that was based on his 1970 doctoral dissertation, which was written under the tutelage of Gary Becker. The health production framework follows from Becker's path-breaking work from the 1960s on the concepts of household production and human capital. According to Grossman's own account (Grossman 2004, p.631), "…Gary suggested the topic of my dissertation. Originally it was supposed to be a study of the effects of education on health, but along the way he encouraged me to broaden it into a theoretical and empirical analysis of the demand for health."

While most of Grossman's early studies on the production of health considered individuals' production of their own health, in the 1980s he considered the production of health across generations by investigating effects of maternal inputs on infant health outcomes. Since the first published paper with this focus in the economics literature, Grossman and Jacobowitz*(1981)[1], research on infant health production has grown substantially, expanding in both breadth of application and methodological

[1] Asterisks denote students or protégés of Michael Grossman.

sophistication. Below we briefly describe the economic model of infant health production, then present a systematic review and synthesis of the literature from the 1980s through 2016 and conclude by discussing by new directions in this line of research.

Infant health production function model

Following Corman, Joyce, and Grossman (1987) and the theoretical literature on which they build, parents' utility can be expressed as a function of consumption goods (C), infant health (H_i), parents' health (H_p), tastes, and any other relevant arguments as follows:[2]

(1) $U=U\ (C, H_i, H_p, tastes)$

Infant health is a function of prenatal inputs (which can be positive, such as prenatal care, or negative, such as smoking or drug use) as well as the health endowment of the mother (which reflects H_p and may affect her reproductive efficiency), as shown in the infant health production function that follows:

(2) $H_i = f\ (input_1, input_2, ...input_n,$ *maternal health endowment)*

The demand for each input can be expressed as follows:

(3) $Input_i = g_i$ *(price and availability of* $input_i$*, prices and availability of substitute and complementary inputs, income, maternal health endowment, tastes, wantedness)*

Thus, infant health is an argument in the parent's utility function (Equation 1), and the parents' utility maximization is constrained by the process underlying the production of infant health (Equation 2). Wantedness reflects the relative importance of infant health versus other factors (e.g., own health) in the parent's utility function and therefore impacts prenatal input use (Equation 3) and other investments in infant health that may be unobserved. The maternal health endowment enters the infant health production directly (through biological processes) and may also affect infant health indirectly through the use of prenatal inputs (e.g., mothers with poor health endowments may attempt to offset an expected unfavorable birth outcome by utilizing more healthy inputs). Maternal risk-taking and time

[2] The model description is borrowed from Reichman et al. (2009).

preference (taste for risky behaviors) affect maternal engagement in risky behaviors (such as smoking and drug use) and investments in own health, which in turn can impact infant health production directly through the maternal health endowment (Equation 2) or indirectly through the maternal health endowment or other inputs (Equation 3).

Most empirical studies based on the infant health production function framework use reduced form models, derived by substituting Equation 3 into Equation 2 (that is., these models include measures of availability of inputs, rather than inputs themselves) or models that directly include the inputs of interest (Equation 2). For example, for studies exploring the effects of prenatal care, reduced form models may include availability of prenatal care services as the treatment of interest, while structural production function models would include a direct measure of prenatal care use. Direct estimation of Equation 2 may produce biased estimates owing to the potential endogeneity of input demand and non-random selection into the use of positive or negative inputs (i.e., investment in a specific input such as prenatal care may be correlated with other unobserved inputs or maternal characteristics that are associated with infant health). For this reason, some studies use instrumental variables for the treatment of interest in the attempt to obtain unbiased estimates. Continuing with the example of prenatal care, some studies use two-stage models that estimate prenatal care use as a function of availability of prenatal care services or other relevant factors (version of Equation 3) and then use the predicted values of prenatal care to estimate the infant health outcome (Equation 2), and some other studies use hybrid or quasi-reduced form models that include direct measures of some inputs while using availability for others—substituting Equation 3 into Equation 2 for some inputs (usually the input of interest) but not for others. Below, we provide a systematic literature review that traces the evolution of the topics, data sources, and methods characterizing the economics literature to date on infant health production.

Systematic literature review

We used EconLit to identify original published research articles from 1980 through 2016 that met the following conditions:

1. Published in economics journals (i.e., journals with the word "economic" or "economics" in their titles, *Journal of Human Resources*, or *Journal of Human Capital*) or were explicitly based on the economic health production framework.

2. Focused on infant outcomes (as opposed to health of older children).

3. Studied high income countries as designated by the World Bank (World Bank Group, 2017).

4. Focused on health outcomes rather than health disparities.

5. Based on data from the second half of the twentieth century or later, as opposed to more historical data.

We arrived at a list of 147 articles that met these criteria, all of which were directly or indirectly influenced by Michael Grossman. These articles are summarized in Tables 1-4, which cover the 1980s, 1990s, 2000s, and 2010-2016, respectively. In subsequent sections, we synthesize each of these tables in turn, highlighting prominent patterns.

1980s: Early studies

Most of the studies in this formative decade used data at the county or state level; estimated direct, reduced form, or 2-stage production functions; and considered infant mortality or birthweight-related outcomes, as detailed in Table 1. In terms of inputs, most studies focused on prenatal care, cigarette smoking, and/or availability of various inputs including prenatal care services, community health centers, family planning and abortion services, prenatal nutrition programs, and neonatal intensive care units. Fuchs (1986) and Joyce,* Grossman & Goldman* (1989) were prescient of developments to come in that they focused on low level radiation exposures and pollution, respectively, as inputs.

The first study of infant health production in the economics literature, Grossman and Jacobowitz* (1981), used county level data to explore determinants of neonatal mortality rates and found that an increase in the legal abortion rate appeared to be the single most important factor, dominating over schooling and poverty [1].[3] A subsequent study by Rosenzweig and Schultz (1983) used individual-level data from the 1967-69 National Natality Followback Survey, considered birthweight-related outcomes rather than infant mortality, and highlighted and addressed (to the extent possible at the time) the issue of endogeneity of prenatal inputs [2]. Rosenzweig and Schultz estimated that prenatal cigarette smoking decreased birthweight by 260 grams and that 5 months of prenatal care delay decreased birthweight by 230 grams, while Corman,* Joyce* and Grossman (1987) found small estimated effects of prenatal care compared to those of smoking when focusing on a measure of early prenatal care (first trimester care) [5]. A consistent finding across studies in this decade was that abortion availability was strongly associated with favorable birth outcomes [1, 2, 5-7], the hypothesized mechanism (i.e., argument in the production function, Equation 2 above) being wantedness. Another consistent finding was that measures of access to health care—including community health centers, Medicaid, and neonatal intensive care—appeared to be important.

Overall, this formative decade in the economics of infant health production provided key building blocks that set the stage for decades of research to come. Most of these early studies used aggregate data, which can provide a sense of the importance of specific inputs at the population level, but not of direct effects on individuals. The infant health production function research in this initial decade, which came at the heels of the legalization of abortion after Roe v. Wade in 1973, strongly suggested the importance of abortion availability for birth outcomes. This small and very new literature also suggested the importance of prenatal cigarette smoking and access to health care.

1990s: Better data and heyday of IVs

[3]Numbers in square brackets refer to the study numbers in the first column of Table 1, 2, 3, or 4, where abbreviated citations are used. Full citations are in the bibliography.

The 1990s saw substantial and widespread improvements in computing capabilities, which allowed researchers to handle exponentially larger data sets, vastly increased the speed of data manipulation, facilitated linkages between administrative datasets, and made it possible to geocode individual-level data and attach area-level characteristics. This development advanced research on infant health production in particular by allowing for analyses at the individual level, consideration of previously unexplored inputs and outcomes, and—perhaps most notably—the use of instrumental variables (IVs) to address the endogeneity of inputs. The majority of studies in the 1990s used administrative data, including micro-level data from U.S. natality files (sometimes linked to infant mortality files), state Medicaid files, and linked administrative datasets from various states. For example, studies used linked birth and hospital discharge records from New Jersey [28] and linked Medicaid and birth records from New York City [29, 36] and California [31]. A few studies used national survey data, including the National Longitudinal Survey of Youth 1979 (NLSY79) [16, 17] and National Maternal and Infant Health Survey (NMIHS) [33, 37]. One article was based on data from a clinical study that took place at large municipal hospitals [27]. The set of infant health outcomes investigated in the 1990s was largely the same as in the previous decade, but a few studies now incorporated length of newborn hospital stay and newborn hospitalization costs as proxies for infant morbidity [22, 28] and one study considered sudden infant deaths instead of infant mortality more generally [19]. Two studies were based on data from high income countries other than the U.S. (Australia, England, and Wales [19]; Canada [26]).

A defining characteristic of the infant health production literature in the 1990s, reflecting a new era of policy experimentation in the U.S., was that studies started focusing on policy changes or variations related to input availability and prices (e.g., Medicaid expansions and healthcare delivery systems; restriction on abortions under Medicaid; Medicaid fee schedules; and cigarette taxes). This new crop of studies led to more broad-based attention to the infant health production literature, as it

provided evidence on the effectiveness of policies of interest to legislators and program directors in addition to providing information of interest to economists about the roles of various inputs. In addition, researchers continued to study the prenatal inputs that were investigated in the 1980s, but extended the set to include prenatal illicit drug use [22, 23, 27] in the aftermath of the crack epidemic in the U.S., as well as income-related inputs [12, 16, 17], and augmented Medicaid prenatal care services [28, 36]. Prenatal care (use, eligibility, scope) was a major focus in this decade.

Along with better data, estimation methods evolved. Simultaneous equation models became more prevalent and sophisticated, and the decade saw many studies utilizing instrumental variables (IV)-based methods to address non-random selection into prenatal inputs. For instance, Grossman and Joyce* [11] was the first study to address both the endogeneity of prenatal care in the birthweight production function and the selection of pregnancies into those that result in live births within a simultaneous three-equation framework that was identified by IVs and exclusion restrictions. This embedding of the infant health production function within a Heckman selection model continued to guide some research in this decade that focused on prenatal care and abortion services [30, 32]. As the 1990s progressed and witnessed an expansion in our understanding and application of IV methods (see, for example, Angrist and Krueger (2001) for a history of instrumental variables), this evolution extended to the literature on infant health production, particularly studies that came out in the latter half of the decade. Many of these studies exploited state or local policy variation that was prevalent in the 1990s as IVs. For example, one influential study constructed a simulated Medicaid eligibility instrument from state program rules, capitalizing on the differential timing of the Medicaid expansions across states over the late 1980s to early 1990s to estimate the causal effects of insurance access on infant health [25]. This innovation, of creating a simulated eligibility instrument that collapsed multi-dimensional program rules into a single variable that plausibly reflected shifts in the program rules over time and was orthogonal to the pregnant woman's individual characteristics, has been used in many studies

thereafter. Another study exploited state variation in cigarette excise taxes as IVs and was one of the seminal studies quantifying the causal effects of prenatal smoking on birthweight [35]. Another noteworthy study in this vein exploited state variation in AFDC program rules as IVs to estimate the effects of welfare participation on birthweight [16].

Whereas the majority of studies in 1980s considered multiple inputs, those in the 1990s (and beyond) started focusing on one input with the goal of identifying causal effects. Studies generally found smaller effect sizes for prenatal care than were found by Rosenzweig and Schultz for an earlier (pre-Medicaid expansion) cohort, although comparisons across studies for this particular input are difficult because (1) studies often used different measures of prenatal care, (2) studies using IV methods addressed endogeneity but tended to produce estimates that were imprecise, and (3) it is plausible that the effects of prenatal care on birth outcomes changed over time (i.e., as prenatal care became more widely used as a result of the Medicaid eligibility expansions in the 1980s, the effects on birth outcomes may have become smaller, as women most likely to benefit gained access to care). Child Trends (2015) reported that about 8% of infants born in the U.S. in 1970 (close to the Rosenzweig and Schultz cohort) had mothers who initiated prenatal care after the second trimester of pregnancy, while the corresponding figure in 1999 was about 4%—representing a decrease of 50 percent. In addition, measures of the timing of initiation of prenatal care do not speak to the quality of that care; one study of augmented Medicaid prenatal care (versus standard Medicaid prenatal care), which included case management services and referrals to other programs, found some evidence of improvements in birth outcomes above and beyond what could plausibly be attributed to timing of care initiation [28]. Finally, prenatal care may operate through indirect channels, wherein greater contact between expectant mothers and physicians could lead to decreases (increases) in health-compromising (health-promoting) behaviors such as smoking (better diet and nutrition). For example, if reductions in prenatal smoking are a mechanism through which prenatal care improves birth outcomes, then studies that control for

prenatal smoking would underestimate the effects of prenatal care on infant health outcomes. Thus, some of the differences in the estimated effects of prenatal care across studies may reflect variations in controls for other prenatal behaviors.

Prenatal cigarette smoking was not frequently studied in this decade, although interest in this input picked up in the subsequent decades with an increasing number of successful state lawsuits against the tobacco industry; the main estimate from this decade—based on individual level natality data and IV models—was that any prenatal smoking led to a reduction in birthweight of between 350 and 600 grams [35]; representing a 10-18% reduction compared to the mean birthweight of 3,365 grams in the U.S. in 1990 (Martin et al., 2005).

Key policy findings in this decade were that expanding Medicaid eligibility for pregnant women led to reductions in infant mortality [25] and that augmented prenatal care programs for pregnant women on Medicaid led to improvements in a number of different birth outcomes [28, 36]. The effects of Medicaid eligibility and content of care on infant mortality could operate through birthweight-related outcomes or through postnatal access to care or infant exposures. In regard to the latter, Reichman et al. (2010), using a multi-pronged approach to address the potential endogeneity of the timing of prenatal care, found that first trimester prenatal care leads to decreased maternal postpartum smoking, increased use of well-baby care, and possibly increased breastfeeding.

2000s: Branching out with focus on plausible estimates

Economic research on infant health production further evolved substantially in the aughts decade. New focuses were on exposures to pollution [46, 57, 78, 84], sanitation interventions [65], and weather events [79], with the last serving as a proxy for prenatal stress. The (by now) routine and efficient practice of geocoding data greatly facilitated this research. These more "passive" exposures are both policy relevant and arguably less endogenous to the infant health outcome compared to inputs directly invested by the expectant mother. Research in this decade also focused on a broader range of

policies including those related to malpractice liability [42], hospital discharge laws [71], tort reform [70] immigration [45], welfare [38, 60, 73], smoking restrictions [75], minimum legal drinking age (MLDA) laws [80], and parental leave [40, 63]. In terms of the health production model, the first three policies (malpractice, tort, and discharge laws) may affect the quality of inputs in the production of health. Smoking restrictions and MLDA laws may affect the demand for tobacco and alcohol. Welfare policy may affect the demand for health inputs through income and time constraints, and potentially through access to health insurance, or can have direct effects on infant health through prenatal stress. Policies that restrict access to public insurance for immigrants may affect the demand for medical inputs among both immigrants (through loss of public insurance) and non-immigrants (through less competition for prenatal services). More generous parental leave policies allow greater postnatal parental time inputs into the production of infant health.

Again, compared to direct input use, laws are arguably less endogeneous to infant health outcomes. Many studies continued to focus on the same inputs as in previous decades (e.g., Medicaid availability/fees/managed care, wantedness, cigarette smoking, illicit drugs, cigarette taxes, and nutrition policy), but with new data sources and methods. In addition, some studies focused specifically on the role of education [47, 64], which had routinely been included in models in the past but generally as a control variable, and other sources of human capital (e.g., maternal pre-pregnancy physical and mental health endowment [83] and maternal prenatal depression [50]). Finally, some studies focused on specific prenatal medical inputs (e.g., relevant prescription drugs [56]) and paternal factors such as paternal education, race/ethnicity, and age [83].

With increasingly rich data and an evolution of thought about the processes leading to infant health, the outcomes in this decade expanded beyond infant mortality (the most extreme outcome) and birthweight-related outcomes to include fetal deaths, birth length, infant malformations, newborn hospital readmissions, Apgar scores, and specific infant morbidities. Although birthweight is a widely

used and well measured index of subsequent morbidity and a valuable outcome in its own right, it is not a direct measure of infant health. Low birthweight is a strong risk factor for infant mortality and morbidity among survivors, but many low birthweight children (even the very lightest) have no serious health problems (Reichman, 2005). Thus, using birthweight or low birthweight to proxy infant health can lead to imprecise or biased estimates of the effects of inputs on infant health. The literature is mixed on the associations between Apgar scores (an index assessing the clinical status of the infant immediately after birth and the need for intervention to augment breathing) and subsequent morbidity and mortality (e.g., AAP 2015); as such, that measure may lack precision and lead to biased estimates. One noteworthy study included a very specific and well-measured indicator of whether the infant had any serious abnormal health condition soon after birth (12% of their sample) and found that while similar inferences could be made about the effects of prenatal drug use on infant health when using birthweight-related outcomes and when using the direct measure of infant health, the same was not true for prenatal smoking; specifically, the effect of smoking on low birthweight was large and positive but on the direct measure of infant health was zero [83]. This study was the very last in our systematic review that estimated single-equation production functions, but the authors were able to use very rich data and incorporate theoretically important but typically unobserved factors into their models and the findings underscore that estimates should be interpreted in the context of the specific outcomes that are modeled.

In addition to the data sources used in previous decades, studies in the aughts used data from a randomized clinical trial of a prenatal smoking cessation program [44], the Pregnancy Risk Assessment Monitoring System [54], the Fragile Families and Child Wellbeing survey [83], restricted hospital data from California [71], the Pregnancy Nutrition Surveillance System [72], and WIC records [81]. Although most of the studies focused on U.S. settings, a few used data from other countries—specifically Canada [56], Spain [69], and Organisation for Economic Co-operation and Development (OECD) countries [63].

The methodologies employed in these studies continued to evolve, with a greater focus on credible identification strategies and deriving plausible causal estimates. The growing importance placed on internal validity necessitated that empirical studies of infant health production focus on a single input and cleanly identify the causal effect of that input. Studies in this decade continued to apply IV-based methods based on both program rules as well as other sources of variation. For example, one of the first national studies on how medical malpractice premiums affect prenatal care use and infant health took place in this decade [42]. In that study, the authors addressed the endogeneity of malpractice premiums for obstetricians by using state laws related to tort reform and malpractice premiums for neurosurgeons as IVs. Other influential studies exploited differential variation in the number of new 2- and 4-year college openings across U.S. counties to identify the effects of maternal education [47], and declines in total suspended particulates across counties (owing to the 1981-82 recession) to identify the effects of pollution [46], on infant health outcomes. The use of panel data and fixed effects models (with area fixed effects or maternal fixed effects) was also quite common in this decade, and studies further exploited natural and/or policy experiments in conjunction with panel data to estimate difference-in-differences (DD) models. For example, a noteworthy study brought new evidence to bear on the question of how access to quality care and provider choice impact infant health, by exploiting an exogenous policy change in California that raised Medicaid payments to hospitals and therefore raised the incentives and willingness of hospitals to serve Medicaid patients [53]; the authors capitalized on this natural experiment within a DD framework by comparing differences in birth outcomes for Medicaid mothers (treatment group) to privately-insured mothers (control group) across areas that witnessed larger declines in segregation (Medicaid births clustered at only public hospitals) vs. areas with little or no decline in segregation from the change in Medicaid payments. Another study exploited differences in the timing of WIC enrollment, comparing women who enrolled in WIC during the prenatal period across

different trimesters (treated group) with women who did not enroll in WIC until postpartum (control group) to assess how program participation affects infant health [72].

The aughts also marked the beginnings of a shift from estimating just an average treatment effect to assessing heterogeneity across relevant population subgroups. One of the earliest studies to estimate heterogeneous effects of maternal inputs, specifically maternal education and prenatal care, used quantile regression methods [41]. While that study did not address the endogeneity of maternal inputs (rather, it included multiple inputs and treated them as exogenous), it underscored the important point that the mean effect of any input may mask considerable heterogeneity across the birthweight distribution. A study a few years later applied a finite mixture model to assess heterogeneity in the causal effect of an input while treating the input as endogenous, necessitating a focus only on one input (in this case, prenatal care) and omitting other maternal inputs and behaviors [55]. This study provided one potential explanation for why some previous work had uncovered only weak effects of prenatal care on infant health—specifically, that prenatal care has beneficial health effects for "normal" pregnancies but may appear to be ineffective when a sample includes "complicated" pregnancies that may be relatively unaffected by prenatal care.

Overall, the literature in this decade marched on to include a broader range of inputs (although there was no dominant focus in this regard), outcomes, data sources, and methods and produced an olio of findings. There was increased attention to magnitudes and precision of estimates. Most of the relevant studies in this decade found small estimated effects of prenatal care (measured various ways) on birth outcomes. The estimated effect of prenatal smoking on birthweight, from a clinical trial of a smoking cessation program, was a reduction of 350 grams [44], which is in the ballpark of the original Rosenzweig and Schultz estimate. Although there had been no significant findings of unemployment on birth outcomes prior to this decade, studies now found that recession-induced decreases in pollution led to decreases in infant mortality [46] and that high unemployment rates led to more favorable birth

outcomes [51]. The latter finding was consistent with the emerging broader literature indicating that recessions can be good for your health (e.g., Ruhm, 2000a).

2010-2016: Infant health production meets lifecourse and intergenerational health research

While empirical research in most fields within economics, and in the social sciences in general, has expanded in similar and corresponding ways (e.g., better and more available data, computing capabilities, and methodological techniques), the current decade of infant health production research is experiencing a unique, and perhaps its most dramatic, evolution. Not only have the boundaries continued to expand (e.g., in terms of scope and methods), but infant health production research has been integrating with the broader literature on intergenerational health. Specifically, recent studies in economics have focused on the mother's pre-conceptional or early childhood health [106] and the child's in-utero exposures, including pollution [86, 96, 97, 108, 112, 125, 146], natural disasters [104, 105, 113], stressful events such as plant layoffs [129], and cortisol measurements of stress [141], as inputs into the production of infant health. Another notable theme is that while most studies of infant health production in earlier decades used U.S. data sources, those in the current decade (which have explored a variety of different inputs, many old and many new) have been based on data from other countries, including Taiwan, the UK, Canada, Chile, Germany, Denmark, Norway, Austria, the Netherlands, and Spain. Thus, what started out as a small field has gotten much larger and has gone global. For example, the number of studies that turned up in our search jumped from 10 in the 1980s, to 27 in the 1990s, 48 in the 2000s, and 62 in just the first 7 years of the current decade. When considering the overall numbers, it is important to note that they are on the conservative side, as many articles based on the infant health production function framework do not meet the relatively strict inclusion criteria for our systematic literature review. For example, articles published in economics journals but based on developing country settings, in which relevant inputs and production processes are quite different than those in developed countries, are not included.

Aside from maternal pre-conceptional health and infant in-utero exposures, research on a plethora of previously unstudied inputs and policies has been published in the current decade. Studies have continued to focus on pollution, smoking, education, income, maternity stay laws, smoking bans in workplaces and restaurants, the WIC program, and nutrition—in several cases using state-of-the-art research designs, such as exploiting Ramadan as a natural experiment for prenatal nutrition [92, 135]. New policies that have been investigated include those that affect fertility and birth timing (e.g., a "baby bonus" program [121] or tax benefits [126]), the federal food stamps program [94], the Earned Income Tax Credit [133], changes in provisions the Hill-Burton Act of 1946 (which eliminated requirements for private hospitals to admit charity care patients and therefore reduced access to care) [93], and laws involving cigarette purchase age [127].

Recent studies have investigated the roles of sunshine [147] and specific prenatal recommendations such as bed rest [132], as well as maternal earnings [137], maternal employment [140], marital status/divorce [123], domestic violence [90], and bereavement (mother recently lost a parent) [142]. Several studies have looked at aspects of obstetric and neonatal technology beyond those that were the focus of earlier studies, including Caesarian section delivery [134], electronic medical records [101], home versus hospital birth [131], availability of birth control pills [107], and the quality of neonatal care [87, 95]. Finally, studies have explored the roles of the built environment, including access to fast food [99]. Advances in technology and exogenous stressful events may shift the production function, while employment, earnings, and marital status can affect both the demand for inputs and the time spent in the production of infant health.

The most studied inputs in the current decade have been smoking and the physical environment, but together, these inputs have been the focus of only about one quarter of the studies. Income and employment became more of a focus. Maternal inputs, including smoking, nutrition and

prenatal care continued to be of interest. The infant health outcomes considered have not changed at all and a few new U.S. survey datasets have been employed.

The research methods employed are another defining characteristic of the current decade. The progression towards stronger emphasis on credible identification has continued, and has led studies utilizing "big data" and rigorous quasi-experimental research designs such as regression discontinuity. One of the early examples exploited hospital reimbursement rules in California to identify the causal effect of postpartum hospital stay on hospital readmission and mortality rates [91]. In that study, the authors capitalized on hospitals typically being reimbursed based on the number of days a patient spends in the hospital, with days counted as midnights receiving care (i.e., an infant born just after midnight would be covered for one additional night of care relative to an infant born just prior to midnight). Another study used administrative data from Denmark coupled with an information shock to obstetricians that discontinuously increased caesarean section (CS) rates for breech babies born at term to assess how CS delivery affected the health of infants who are at the margin of having a CS vs. a vaginal birth [134]. Yet another study applied an RD design to the question of how prenatal smoking affects birthweight, a question previously studied through IV and other methods, by exploiting the discontinuous shift in the cost of accessing cigarettes at the minimum legal purchase age [127]. Studies have also continued to use longitudinal or panel data and quasi-experimental research designs from the previous two decades including IV and DD methods, with many of these studies relying on multiple strategies and identification checks. For example, one study used IV, DD, and maternal fixed effects estimators, applied to population data from Norway, to explore how maternal stress during pregnancy due to the death of one of her parents affects birth outcomes [142].

Overall, the 2010s have been a period of great expansion of the infant health production literature. The field has gone truly global, capitalized on big data and increasingly sophisticated research

designs, and become an essential part of the broad and highly salient literature on intergenerational health.

Conclusion

Much has been learned about determinants of infant health since Michael Grossman developed and introduced the infant health production framework almost four decades ago. His framework has (conservatively) been applied in hundreds—and more likely thousands—of research studies, many of which have been conducted by Grossman's academic descendants. From this body of work, several broad themes emerge.

First, policies matter for infant health, particularly those affecting access to health care. Healthcare access for pregnant women and children improved dramatically during the past 3-4 decades and had positive effects on infant health. Although the estimated effects of prenatal care use on birth outcomes have tended to be small in recent decades, late (or no) prenatal care initiation in the U.S. decreased substantially during the 1990s and stood at less than 4% of all births in 2002 (no comparable figures are available thereafter; see Child Trends Databank, 2015), leaving limited room for improvements in this regard (although enhancements to the content and scope of prenatal care may be promising strategies). Moreover, prenatal care may be "too little too late" to improve birth outcomes for some women, who may enter pregnancy with a host of physical, mental, and psychosocial problems, the effects of which cannot be addressed within the confines of a pregnancy. As found in a 2009 study [85] and convincingly confirmed by recent studies linking maternal pre-conceptional and early childhood health [106] and in-utero exposures [92, 96, 97, 104, 105, 108, 112, 141] to offspring birth outcomes, women's pre-pregnancy mental and physical health are important predictors of birth outcomes above and beyond pregnancy-related health, suggesting that healthcare access and quality for young girls and women of reproductive age is a promising strategy for improving infant health. The availability of

abortion services stands out as an important predictor of infant health, suggesting the importance of access to family planning services—ideally as part of comprehensive and multifaceted health care.

Another theme that is obvious from this review is that prenatal smoking and other chemical exposures compromise infant health. The most consistent metric for prenatal smoking is birthweight in grams associated with any smoking during pregnancy, and the estimates have been in the "few hundred grams" range (reductions in birthweight attributed to smoking) across four decades with evolving methodological sophistication. Because there are (understandably) few randomized controlled trials of the effects of prenatal smoking, the infant health production literature provides much of the evidence base in this regard. Nevertheless, it is noteworthy that estimates of the causal effect of prenatal smoking on birthweight based on observational data and quasi-experimental evidence are close to estimates derived from a randomized control trial of a smoking cessation intervention directed at pregnant women [35]. Recent studies also provide strong evidence of the adverse effects of air pollution on infant health, which may operate through fetal health or postnatal exposures. Sorting out the various pathways underlying these effects is a potentially fruitful direction for future research, as is explaining the largely inconsistent estimated effects of nutrition, education, and other less-studied arguments in the infant health production function.

Other potentially fruitful directions for further research include the effects of pre-conceptional and lifetime health care on birth outcomes (for reasons elucidated above); the roles of paternal factors, which have scarcely been studied by economists while findings from other fields (e.g., occupational health, psychology, and sociology) suggest that paternal biological, economic, social, and behavioral inputs are important for children's health; the potential roles of grandparents and social support (which relates to the growing literature on social capital and health); the potential role of housing stability and characteristics (very few studies in this regard came up in our systematic review and there is increasing interest in the role of housing as both a resource and an environment on health); the potential

complementarity or substitutability of inputs (i.e., most studies consider inputs in isolation, while it is possible that bundles of inputs are more important); and factors that may exacerbate or buffer the effects of adverse exposures and enhance or mitigate the effects of favorable exposures. In addition, as medical technology evolves (e.g., applications of genomics or targeted interventions), there will be additional inputs to consider and possibly more precise measures of health in infancy. There is a lot of work to do in coming decades, so Michael Grossman's infant health production tree will undoubtedly continue to branch out, fertilize new ideas, and have major impact.

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Table 1. 1980s: Early Studies

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Findings
1	Grossman, M., & Jacobowitz, S.* (1981)	Multiple inputs including education and availability of physicians, Medicaid, federal health centers, and abortion	County-level neonatal mortality rates (3-yr. average)	Natality and mortality data, U.S., 1970-1972	OLS	Increase in legal abortion rate is single most important factor associated with reductions in both white and nonwhite neonatal mortality rates; dominates over schooling and poverty
2	Rosenzweig, M. R., & Schultz, T. P. (1983)	Multiple inputs including prenatal care, smoking	Individual-level BW and GA-related outcomes	National Natality Followback Survey, 1967-69	IV	Effect of prenatal smoking on BW: 230 grams; effect of 5-month increase in prenatal care delay on BW: 260 grams; no effect of maternal age; small effect of parity
3	Corman, H.,* & Grossman, M. (1985)	Multiple inputs including education and availability of Medicaid, family planning, federal health centers, WIC, abortion, neonatal intensive care	County-level neonatal mortality rates (3-yr. average)	Natality and mortality data, U.S., 1976-1978	OLS	Neonatal intensive care, Medicaid, and abortion access (and WIC for whites) are associated with reduced mortality for both blacks and whites
4	Fuchs, V. R. (1986)	Pollution/radiation from 3 Mile Island	State-level infant, neonatal, and post-neonatal mortality rates	Mortality data, 1960-1970	OLS	No effects of radiation from 3 Mile Island
5	Corman, H.,* Joyce, T.,* & Grossman, M. (1987)	Multiple inputs including smoking, prenatal care, abortion, family planning, federal health centers, WIC, and neonatal intensive care	County-level neonatal mortality, LBW (3 yr. average)	Natality and mortality data, U.S., 1976-1978	IV	Increase of average number of cigarettes per capita in state by 1 unit increases neonatal mortality by 6% for blacks and whites; increase of 1 percentage point in women who receive first trimester prenatal care reduces neonatal mortality by 1% for both races
6	Joyce, T.* (1987)	Abortion rates	County-level neonatal mortality, LBW, GA (3 yr. average)	Natality and mortality data, U.S., 1976-1978	IV	Higher abortion rates decrease unfavorable birth outcomes for blacks and whites

Table 1. 1980s: Early Studies

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Findings
7	Joyce, T.,* Corman, H.,* & Grossman, M. (1988)	Multiple inputs including prenatal care, smoking, abortion, family planning, federal health centers, WIC, neonatal and intensive care	County-level neonatal mortality rates (3 yr. average)	Natality and mortality data, U.S., 1976-1978	IV	Detrimental effects of reduced spending levels for social programs may have been more than offset by the continued growth in abortion availability, neonatal intensive care availability, and female schooling levels
8	Goldman, F.,* & Grossman, M. (1988)	Community Health Centers (CHCs)	Annual county-level infant, neonatal, and post-neonatal mortality rates	Natality and mortality data, U.S., 1970-1978	OLS	CHCs contributed ~2-4% reductions in short run and 4-6% reductions in long run; effects for blacks larger than for whites
9	Joyce, T.,* Grossman, M., & Goldman, F.* (1989)	Pollution	County-level neonatal mortality rates (3 yr. average)	Natality and mortality data, U.S., 1976-1978	IV	Higher sulfur dioxide levels significantly increase neonatal mortality rates
10	Yamada, T.,* Yamada, T.* & Chaloupka, F.* (1989)	Nutrition	Prefecture-level neonatal & infant death	Mortality data, prefectures in Japan, 1980-1981	OLS, IV	Protein and vitamin A consumption positively related to neonatal and infant mortality; calcium and iron consumption negatively related to those outcomes

Note: See notes at bottom of Table 4

Table 2. 1990s: Better Data and Heyday of IVs

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
11	Grossman, M., & Joyce, T.* (1990)	Prenatal care use	Individual-level BW	Birth records, NYC, 1984	IV; sample selection model	Each month prenatal care delay associated with 4-37 gram reduction in BW
12	Joyce, T.* (1990)	Unemployment rates	Monthly rates of LBW	Natality data, NYC, 1970-1986	Time-series	No effect of unemployment on LBW
13	Joyce, T.,* & Grossman, M. (1990)	Abortion rates	Monthly rates of LBW	Natality data, NYC, 1972-1988; induced abortions	Time series	Higher rates of abortion associated with lower rates of LBW for blacks; no effect for whites; no effect of early prenatal care on LBW
14	Jones, A. (1991)	Multiple inputs, including rates of prenatal care, abortion, public assistance, education	State-level LBW	Children's Defense Fund publication, 1984	OLS	Early (first trimester) prenatal has poorly determined small magnitude negative association with LBW; economic factors have much larger associations
15	Frank, R. G., Strobino, D. , Salkever, D.., & Jackson, C. A. (1992)	Prenatal care	County-level LBW	Natality data, U.S., 1975-1984	FE (pooled, time series, cross-sectional study)	Outcome elasticities of prenatal care initiation (first trimester) are -0.10 to -.011
16	Currie, J., & Cole, N. (1993)	AFDC participation	Individual-level BW, LBW	NLSY79 births, 1979-1988	IV; maternal FE	Mothers who participate in AFDC are most at risk of having LBW infant, but relationship is not causal
17	Currie, J., Nixon, L., & Cole, N. (1993)	Access to abortion	Individual-level BW, LBW	NLSY79 births, 1980-1988	Random effects	Little indication that abortion restrictions reduce average BW
18	Joyce, T.,* & Mocan, H.* (1993)	Unemployment rates	Monthly rates of LBW	Natality data, Tennessee, 1970-1988	Time series	No relationship between structural/cyclical unemployment and LBW for blacks; weak negative relationship between structural unemployment and LBW for whites

Table 2. 1990s: Better Data and Heyday of IVs

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
19	Campbell, M. J. (1994)	Weather (temperature)e	Daily SIDS counts	Mortality data, England & Wales, 1979-83 and 1984-86; Mortality data, New South Wales, Australia, 1981-85	Time series	Strong relationship between a drop in temperatures & SIDS 2-5 days later
20	Joyce, T.* (1994)	Prenatal care	Individual-level BW	Birth records, NYC, 1984	IV	Higher BW for women who receive intermediate rather than inadequate prenatal care (Kessner Index); more of an association than from intermediate to adequate prenatal care
21	Currie, J., Gruber, J., & Fischer, M. (1995)	Medicaid fee pollicy	State-level annual infant mortality rates	Mortality data, U.S., 1979-1988, 1989-1992	FE	Increases in Medicaid fee ratio are associated with small/significant declines in infant mortality rate; raising the fee ratio by 10% lowers infant mortality by 0.5-0.9%
22	Joyce, T.,* Racine, A., McCalla ,S. & Wehbeh, H. (1995)	Cocaine, other illicit drugs	Individual-level data on hospital costs, length of stay and service intensity; includes hospital measures of drug use	Large municipal hospital in NYC, Nov. 1991 and Apr. 1992	OLS	Infants exposed to cocaine or other illicit drugs stay approximately 7 days longer in hospital , with $7,731 more costs
23	Mocan, H.,* & Topyan, K. (1995)	Illicit drug use	Monthly rates of LBW	Natality data, NYC, 1963-1990	Time series	Smoking during pregnancy, early initiation of prenatal care (first trimester), illicit drug use during pregnancy have no effects on rates of LBW for whites; prenatal smoking and drug use significantly increase rates of LBW for blacks
24	Warner, G.* (1995)	Prenatal care	Individual-level BW, gestational age	Birth records, NYC, 1980-1990	IV	PNC delay (days) significantly associated with a 1 gram reduction in BW for black mothers

Table 2. 1990s: Better Data and Heyday of IVs

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
25	Currie, J., & Gruber, J. (1996)	Increased access to Medicaid for pregnant women	State-year rates of LBW and infant mortality	Natality and mortality data, U.S., 1979-1992	IV	30 % point increase in fraction of women eligible for Medicaid during pregnancy associated with decrease in infant mortality of 8.5%
26	Hanratty, M. (1996)	Universal health care in Canada	County-level rates of LBW and infant mortality	Vital Statistics data, Canada, 1960-1975	FE	Implementation of national health insurance associated with 4% decline in infant mortality and 8.9% decrease in LBW for single parents
27	Kaestner, R.*, Joyce, T.,* & Wehbeh, H. (1996)	illicit drug use	Individual-level BW	Large municipal hospital in NYC, Nov. 1991- Apr. 1992; birth records from NYC	IV with correction for self-reported data	Underreporting of maternal drug use results in overestimate by a magnitude of about 50% of actual effect of drug use on BW
28	Reichman, N.,* & Florio, M. (1996)	Enriched prenatal care for Medicaid recipients	Individual-level BW, LBW, VLBW, newborn hospitalization costs, 1989-1990	Linked birth/death and hospital discharge records, New Jersey, 1989 & 1990	IV	Increased BW, lower newborn hospitalization costs and reduced rates of LBW and VLBW for those receiving enriched care, for blacks; no evidence that enriched care was associated with improved birth outcomes or lower costs for whites
29	Levinson, A., & Ullman, F. (1998)	Medicaid managed care vs. fee for service	Individual-level BW	Birth records linked to Medicaid files, Wisconsin, 1994	OLS	No significant associations between managed care and BW or LBW
30	Liu, G.* (1998)	Prenatal care	Individual-level BW	Birth and abortion records, Virginia, 1984	Selection & IV models	Each Month of prenatal care delay results in 35-107 gram reduction in BW
31	Oleske, D. (1998)	Medicaid fee for service vs. managed care	Individual-level LBW for Medi-Cal births	Birth records, California, 1993, selected counties (plausibly exogenous differences in assignment)	OLS "natural experiment"	Among Medi-Cal women, the likelihood of LBW was lower in capitated payment group than fee for service group; OR=.62

Table 2. 1990s: Better Data and Heyday of IVs

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
32	Walker, M. & Wallace, S. (1998)	Abortion availability	Individual-level LBW	Birth records, Georgia and New York, 1989-1991	Selection model	Some evidence for "cost of abortion" model - assumes increasing full costs of abortion associated with LBW
33	Warner, G.* (1998)	Prenatal care	Individual-level BW	NMIHS 1988 Survey	IV	Prenatal care increases BW through visits, not timing of initiation
34	Cremieux, P., Ouellette, P., & Pilon, C. (1999)	Healthcare spending in Canada	Province-level infant mortality rates	Health Statistics Canada, Quebec, 1978-1992	FE	Lower healthcare spending associated with increased infant mortality rates
35	Evans, W., & Ringel, J. (1999)	Cigarette taxes	Individual-level BW, LBW, VLBW	Birth records, U.S., 1989-1992	IV	Smoking during pregnancy reduces BW by 350-600 grams; increases probability of LBW by 10-16 % points; increases VLBW by 1-5 % points
36	Joyce, T.* (1999)	Augmented prenatal care for Medicaid recipients	Individual-level BW, LBW, VLBW	Linked Medicaid administrative files and birth records, NYC, 1989-1991	IV	Prenatal Care Assistant Program associated with increase in BW by 0-124 grams; decrease in LBW by 0-3.4 % points
37	Kaestner, R.* (1999)	Payer source: Medicaid, private, uninsured	Individual-level BW, LBW	NMIHS 1988 Survey	IV	No statistically significant relationship between insurance status and BW

Note: See notes at bottom of Table 4

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
38	Currie, J., & Grogger, J. (2000)	Medicaid income eligibility threshold, welfare participation rate	Individual-level fetal death, LBW, VLBW	Birth and fetal death records, U.S., 1990-1996	FE	Increases in income cut-off for Medicaid eligibility reduced fetal deaths for blacks; reduced rates of welfare participation increased fetal deaths for blacks and whites; no effects of either on BW-related outcomes
39	Joyce, T.,* Kaestner, R.,* & Korenman, S. (2000)	Pregnancy intention (wantedness)	Individual-level BW, LBW	NLSY79 1979- 1992	FE	No significant effect of wantedness on LBW
40	Ruhm, C. (2000b)	Parental leave	County-year rates of LBW; infant, perinatal, neonatal, and post-neonatal mortality	Aggregate data for 16 countries, 1969-1994	FE	Magnitudes of estimated effects are substantial; stronger negative relationship between leave durations and post-neonatal than for perinatal mortality, neonatal mortality, or LBW
41	Abrevaya, J. (2001)	Multiple inputs including education, nutrition, prenatal care, smoking	Individual-level BW	Birth records, U.S., 1992 & 1996	Quantile regression	Race, education & trimester began prenatal care have larger associations at lower quantiles of BW than higher quantiles; average smoking effect on BW: 161 grams
42	Dubay, L., Kaestner, R.,* & Waidmann, T. (2001)	Malpractice liability pressure (insurance rates)	Individual-level LBW, Apgar scores	Birth records, U.S., 1990-1992	IV	No effect of premiums on LBW, Apgar scores
43	Gray, B. (2001)	Medicaid reimbursement rates	Individual-level BW- and GA-related outcomes, infant death	NMIHS 1988	DD	10% higher than average fee associated with 0.074% lower risk of LBW and 0.035% lower risk of VLBW among women on Medicaid
44	Hamilton, B. (2001)	Smoking	Individual-level BW	Randomized clinical trial conducted in early 1980s	Bayesian Markov Chain Monte Carlo	Average treatment effect of smoking cessation at 7 months gestation on BW: ~350 grams

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
45	Amuedo-Dorantes, C., & Mundra, K. (2003)	Immigration policy	Individual-level BW	Birth records, California, 1991 & 2000	3SLS	10% increase in % immigrant in mother's zip code results in 2% decline in prenatal care visits; 2% increase in prenatal care visits results in increase in BW of ~16 grams
46	Chay, K. Y., & Greenstone, M. (2003)	Recession- caused pollution shocks	County-year rates of neonatal and infant mortality	Natality and mortality data, U.S., 1978-1984	FE, IV	Reduction in total suspended particulates associated with fewer infant deaths; elasticity of infant death rate with respect to particulates is ~0.35
47	Currie, J., & Moretti, E. (2003)	Education	Individual-level BW-and GA-related outcomes	Birth records, U.S., 1970-1999 (10% random sample of first births)	IV	Higher maternal education reduces LBW and preterm birth
48	Li, K., & Poirier, D. (2003a)	Multiple inputs including smoking, alcohol consumption, prenatal care, nutrition	Individual-level BW- and GA-related outcomes, birth length for Native Americans	NLSY79 1979-1994	Simultaneous equations model with 7 endogenous variables	Smoking has negative association with GA; alcohol consumption and first trimester prenatal care appear to have no substantive effects on GA, birth length, or BW; birth length affected by inputs mainly through weight gain; BW affected by inputs through GA
49	Li, K., & Poirier, D. (2003b)	Multiple inputs including smoking, alcohol consumption, prenatal care, nutrition	Individual-level BW- and GA-related outcomes, birth length	NLSY79 1979-1994	Simultaneous equations model w/7 endogenous variables	Smoking, alcohol, and gestational weight gain appear to affect birth outcomes in expected directions but early (first trimester) prenatal care is the most important factor
50	Conway, K., & Kennedy, L. (2004)	Maternal depression	Individual-level BW, LBW	NMIHS 1988	IV	Maternal depression reduces BW by 46-73 grams; increases LBW by 0-2 % points
51	Dehejia, R., & Lleras-Muney, A. (2004)	Unemployment rates	State-year rates of LBW, VLBW, low (<=5) Apgar	Natality and Mortality data, U.S., 1975-1998; vital	FE, maternal FE	Infants conceived in times of high unemployment have reduced incidence of LBW and VLBW, fewer

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
			scores; infant, neonatal, post-neonatal mortality; congenital defects	statistics data, California, 1990-2000		congenital malformations, lower rates post-neonatal mortality
52	Rous, J., Jewell, R., & Brown, R. (2004)	Prenatal care	Individual-level BW	Birth records, Texas, 1993	IV, selection, IV & selection	Range of estimates of effects of prenatal care (number of visits) on BW, depending on specification
53	Aizer, A., Lleras-Muney, A., & Stabile, M. (2005)	California's Disproportionate Share program (encouraged hospitals to accept Medicaid patients)	County-year rates of neonatal mortality	Mortality data, California, 1989-1995	DD	Black mothers benefited most, with largest decline in neonatal mortality, but moved to better hospitals at lower rates; all other Medicaid subgroups took advantage of increased access
54	Bitler, M., & Currie, J. (2005)	WIC participation	Individual-level BW- and GA-related outcomes, nights infant in hospital	Pregnancy Risk Assessment Monitoring System, 19 states 1992-1999	FE, IV	WIC participation reduces probability that infant is LBW and VLBW
55	Conway, K., & Deb, P. (2005)	Prenatal care	Individual-level BW	NMIHS 1988	IV; finite mixture models	Prenatal care (weeks delay) has substantial effect on 'normal' pregnancies (using finite mixture model)
56	Cremieux, P., Meilleur, M., Ouellette, P., Petit, P., Zelder, M., & Potvin, K. (2005)	Prescription drug spending (proxy for prescription drug availability/use)	Province-year infant mortality	Statistics Canada 1981-2000	FE	Increased spending on pharmaceuticals improves infant mortality rates
57	Currie, J., & Neidell, M. (2005)	Pollution	Individual-level infant mortality	Linked birth and death records, California, 1989-2000	FE	Significant adverse effect of carbon monoxide (CO) exposure on infant mortality; reduction in CO over 1990s saved about 1000 infant lives in California

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#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
58	Evans, W., & Lien, D. (2005)	Bus strike that may have limited access to prenatal care	Individual-level BW and GA-related outcomes	Birth records, Allegheny County, PA, 1990-1994	IV	Suggestive evidence that visits lost early in pregnancy negatively affect BW and GA, but estimates are imprecise
59	Joyce, T.,* Gibson, D., & Colman, S.* (2005)	WIC participation	Individual-level BW- and GA-related outcomes	Birth records, New York City, 1988-2001	OLS	Few associations between prenatal WIC participation and fetal growth and other birth outcomes
60	Kaestner, R.*, & Lee, W. (2005)	Welfare participation/welfare reform	Individual-level BW- and GA-related outcomes	Birth records, U.S., 1992-2000	DD	50% reduction in welfare caseload associated with 0-10% increase in LBW
61	Kaestner, R.,* Dubay, L., & Kenney, G. (2005)	Medicaid managed care (MMC)	Individual-level BW- and GA-related outcomes	Birth records, U.S., 1990-1996	DD	MMC associated with increased preterm birth for non-HIspanic white women
62	Lien, D., & Evans, W. (2005)	Smoking/cigarette taxes	Individual-level BW	Birth records, U.S., 1990-1997	IV, DD	Smoking doubles the likelihood of LBW
63	Tanaka, S. (2005)	Parental leave policies	Country-year rates of infant, perinatal, neonatal, post-neonatal mortality & LBW	18 OECD countries, 1969-2000	FE	10-week extension in paid leave is predicted to decrease post neonatal mortality rate by 4.1%; significant favorable relationship between paid leave and LBW
64	McCrary, J., & Royer, H. (2006)	Education/ school entry date as proxy	Individual-level BW- and GA-related outcomes, infant mortality	1989-2001 (Texas) and 1989-2002 (California) natality data merged with 1969-1988 natality data (to proxy mother's education); TX data linked to mortality data 1989-2002	IV	No effect of education on infant health

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
65	Watson, T. (2006)	Sanitation interventions in U.S. Indian reservations	County group/year rates of infant mortality	Mortality data merged with public health intervention locations and dates, 1968-1998	FE	10% increase in share of homes with sanitation improvements reduced infant mortality by 0.51 per 1000 births
66	Aizer, A., Currie, J., & Moretti, E. (2007)	Medicaid managed care (MMC)	Individual BW- and GA-related outcomes, neonatal death	Linked birth and death records, California, 1990 & 2000	FE	MMC increases LBW, preterm birth, & neonatal death
67	Noonan, K., Reichman, N.,* Corman, H.,* & Dave, D.* (2007)	Illicit drug use	Individual-level LBW, abnormal infant conditions	FFCWB survey data linked to medical records, 1998-2000	IV	Illicit drug use increases LBW by 4-6% and likelihood of abnormal infant health condition by 7-12%
68	Abrevaya, J., & Dahl, C. (2008)	Multiple inputs including prenatal care, smoking	Individual-level BW (quantiles)	Birth records, Washington State (1992-2002) & Arizona (1993-2002), with links between mothers' first & second births	Quantile regressions using maternal RE	Negative effect of smoking is largest in middle quantile (ranges from 80 to 180 grams at 50th percentile); prenatal care effects hard to interpret
69	Cantarero, D., & Pascual, M. (2008)	Income, decentralization of healthcare	Infant mortality rates by year/region	Panel of regions, Spain, 1992-2003	FE, RE	Decentralized healthcare negatively related to infant mortality
70	Currie, J., & MacLeod, W. (2008)	Tort reform	Individual-level Apgar scores, preventable birth complications	Birth records, U.S., 1989-2001	FE	No effect of tort reform on Apgar scores; Rule of Joint and Several Liability associated with decline in preventable complications
71	Evans, W., Garthwaite, C., & Wei, H. (2008)	Postpartum discharge laws that increased length of stay	Individual-level infant readmission after newborn hospitalization	Linked birth and hospital discharge records, California, 1/95-12/00	Interrupted time series, IV	Discharge law reduced re-admission rates for privately insured c-section-delivered and Medicaid-insured vaginally-delivered newborns

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
72	Joyce, T.,* Racine, A., & Yunzal-Butler, C. (2008)	WIC participation	Individual-level BW- and GA-related outcomes	Pregnancy Nutritional Surveillance System, 9 states, 1995-2004	DD	Modest favorable effects of WIC participation on fetal growth
73	Leonard, J., & Mas, A. (2008)	Welfare reform – hitting time limits	Individual-level infant mortality	Linked birth and death records, U.S., 1995-2002	FE	Significant increases in infant mortality when time limits become binding in a state
74	Lhila, A., & Simon, K. (2008)	Knowing child sex (boy)	Individual-level BW, LBW, Apgar scores	Birth records, U.S., 1989-2001	DD	No evidence of gender bias
75	Markowitz, S.* (2008)	Smoking/cigarette control policies	State-year counts of SIDS	Mortality data, U.S., 1973-2003	IV	Higher cigarette prices and taxes associated with reductions in SIDS cases; stronger smoking restrictions in workplaces/restaurants/ child care centers also associated with reduced SIDS deaths
76	Mukhopadhyay, S., Wendel, J., Lee, W., & Yang, W. (2008)	Prenatal care	Individual-level LBW, marginal cost of providing infant hospital care	Linked data from one U.S. hospital, its subsidized prenatal care clinic, and birth records	OLS	Effect of PNC on infant health derived from birth certificates is problematic because self-reported PNC visits does not correlate with provider-reported PNC visits and LBW is a narrow measure of health
77	Currie, J., & Schmieder, J. (2009)	Pollution	County-year BW- and GA-related outcomes, infant mortality	Natality and mortality data, U.S., 1988-1999; linked with data from EPA Toxics Release Inventory	FE	Within-county variations in reported toxic releases are related to infant health outcomes - nearly all estimates indicate adverse effects of exposures
78	Currie, J., Neidell, M., & Schmieder, J. (2009)	Pollution	Individual-level BW- and GA-related outcomes, infant mortality	Linked birth and death records, New Jersey, 1989-2003	FE and maternal FE	Consistent negative effects of carbon monoxide exposures before and after birth (particularly for smokers and older mothers)

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
79	Deschenes, O., Greenstone, M., & Guryan, J. (2009)	Climate change	Individual-level BW, LBW	Birth records, U.S., 1972-1988. Linked to National Climatic Data Center Temperature data	FE	Exposure to extreme ambient temperatures decreases BW and increases LBW; sensitivity of BW to temperature mostly in second and third trimesters
80	Fertig, A., & Watson, T. (2009)	Minimum drinking age laws	Individual-level BW- and GA-related outcomes, congenital anomalies	Birth records, U.S., 1978-1989; NLSY79	FE	Minimum legal drinking age of 18 associated with adverse birth outcomes for young mothers
81	Figlio, D., Hamersma, S., & Roth, J. (2009)	WIC participation	Individual-level BW- and GA-related outcomes	Birth records, Florida, 1997-2001, linked to WIC and school records	IV	WIC participation has no effect on mean BW and GA but reduces likelihood of LBW and premature birth
82	Lin, W. (2009)	Multiple inputs including smoking, prenatal care, nutrition	Individual-level Apgar scores, neonatal and infant mortality	Linked birth and death records, U.S., 1983-2000	OLS, propensity score weighting	Most important factor in explaining infant health gaps (by maternal education) appears to be access to medical care (prenatal care adequacy) prenatal behaviors also appear to be important
83	Reichman, N.,* Corman, H.,* Noonan, K., & Dave, D.* (2009)	Multiple inputs including illicit drugs, smoking, prenatal care, wantedness, Medicaid, nutrition, physical and mental health	Individual-level BW, LBW, abnormal infant health conditions	FFCWB survey linked to medical records, 1998-2000	OLS	Smoking reduces BW by 174 grams, increases LBW by 4 % points; illicit drugs significantly reduce BW and increase LBW and abnormal conditions; pre-pregnancy physical and mental health conditions are strong predictors of birth outcomes
84	Sneeringer, S. (2009)	Pollution	County-year rates of neonatal and infant mortality	Natality and mortality data linked to data on livestock numbers, U.S., 1980-1999	FE	Doubling of livestock production leads to 7.4% increase in infant mortality, driven by elevated levels of respiratory diseases

Table 3. 2000s: Branching out with focus on plausible estimates

#	Article	Input/Policy/Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
85	Walker, M., Tekin, E., & Wallace, S. (2009)	Smoking	Individual-level LBW	Birth records, Georgia, 1994-2002	Matched sample, maternal FE	Large effects of smoking on BW; effects vary with specification

Note: See notes at bottom of Table 4

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
86	Agarwal, N., Banternghansa, C., & Bui, L. (2010)	Pollution	County-year rates of infant and fetal mortality	Mortality data, U.S., 1989-2002, linked with Toxic Release Inventory data from the EPA and county-level census data	FE	Higher infant mortality rates with increasing concentrations of toxic pollutants
87	Almond, D., Doyle, J., Kowalski, A., & Williams, H. (2010)	Intensity of hospital care for LBW vs. VLBW infants	Individual-level neonatal and infant mortality	Linked birth and infant death records, U.S., 1983-1991 & 1995-2002; California, 1991-2002 natality data linked to hospital discharge & death certificates	RD	VLBW infants have lower mortality rate if receive more intensive treatment; cost of saving life for newborn near 1,500 grams is $550,000 (upper bound of 1.2 mil) in 2006 $
88	Chou, S., Liu, J., Grossman, M., & Joyce, T.* (2010)	Education	Individual-level LBW and neonatal, post-neonatal, and infant mortality	Linked birth and infant death records, Taiwan, 1978-1999	IV	Increase in parental schooling decreases LBW and neonatal and post-neonatal mortality
89	Fertig, A. (2010)	Smoking	Individual-level BW- and GA-related outcomes, fetal growth	1958 National Child Development Study, the 1970 British Cohort Study	DD	Effect of prenatal smoking on LBW is significantly smaller in 1958 than 2000; appears to reflect increased adverse selection into smoking across the cohorts
90	Aizer, A. (2011)	Prenatal assault (exposure to violence)	Individual-level BW-related outcomes and fetal and infant death	Birth records linked with maternal hospitalization records, California 1991-2002	Control function IV model, matching estimates	Assault associated with ~150-200 grams lower BW and increased risk of fetal and infant mortality; BW association largest in first trimester
91	Almond, D., & Doyle, J. (2011)	Length of newborn hospital stay	Individual-level neonatal, post-neonatal, and infant mortality, readmission rate to hospital	Hospital discharge records linked to birth and infant death records, California, 1991-2002	RD	Infants born just after midnight stay .25 nights longer than those born just prior to midnight; no differences in infant health outcomes between the 2 groups

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
92	Almond, D., & Mazumder, B. (2011)	Nutrition/exposure to Ramadan fasting	Individual-level BW	Birth records, Michigan, 1989-2006	DD	Fasting reduces BW by ~18 grams
93	Almond, D., Currie, J., & Simeonova, E. (2011)	Changes to Hill-Burton Provision of Charity Care (elimination of requirements for private hospitals to admit charity care patients; reduced access to care)	Individual-level infant mortality, BW- and GA-related outcomes, Apgar scores	Florida linked birth and infant death records, 1989-2003, also linked with data on hospital of birth	FE, FE IV	No effects on birth outcomes
94	Almond, D., Hoynes, H., & Schanzenbach, D. (2011)	Nutrition/implementation of food stamps	County-level rates of BW, LBW, neonatal mortality	Natality and mortality data, U.S., 1959-1977	DD	Implementation of food stamp program led to 1-5 gram increases in BW, .06 % point reduction in LBW
95	Barreca, A., Guldi, M., Lindo, J.., & Waddell, G. (2011)	Intensity of hospital care for LBW infants (replication of Almond et al. 2010 [87]	Individual-level neonatal and infant mortality	Linked birth and infant death records, U.S., 1983-1991 & 1995-2002; birth records linked to hospital discharge & death files, California, 1991-2002	RD	< 1500 gram cutoff for VLBW results in effect sizes 39-63 % lower than found in article 87
96	Currie, J., & Walker, R. (2011)	Pollution/ E-Z Pass adoption	Individual-level GA- and BW-related outcomes	Birth data, Pennsylvania, 1997- 2002, and New Jersey, 1994-2003	DD	Adoption of EZ Pass associated with improvements in preterm birth and LBW in vicinity of toll plazas
97	Currie, J., Greenstone, M., & Moretti, E. (2011)	Pollution/Superfund cleanup	Individual-level BW- and GA-related outcomes, congenital anomalies, infant mortality	Linked birth & death records, 5 states, 1989-2003; linked to Superfund site data	DD	Superfund cleanups reduce incidence of congenital anomalies by 20-25%
98	Hoynes, H., Page, M., & Stevens, A. (2011)	Nutrition/WIC implementation	County-year average BW and rate of LBW	Natality data, U.S., 1974, 1975, 1978, 1979, 1989	DD	Implementation of WIC led to increases in average BW and decreases in rates of LBW

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
99	Lhila, A. (2011)	Nutrition/fast food access	Individual-level BW- and GA-related outcomes, fetal growth, Apgar scores	Birth data, U.S., 1998 and 2004, merged with fast food data	FE	Greater access to fast food restaurants is positively associated with prenatal excessive weight gain but not BW
100	Lindo, J. (2011)	Paternal job loss	Individual-level BW and LBW	Panel Study of Income Dynamics 1968-1997	DD, maternal FE	Husbands' job loss reduces BW by 4.5%
101	Miller, A., & Tucker, C. (2011)	Electronic medical records (EMRs)	County-year rates of neonatal mortality, cause of death, death rate first and seventh days, stillbirths, preterm birth	Natality and mortality data, U.S., 1995-2006, merged with hospital information technology data	FE, IV	10% increase in births that occur in hospitals with EMRs is associated with reduction in neonatal mortality by 16 deaths per 100,000 live births
102	Rossin, M. (2011)	Maternity Leave/1993 Family & Medical Leave Act	Monthly county-level BW- and GA-related outcomes, infant mortality rate, Apgar scores	Natality and mortality data, U.S., 1989-1997 merged w/county-level firm data (50+ employees)	DDD	Maternity leave leads to small increase in BW, decrease in likelihood of preterm birth, and substantial decrease in infant mortality among college educated and married mothers (most able to take advantage of unpaid leave)
103	Sen, A., & Pierard, E. (2011)	Smoking/cigarette taxes	Province-year rates of infant mortality, LBW, fetal death	Provincial data, Canada, 1979-2004	FE	Increase in cigarette taxes is significantly associated with lower infant mortality rates; some evidence of a counter-intuitive positive association between taxes and fetal deaths
104	Simeonova, E. (2011)	Natural disasters (weather events)	County-month BW- and GA-related outcomes	Natality data, U.S., 1968-1988, merged with natural disaster data	FE	Maternal exposure to plausibly exogenous adverse weather events decreases GA and BW; effects strongest in second/early third trimesters of pregnancy

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
105	Torche, F. (2011)	Natural disaster (earthquake)	Individual-level BW- and GA-related outcomes	Birth records, Chile, 2004, 2005, and 2006	DD	Maternal exposure to stress (proxied by earthquake) results decreases BW and increases LBW
106	Almond, D., Currie, J., & Herrmann, M. (2012)	Maternal childhood exposure to disease (her postnatal mortality rate environment)	LBW rates for mothers born in a given state-year and giving birth in a given state-year	Natality data, 1989-2006, merged with postnatal mortality rates in the state-year of the mother's birth	FE	White mothers exposed to high postnatal mortality rates in early life have higher rate of LBW infants
107	Ananat, E., & Hungerman, D. (2012)	Contraception/ access to the pill	State-year rates of LBW	Birth records, U.S., 1968-1980	DDD	Access to the pill leads to reduction in LBW
108	Coneus, K., & Spiess, C. (2012)	Pollution	Individual-level length and weight at birth; fetal growth; disorder in first year of life	Socio-Economic Panel, 2002-2007; German Federal Environment Agency	FE, maternal FE	Carbon monoxide adversely affects fetal growth and BW; ozone adversely affects birth length and fetal growth
109	Gai, Y., & Feng, L. (2012)	WIC participation	Individual-level BW- and GA-related outcomes	Early Childhood Longitudinal Study—Birth Cohort, U.S., 2001	IV, bivariate probit	WIC does not affect average BW or GA, but reduces probability of very preterm birth and VLBW; thus, more effective for births that are at high risk
110	Guindon, G.., & Contoyannis, P. (2012)	Rx spending at government level as proxy for pharmaceutical input availability/use	Province-year infant mortality	Statistics Canada and Canadian Institute for Health Information, 1981-2003	Feasible Generalized Least Squares methods w/ correction for panel-specific first-order autocorellation and cross-panel heteroscedasticity	No discernable association between spending on private or public pharmaceutical products and infant mortality

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
111	Bache, S., Dahl, C., & Kristensen, J. (2013)	Smoking	Individual-level LBW	Aarhus University Hospital Skejby), Denmark, 1992-2005	Quantile regression with panel data	Prenatal smoking has adverse effects on BW; no significant effect of pre-pregnancy smoking on BW
112	Currie, J., Zivin, J., Meckel, K., Neidell, M., & Schlenker, W. (2013)	Pollution	Individual-level BW- and GA-related outcomes	Birth records, New Jersey, 1997-2007, linked to records of drinking water violations	Maternal FE, IV	Living in a water district with contaminated water during pregnancy is associated with increase in LBW by 14.55% among less educated mothers; potential exposure to contaminated water increases incidence of preterm term by 10.3% among less educated mothers
113	Currie, J., & Rossin-Slater, M. (2013)	Stressful events/hurricanes	Individual-level BW- and GA-related outcomes, abnormal newborn conditions	Birth records, Texas, 1996-2008, linked to data on hurricanes	Maternal FE, IV	Exposure to hurricane during pregnancy increases probability of abnormal newborn conditions; effects on BW and GA sensitive to specification
114	Kemptner, D., & Marcus, J. (2013)	Education	Individual-level BW- and GA-related outcomes	German Socio-Economic Panel Study of children born. 2002-2010	IV probit	An additional year of education decreases preterm birth by 1-4 percentage points; effects on LBW differ by specification
115	Markowitz, S.,* Adams, E., Dietz, P., Kannan, V., & Tong, V. (2013)	Cigarette control policies	Individual-level BW- and GA-related outcomes	Prenatal Risk Assessment Monitoring System data from 29 states and NYC, 1996-2008	FE	Smoking policies limited in effectiveness; largest improvements in birth outcomes from higher cigarette prices are for women who have the least human capital
116	Menclova, A. (2013)	Unemployment rates	County-year rates of LBW, VLBW	Natality data, U.S., 1989-1999	FE	Overall effects of unemployment are favorable; reflect, at least to some extent, increased eligibility for Medicaid

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
117	Rettenmaier, A., & Wang, Z. (2013)	Multiple inputs including smoking, nutrition, alcohol, STDs, access to care, quality of care	County-year rates of LBW	U.S. "County Health Ratings" 2000-2006	Directed acyclic graphs	Chlamydia rate, community safety, and liquor store density associated with LBW
118	Wehby, G., Wilcox, A., & Lie, R. (2013)	Quitting smoking	Individual-level BW-related outcomes	Population-based study, Norway, 1996-2001	IV, bivariate probit	Some evidence that cigarette quitting during pregnancy increases multivitamin use and caloric intake and reduces caffeine consumption; evidence that multivitamin use reduces LBW and caffeine reduces BW
119	Yan, J. (2013)	Smoking	Individual-level BW- and GA-related outcomes	Birth records, Washington State, 2003-2006; matched panel of sibling births, Pennsylvania, 2003-2006	Maternal FE	Smoking cessation in first trimester has a negligible effect on infant health but cessation as late as second trimester or smoking throughout pregnancy is associated with substantially increased BW and risk of LBW; 2/3 of total detrimental smoking impact on birth outcomes occurs in 2nd trimester
120	Bharadwaj, P., Johnsen, J., & Loken, K. (2014)	Smoking bans	Individual-level BW- and GA-related outcomes, Apgar scores, birth defects	Birth registry data, Norway, 1967-2010	DD	After law change, for mothers working in affected places: VLBW decreased; mothers 15% more likely to quit smoking; for mothers that quit, large favorable effects on BW preterm birth

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
121	Brunner, B., & Kuhn, A. (2014)	Timing of birth due to cancellation of a benefits program at the end of December	Monthly aggregates: BW- and GA-related outcomes, Apgar scores, short birth length	Natality data, Austria, 1992.11-2006.12	Time-series	8% more babies born in December of 1996 (month before cancellation of benefit) than predicted. significant increase in birth complications; no adverse immediate impact on infant health
122	Chou, S., Grossman, M., & Liu, J. (2014)	Introduction of National Health Insurance (NHI)	Annual county-group-year level rates of post-neonatal mortality	Annual linked birth and infant death records, Taiwan, 1990-2001	DD	Introduction of NHI led to drop in post neonatal mortality of 8-16%, for farm households but not private sector households
123	Frimmel, W., & Pruckner, G. (2014)	Marital status	Individual-level BW- and GA-related outcomes	Registry data, Austria, 1984-2007, matched with divorce registry	Maternal FE, IV, quantile regression	babies born to single mothers are about 40 grams lighter
124	Jensen, V. (2014)	Capitation v. fee for service	Individual-level BW- and GA-related outcomes	Administrative data, Copenhagen City and County, October 1981 - September 1990	DD	First born infants exposed in utero to care to general practitioners with capitation contracts have poorer infant health outcomes than those whose practitioners have fee for service contracts
125	Luechinger, S. (2014)	Pollution: sulfur dioxide (SO_2)	County-year-gender-wedlock status rates of infant mortality, 1-day mortality, neonatal mortality, stillbirth, length, and BW- and GA-related outcomes	Natality and mortality data, Germany, 1985-2003, linked to environmental data	FE, IV	No evidence of effects of SO_2 on neonatal mortality, but LBW increased and birth length with exposure
126	Schulkind, L., & Shapiro, T. (2014)	Birth timing (differential tax benefits)	Individual-level BW- and GA-related outcomes, Apgar scores, assisted ventilation	Natality data, U.S., 1990-2001 (December & January; October & November)	FE, DD	Increase in tax benefits associated with lower BW, higher likelihood of LBW, and lower Apgar scores

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
127	Yan, J. (2014)	Minimum cigarette purchase age	Individual-level BW- and GA-related outcomes, Apgar scores	Birth records, Pennsylvania, 1992-2002 (restricted to mothers ages 19-21)	RD	Minimum cigarette purchase age of 21 decreases daily prenatal smoking by 15% and LBW by 19%
128	Barreca, A., & Page, M. (2015)	Minimum legal drinking age (MLDA)	State-year-age BW- and GA-related outcomes, Apgar scores, congenital anomalies	Natality data, U.S., 1968-1989	DDD	Limited evidence that MLDA policies affect birth outcomes
129	Carlson, K. (2015)	Stress /anticipatory news of plant layoffs	County-month panel data on BW, GA	Natality data, 1999-2008, 4 U.S. states, linked with data on plant closures	FE, IV	Announcement of impending job losses leads to a transient decrease in mean BW within firm's county 1-4 months before job losses; 500 jobs lost leads to decrease of 15-20 grams in average BW & 16% increase in LBW; announcements later in pregnancy have stronger effects
130	Choi, Y., Ha, H., Lim, J., & Lee, E. (2015)	Prenatal care	Individual-level BW, Apgar scores	Birth records, U.S., 1995-2002	Heckman sample selection, IV estimation	Marginal impact of visits on birth outcomes declines with number of visits
131	Daysal, N., Trandafir, M., & van Ewijk, R. (2015)	Home birth	Individual-level 7- and 28-day mortality, Apgar scores	Prenatal registry data, the Netherlands, 2000-2008; limited to low-risk first births	IV	Giving birth in a hospital (vs. at home) substantially reduces newborn mortality
132	Durrance, C., & Guldi, M. (2015)	Recommended bed rest	Individual-level BW- and GA-related outcomes	Pregnancy Risk Assessment Monitoring System, U.S., 2000-2008; sample limited to those with pregnancy problems	FE, matching methods	Positive relationship between bed rest and likelihood of LBW and prematurity; but bed rest decreases VLBW, very preterm birth, and infant death
133	Hoynes, H., Miller, D., & Simon, D. (2015)	Earned Income Tax Credit (EITC)	BW-related outcomes across groups by parity/age group/race/ethnicity/	Natality data, U.S., 1983-1999	DD	EITC reduces LBW and increases BW; $1000 treatment on the treated leads to 2-3% decline in LBW

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
			state/year, other			
134	Jensen, V., & Wust, M. (2015)	Caesarean-section (for breech infants)	Individual-level Apgar scores, infant hospitalizations, serious morbidity	Registry data, Denmark, Aug. 1997 - Apr. 2004; breech and second or higher-order births	RD, IV	Caesarean section improves Apgar scores, reduces number of family doctor visits in year 1; no significant effects for severe neonatal morbidity, hospitalizations, or post-birth complications
135	Jurges, H. (2015)	Ramadan (fasting)	Individual-level BW	Birth records, Germany, 1996-2010; Muslim mothers	DD	No effect of Ramadan exposure
136	King, C., Markowitz, S., & Ross, H. (2015)	Tobacco control policies and taxes	Country-year counts of SIDS deaths	WHO data, 23 countries, 1990-2009, linked with data on tobacco control policies	FE	Higher cigarette prices result in lower prevalence of SIDS; no effects of smoke-free policies
137	Mocan, N.,* Raschke, C., & Unel, B. (2015)	Earnings	Individual-level BW- and GA-related outcomes	Natality data, U.S., 1989-2004, merged with Current Population Survey demographic data	Two-sample IV	Among mothers with low skills and not likely to be on Medicaid, Increase in weekly earnings has small positive effects on BW and GA; doubling of those mothers' earnings increases BW by 100g and GA by 0.7 weeks; no effects for high skill mothers
138	Salmasi, L., & Pieroni, L. (2015)	Immigration policy (granting "foreign national" status for 650,000 illegal immigrant workers)	Individual-level LBW	Birth sample survey, Italy, wave 1 2000-2001 & wave 2 2003	Propensity score matching within DD model	Regularizing immigration reduces LBW
139	Sonchak, L. (2015)	Medicaid reimbursement rates	Individual-level BW	Birth records, U.S., 2001-2010	IV	Medicaid reimbursement rates increase number of prenatal visits; additional visits increase BW for white disadvantaged mothers

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
140	Wust, M. (2015)	Maternal employment	Individual-level BW- and GA-related outcomes	Survey and administrative data, Denmark, 1998-2003	Maternal FE	Mothers who work during first trimester have lower risk of preterm birth; no effects on small size for gestational age
141	Aizer, A., Stroud, L., & Buka, S. (2016)	Stress/cortisol levels	Individual-level BW- and GA-related outcomes	National Collaborative Perinatal Project, Boston, MA & Providence, RI, 1959-1965	Maternal FE	Higher cortisol levels result in ~1-2% decrease in BW (29-66 grams)
142	Black, S., Devereux, P., & Salvanes, K. (2016)	Bereavement (death of a mother's parent during the pregnancy)	Individual BW- and GA-related outcomes, Apgar scores, birth length, infant in NICU	Birth registry, Norway, 1967-2009, linked to relevant years of death registry data	DD, maternal FE, IV	Maternal bereavement has small but significant adverse effects on birth outcomes
143	Borra, C., Gonzalez, L., & Sevilla, A. (2016)	Income benefits program cancellation	Individual-level neonatal hospitalization	Spanish birth data National Statistical Institute 2000-2012 linked with Hospital Morbidity Survey	DD	Infants born close to benefit cancellation date had higher post-birth hospitalization rates; no effects on medical conditions at birth or during the week after, increase started 2 weeks after birth
144	Cesarini, D., Lindqvist, E., Östling, R., & Wallace, B. (2016)	Wealth shock (Swedish lottery)	Individual-level BW- and GA-related outcomes	Birth registry, Sweden, 1973-2007 (children born to female players post-lottery)	OLS models with conditional random assignment in lottery winnings	No effect of wealth on BW, LBW, or preterm birth
145	Haeck, C., & Lefebvre, P. (2016)	Canadian eggs-milk-orange nutrition program (similar to WIC)	Individual-level BW- and GA-related outcomes	Birth registry data, Quebec Province, 1986-2008	DD	Program significantly increased BW of treated children , reduced LBW by 3.6%; reduced preterm birth by 2.2%, and increased GA but GA effects not significant
146	Knittel, C., Miller, D., & Sanders, N. (2016)	Pollution	Weekly infant mortality rates in postal codes	Linked birth and infant death data, California, 2000-2007	FE, IV	Large effects of particulate matter on infant mortality rates (for preterm or LBW infants); large adverse effects of carbon

Table 4. 2010-2016: Infant health production meets lifecourse and intergenerational health research

#	Article	Input/Policy/ Exposure	Outcome(s)	Data Source	Method(s)	Key Findings
						monoxide
147	Trudeau, J., Conway, K., & Menclova, A. (2016)	Sunshine (vitamin D)	Monthly county-level BW	Natality data, U.S., 1989-2004, linked to weather data	FE	Sunshine has positive but diminishing effect on BW for blacks and adverse effect for whites

Notes: Asterisks denote doctoral students of Michael Grossman; 3SLS = Three-stage Least Squares; Apgar = 10 point scale to assess newborn health; BW = Birthweight (grams); DD = Difference in Differences ; DDD = Difference in Differences with a comparison group; FE = Fixed Effects model based on area/time(maternal FE = Fixed Effects model comparing different children to the same mother); FFCWB = Fragile Families & Child Wellbeing Survey; GA = Gestational Age; IV = Instrumental Variables; LBW = Low Birthweight (< 2500 grams); NLSY9 = National Longitudinal Survey of Youth 1979; NMIHS = National Maternal & Infant Health Survey; OLS = Ordinary Least Squares; Preterm birth = < 37 completed weeks GA.; RD = Regression Discontinuity Design; RE = Random Effects; SIDS = Sudden Infant Death Syndrome; VLBW = Very Low Birthweight (< 1500 grams);WIC = The Special Supplemental Nutrition Program for Women, Infants, and Children.